

# **Akademia Wychowania Fizycznego i Sportu im. Jędrzeja Śniadeckiego w Gdańsku**



**mgr inż. Monika Szot**

## ***Ocena wybranych elementów stylu życia polskich e-sportowców***

Promotor:

prof. dr hab. Barbara Frączek

Promotor pomocniczy:

dr Paulina Mazur-Kurach

**Gdańsk 2024**

GDHUSK, 10.05.2024  
AKC MZS, ROZMANE DOZOPALA  
MEK 102. HANCI 201

MF  
Rauline ME

*Na powstanie i ostateczny kształt mojej pracy doktorskiej miało wpływ wiele osób,  
którym chciałabym w tym miejscu podziękować.*

*Pragnę złożyć serdeczne podziękowania Moim Promotorom:  
Pani prof. dr hab. Barbarze Frączek i Pani dr Paulinie Mazur-Kurach,  
za nieocenioną pomoc, życzliwość, wsparcie, cenne wskazówki i opiekę naukową.*

*Dziękuję moim Rodzicom, Bliskim i Przyjaciołom.*

## Spis treści

|                                                                                                                                                                                                                                                                                                                                                                       |           |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| <b>Wykaz skrótów .....</b>                                                                                                                                                                                                                                                                                                                                            | <b>6</b>  |
| <b>Wprowadzenie wraz z wykazem publikacji wchodzących w skład rozprawy.....</b>                                                                                                                                                                                                                                                                                       | <b>8</b>  |
| <b>1. Cel pracy, pytania i hipotezy badawcze .....</b>                                                                                                                                                                                                                                                                                                                | <b>12</b> |
| <b>2. Metodologia badań własnych .....</b>                                                                                                                                                                                                                                                                                                                            | <b>14</b> |
| 2.1. Materiał badawczy.....                                                                                                                                                                                                                                                                                                                                           | 14        |
| 2.2. Metody badań.....                                                                                                                                                                                                                                                                                                                                                | 14        |
| 2.2.1. Ocena sposobu żywienia, wartości energetycznej i odżywczej diety oraz<br>wyłanianie wzorów żywieniowych polskich e-sportowców - kwestionariusz<br>szybkiej oceny sposobu żywienia (QDS), kwestionariusz do badania poglądów i<br>zwyczajów żywieniowych (Kom-PAN), kwestionariusz częstości spożycia (FFQ)<br>oraz metoda 3-dniowego bieżącego notowania ..... | 14        |
| 2.2.2. Ocena poziomu aktywności fizycznej - Międzynarodowy Kwestionariusz<br>Aktywności Fizycznej (IPAQ).....                                                                                                                                                                                                                                                         | 17        |
| 2.2.3. Ocena wydolności i sprawności fizycznej - test o narastającym obciążeniu<br>oraz zmodyfikowany Międzynarodowy i Europejski Test Sprawności Fizycznej                                                                                                                                                                                                           | 17        |
| 2.2.4. Metody analizy statystycznej .....                                                                                                                                                                                                                                                                                                                             | 18        |
| <b>3. Wyniki.....</b>                                                                                                                                                                                                                                                                                                                                                 | <b>20</b> |
| 3.1. Wyniki badań opublikowane w pracy pt. „Can nutrients and dietary supplements<br>potentially improve cognitive performance also in esports?”.....                                                                                                                                                                                                                 | 20        |
| 3.2. Wyniki badań opublikowane w pracy pt. „Nutrition Patterns of Esports players” ..                                                                                                                                                                                                                                                                                 | 23        |
| 3.3. Wyniki badań opublikowane w pracy pt. „Evaluation of the eating habits of Polish<br>esports players using the Quick Diet Survey (QDS)” .....                                                                                                                                                                                                                     | 24        |
| 3.4. Wyniki badań opublikowane w pracy pt. „Characteristics of the gut microbiome in<br>esports players compared with those in physical education students and professional<br>athletes” .....                                                                                                                                                                        | 25        |
| 3.5. Wyniki badań opublikowane w pracy pt. „Assessment of physical activity, exercise<br>capacity and fitness level of Polish esports players”.....                                                                                                                                                                                                                   | 27        |
| <b>4. Podsumowanie i wnioski.....</b>                                                                                                                                                                                                                                                                                                                                 | <b>29</b> |
| <b>5. Bibliografia .....</b>                                                                                                                                                                                                                                                                                                                                          | <b>34</b> |
| <b>6. Streszczenie i Abstract.....</b>                                                                                                                                                                                                                                                                                                                                | <b>42</b> |
| <b>7. Załączniki.....</b>                                                                                                                                                                                                                                                                                                                                             | <b>47</b> |
| Załącznik 1. Kopie publikacji wchodzących w skład rozprawy doktorskiej.....                                                                                                                                                                                                                                                                                           | 47        |
| Załącznik 2. Oświadczenia współautorów publikacji .....                                                                                                                                                                                                                                                                                                               | 147       |
| Załącznik 3. Skan opinii Komisji Bioetycznej .....                                                                                                                                                                                                                                                                                                                    | 160       |
| Załącznik 4. Kwestionariusze ankiet.....                                                                                                                                                                                                                                                                                                                              | 168       |
| Kwestionariusz szybkiej oceny sposobu żywienia - Quick Diet Survey (QDS) .                                                                                                                                                                                                                                                                                            | 168       |



|                                                                                                                                    |     |
|------------------------------------------------------------------------------------------------------------------------------------|-----|
| Międzynarodowy Kwestionariusz Aktywności Fizycznej - The International Physical Activity Questionnaire (IPAQ) .....                | 170 |
| Kwestionariusz częstości spożycia żywności - Food Frequency Questionnaire (FFQ) .....                                              | 175 |
| Kwestionariusz do badania poglądów i zwyczajów żywieniowych oraz procedura opracowania danych (Część A. Zwyczaje żywieniowe) ..... | 182 |

## Wykaz skrótów

| <b>Skrót</b>            | <b>Wyjaśnienie skrótu w języku angielskim</b> | <b>Wyjaśnienie skrótu w języku polskim</b>         |
|-------------------------|-----------------------------------------------|----------------------------------------------------|
| <b>AI</b>               | Adequate Intake                               | Wystarczające Spożycie                             |
| <b>BMI</b>              | Body Mass Index                               | Wskaźnik Wagowo-Wzrostowy                          |
| <b>CS:GO</b>            | Counter Strike:Global Offensive               | Nazwa gry z gatunku FPS                            |
| <b>DNA</b>              | Deoxyribonucleic Acid                         | Kwas deoksyrybonukleinowy                          |
| <b>DPs</b>              | Dietary Patterns                              | Wzory Żywienia                                     |
| <b>EAR</b>              | Estimated Average Requirement                 | Średnie Zapotrzebowanie                            |
| <b>EFSA</b>             | European Food Safety Authority                | Europejski Urząd ds. Bezpieczeństwa Żywności       |
| <b>EUROFIT</b>          | European Fitness Test                         | Europejski Test Sprawności Fizycznej               |
| <b>FA</b>               | Factor Analysis                               | Analiza czynnikowa                                 |
| <b>FFQ</b>              | Food Frequency Questionnaire                  | Kwestionariusz częstości spożycia żywności         |
| <b>FPS</b>              | First-Person Shooter                          | Strzelanka z perspektywy pierwszej osoby           |
| <b>HR</b>               | Heart Rate                                    | Częstość skurczów serca                            |
| <b>HR at AeT</b>        | Heart Rate at Aerobic Threshold               | Częstość skurczów serca przy progu tlenowym        |
| <b>HR at AnT</b>        | Heart Rate at Anaerobic Threshold             | Częstość skurczów serca przy progu beztlenowym     |
| <b>HR<sub>max</sub></b> | Maximum Heart Rate                            | Maksymalna częstość skurczów serca                 |
| <b>IPAQ</b>             | International Physical Activity Questionnaire | Międzynarodowy Kwestionariusz Aktywności Fizycznej |
| <b>KMO</b>              |                                               | Wskaźnik Kaisera-Meiera-Olkina                     |
| <b>LoL</b>              | League of Legends                             | Nazwa gry z gatunku MOBA                           |
| <b>M</b>                | Mean                                          | Średnia arytmetyczna                               |
| <b>Me</b>               | Median                                        | Mediana                                            |
| <b>MET</b>              | Metabolic Equivalent of Task                  | Równoważnik Metaboliczny                           |

|                                |                                                  |                                                 |
|--------------------------------|--------------------------------------------------|-------------------------------------------------|
| <b>MOBA</b>                    | Multiplayer Online Battle Arena                  | Wieloosobowa arena bitew online                 |
| <b>N</b>                       | Number                                           | Liczebność                                      |
| <b>NHANES</b>                  | National Health and Nutrition Examination Survey | Narodowe badanie zdrowia i odżywiania           |
| <b>NKT</b>                     |                                                  | Nasycone kwasy tłuszczowe                       |
| <b>PCA</b>                     | Principal Component Analysis                     | Analiza głównych składowych                     |
| <b>PO at AeT</b>               | Power Output at Aerobic Threshold                | Moc wyjściowa przy progu tlenowym               |
| <b>PO at AnT</b>               | Power Output at Anaerobic Threshold              | Moc wyjściowa przy progu beztlenowym            |
| <b>PO at VO<sub>2max</sub></b> | Power Output at Maximum Oxygen Rate              | Moc wyjściowa przy maksymalnej zawartości tlenu |
| <b>QDS</b>                     | Quick Diet Survey                                | Kwestionariusz szybkiej oceny sposobu żywienia  |
| <b>RFPM</b>                    | The Remote Food Photography Method               | Metoda Zdalnego Fotografowania Żywności         |
| <b>RNA</b>                     | Ribonucleic Acid                                 | Kwas rybonukleinowy                             |
| <b>RTS</b>                     | Real-Time Strategy                               | Strategie czasu rzeczywistego                   |
| <b>SCFA</b>                    | Short Chain Fatty Acid                           | Krótkołańcuchowe kwasy tłuszczowe               |
| <b>SD</b>                      | Standard Deviation                               | Odchylenie standardowe                          |
| <b>VE<sub>max</sub></b>        | Maximum Minute Ventilation                       | Maksymalna wentylacja minutowa                  |
| <b>VO<sub>2max</sub></b>       | Maximum Oxygen Uptake                            | Maksymalny pobór tlenu                          |
| <b>WHO</b>                     | World Health Organization                        | Światowa Organizacja Zdrowia                    |
| <b>WNKT</b>                    |                                                  | Wielonienasycone kwasy tłuszczowe               |
| <b>%HR<sub>max</sub></b>       | Percentage of Maximum Heart Rate                 | Odsetek maksymalnej częstości skurczów serca    |

# **Wprowadzenie wraz z wykazem publikacji wchodzących w skład rozprawy**

## **Wprowadzenie**

Gry rywalizacyjne, znane jako sport elektroniczny lub e-sport, są jedną z najpopularniejszych form rozrywki cyfrowej, odnoszącej się do zorganizowanych i konkurencyjnych zawodów gier wideo, w których indywidualne osoby lub drużyny rywalizują ze sobą poprzez interakcję człowiek-komputer (Mangeloja i wsp. 2019, Nagorsky i Wiemeyer 2020, Giakoni-Ramírez i wsp. 2022, Pluss i wsp. 2022). Pomimo ciągłego rozwoju e-sportu, wciąż brakuje naukowej diagnozy i analizy czynników, które sprzyjają osiągnięciu sukcesu sportowego. Istnieje zatem potrzeba interdyscyplinarnych badań, które pozwolą określić zarówno indywidualne predyspozycje e-graczy, jak również szerokie spektrum czynników środowiskowych sprzyjających osiągnięciu zadowalających rezultatów w rozgrywkach (Pedraza-Ramirez i wsp. 2020). Aby sprostać wymaganiom w e-sporcie, gracze koncentrują się na doskonaleniu umiejętności poprzez trening w różnych obszarach, w tym w sferze poznawczej (zwinność umysłowa, pamięć przestrzenna, podejmowanie decyzji), psychologicznej (samokontrola emocjonalna, koncentracja, poczucie własnej skuteczności), fizycznej (wydolność tlenowa i czas reakcji), technicznej, taktycznej (znajomość gry i jej strategii) i koordynacji (np. koordynacja ręka-oko), a także w zakresie tradycyjnych wartości (indywidualny wysiłek, praca zespołowa i pokonywanie przeszkód) (García-Lanzo i wsp. 2020). W przeciwieństwie do sportu tradycyjnego, w którym ważną determinantę sukcesu stanowią cechy fizyczne, dominującą rolę w e-sporcie odgrywają zdolności mentalne i kognitywne (Tartar i wsp. 2019, Thomas i wsp. 2019). Funkcje poznawcze, które stanowią kluczowy osobniczy czynnik warunkujący sukces e-sportowy zależą od czynników środowiskowych. W literaturze naukowej przedstawiono dowody potwierdzające korzystne oddziaływanie wybranych składników pokarmowych i suplementów na funkcjonowanie mózgu (Meeusen i Decroix 2018). Do tej pory funkcje poznawcze były oceniane głównie w kontekście profilaktyki i wspomagania leczenia chorób neurodegeneracyjnych (Chiu i wsp. 2008, Morgan i wsp. 2010, de Jager i wsp. 2012, Dysken i wsp. 2014, Attia i wsp. 2012, Chen i wsp. 2012, Darwish i wsp. 2017, Hu i wsp. 2018) oraz poprawy zdolności poznawczych osób zdrowych (Maylor i wsp. 2006, Lewis i wsp. 2014, Kumar i wsp. 2016, Pettersen 2017, Mariage i wsp. 2020, Aslanyan i wsp. 2010). Mimo licznych publikacji, dotychczas nie dokonano oceny potencjalnego wpływu diety na zdolności kognitywne graczy e-sportowych.

Różne aspekty stylu życia, w tym sposób żywienia, sen i aktywność fizyczna wydają się być istotne dla funkcji poznawczych e-sportowców (Baumann i wsp. 2022). Dieta i ćwiczenia fizyczne są związane z przebiegiem procesów katabolicznych i generowaniem energii, co jest ważne dla utrzymania pobudliwości neuronów i funkcji synaptycznych. Dieta i aktywność fizyczna łącznie mogą mieć addytywny wpływ na plastyczność synaptyczną i funkcje poznawcze. Stosowanie diety śródziemnomorskiej sprzyja poprawie funkcji poznawczych i pamięci epizodycznej (Lehert i wsp. 2015). Z kolei dieta wysokotłuszczowa i wysokocukrowa wywołuje odmienne efekty. Również odwodnienie pogarsza wydolność poznawczą, szczególnie w przypadku zadań wymagających uwagi, funkcji wykonawczych i koordynacji (Karpęcka i Frączek 2020). Na podstawie przeglądu dostępnych badań można założyć, że prawidłowe odżywianie odgrywa istotną rolę w wydolności poznawczej e-sportowców. Doniesienia na temat sposobu żywienia e-sportowców są nieliczne, jednak dostępne prace wskazują na rozpowszechnienie nieprawidłowych zachowań żywieniowych wśród e-graczy z różnych krajów (Huth i wsp. 2021, Goulart i wsp. 2023, Ribeiro i wsp. 2023, Szot i wsp. 2022).

Zainteresowanie profesjonalnym e-sportem dotyczy szczególnie osób młodych (Yin i wsp. 2020). Johnson i Wodstock (2021) twierdzą, że światowej klasy profesjonaliści są integralną częścią środowiska e-sportowego, jednak w kontekście zawodowego e-sportu są niestabilni, gdyż nie mogą utrzymać najwyższego poziomu umiejętności po ukończeniu 30. roku życia. Potencjalne negatywne skutki gier e-sportowych mogą wynikać ze stresującego, długotrwałego treningu, a także z zaciętej rywalizacji w środowisku wirtualnym, która dotyczy szczególnie e-graczy na wysokim poziomie rozgrywkowym. Z danych literaturowych wynika, że gracze e-sportowi poświęcają na trening od 5,5 do 14 godzin dziennie, w celu doskonalenia umiejętności w wymuszonej pozycji siedzącej (DiFrancisco-Donoghue i wsp. 2019, Emara i wsp. 2020, Truong i wsp. 2020), co może zwiększać ryzyka zdrowotne. E-sportowcy narażeni są na chroniczne przeciążenia i kontuzje, zmęczenie oczu, dolegliwości bólowe szyi, pleców i nadgarstków oraz inne negatywne konsekwencje zdrowotne związane z rozregulowaniem metabolizmu i zaburzeniami rytmu dobowego. Pogorszeniu może ulec również ich kondycja psychiczna (depresja, objawy wypalenia zawodowego) i psycho-społeczna (lęk społeczny, zaburzenia snu, problemy z higieną osobistą) (Martin-Niedecken i Schättin 2020, Giakoni-Ramírez i wsp. 2022).

W ostatnim czasie w literaturze naukowej pojawiły się wyniki badań z różnych ośrodków naukowych dotyczące poziomu aktywności fizycznej e-sportowców (Rudolf i wsp. 2019, Trotter i wsp. 2020, Seng i wsp. 2021, Paramitha i wsp. 2021, Giakoni-Ramirez i wsp.

2022, DiFrancisco-Donoghue i wsp. 2022, Pereira i wsp. 2019, Pereira i wsp. 2021) i zgłaszanych dolegliwościach bólowych (Seng i wsp. 2021, DiFrancisco-Donoghue i wsp. 2019, Clements i wsp. 2022, Lindberg i wsp. 2020, Lam i wsp. 2022, Zwibel i wsp. 2019), natomiast problematyka wydolności i sprawności fizycznej graczy e-sportowych nie została zbadana.

Mając na uwadze nieustanny rozwój i profesjonalizację e-sportu w Polsce i na świecie, istnieje wyraźna potrzeba naukowego zbadania i zrozumienia czynników behawioralnych związanych ze stylem życia, które mają bezpośredni wpływ na zdrowie i wyniki w e-sporcie, zatem podejmowanie badań w przedmiotowym obszarze można uznać za uzasadnione.

### **Publikacje wchodzące w skład rozprawy**

Niniejszą rozprawę doktorską stanowi cykl publikacji naukowych pod wspólnym tytułem: *“Ocena wybranych elementów stylu życia polskich e-sportowców”*, na który składa się pięć prac opublikowanych w recenzowanych czasopismach naukowych o sumarycznej punktacji Impact Factor (IF): 14,6 i MNiSW: 390 pkt.:

- I. “Can nutrients and dietary supplements potentially improve cognitive performance also in esports?”. **Monika Szot**, Ewa Karpęcka-Gałka, Remigiusz Dróżdż, Barbara Frączek. *Healthcare* 2022; 10(2):186. DOI: 10.3390/healthcare10020186

Impact Factor: 2,8, punktacja MNiSW: 40 pkt.

- II. “Nutrition Patterns of Esports players”. **Monika Szot**, Barbara Frączek, Florentyna Tyrała. *Nutrients* 2023; 15(1):149. DOI: 10.3390/nu15010149

Impact Factor: 5,9, punktacja MNiSW: 140 pkt.

- III. “Characteristics of the gut microbiome in esports players compared with those in physical education students and professional athletes”. Maria Kulecka, Barbara Frączek, Aneta Balabas, Paweł Czarnowski, Natalia Zeber-Lubecka, Barbara Zapala, Katarzyna Baginska, Maria Glowienka, **Monika Szot**, Maciek Skorko, Anna Kluska, Magdalena Piątkowska, Michał Mikula, Jerzy Ostrowski. *Frontiers in Nutrition* 2023; 9:1092846. DOI: 10.3389/fnut.2022.1092846

Impact Factor: 5,0, punktacja MNiSW: 70 pkt.

- IV. “Assessment of physical activity, exercise capacity and fitness level of Polish esports players”. Barbara Frączek, **Monika Szot**, Andrzej Sagalara, Sebastian Krzepota,

Maciek Skorko, Dariusz Błachnio, Bartosz Bertrandt, Krzysztof Szymaniuk, Andrzej Klimek. *Physical Activity Review* 2024; 12(1): 32-46. DOI: 10.16926/par.2024.12.04

Impact Factor: 0,9, punktacja MNiSW: 70 pkt.

- V. "Evaluation of the eating habits of Polish esports players using the Quick Diet Survey (QDS)". **Monika Szot** i Barbara Frączek. *Journal of Kinesiology and Exercise Sciences* 2024; 107(34): 1-14. DOI: 10.5604/01.3001.0054.5121

punktacja MNiSW: 70 pkt.

*Prace opublikowane poza cyklem:*

"Dieta dr Dąbrowskiej jako strategia żywieniowa – przegląd i możliwe kierunki badań nad wpływem diet o bardzo niskiej kaloryczności na zdrowie człowieka". **Monika Szot**, Florentyna Tyrała, Barbara Frączek. *Promocja Zdrowia i Ekologia* 2021; (2):8-17.

## 1. Cel pracy, pytania i hipotezy badawcze

Uwzględniając wybrane aspekty stylu życia polskich e-sportowców, określono następujące cele badawcze:

1. Przeglądowa charakterystyka mikroskładników pokarmowych i suplementów diety w kontekście ich potencjalnego wpływu na funkcje poznawcze;
2. Ocena sposobu żywienia (częstości spożycia i zachowań żywieniowych) oraz wartości energetycznej i odżywczej diety e-sportowców;
3. Analiza częstości spożycia składników pokarmowych o potencjalnie korzystnym wpływie na funkcje poznawcze e-sportowców;
4. Wyłonienie i określenie profili żywieniowych (modeli żywieniowych) e-sportowców;
5. Ocena poziomu aktywności, wydolności i sprawności fizycznej e-sportowców.

W związku z realizacją celu pracy sformułowano następujące pytania badawcze:

1. Jakie składniki pokarmowe i suplementy diety o potencjalnie korzystnym wpływie na zdolności poznawcze są szczególnie istotne w diecie e-sportowców?
2. Jaka jest skala prawidłowych zwyczajów żywieniowych oraz jakie są najczęstsze błędy żywieniowe wśród polskich e-sportowców w zależności od poziomu sportowego?
3. Jak kształtuje się częstość spożycia wybranych grup żywności, ze szczególnym uwzględnieniem źródeł składników pokarmowych o potencjalnie korzystnym wpływie na funkcje poznawcze, tj. makroskładników, mikroelementów (cynk, jod, żelazo, magnez), witamin (grupy B, E, C, D) oraz suplementów i substancji biologicznie czynnych (kofeina, L-teanina, polifenole, flawanole kakaowe, kreatyna, luteina, sok z buraków, probiotyki i prebiotyki) wśród e-sportowców?
4. Czy w kontekście podaży energii i składników pokarmowych, dietę polskich e-sportowców można uznać za zbilansowaną?
5. Jakie wzory żywienia są charakterystyczne dla polskich e-sportowców?
6. Jak kształtuje się poziom aktywności fizycznej oraz wydolności tlenowej i sprawności fizycznej polskich e-sportowców w zależności od poziomu sportowego?

Przyjęto cztery hipotezy badawcze:

1. Polscy e-sportowcy w ograniczonym stopniu realizują zalecenia prozdrowotnego stylu życia.



2. Rozpowszechnione wśród e-sportowców nieprawidłowości żywieniowe nie wykazują zróżnicowania w zależności od poziomu sportowego (gracze profesjonalni vs półprofesjonalni).
3. Wśród polskich e-sportowców dominują wzory żywienia charakterystyczne dla tzw. diety zachodniej.
4. Polscy e-sportowcy cechują się niskim poziomem aktywności fizycznej i nadmierną masą ciała, a gracze profesjonalni spędzają istotnie więcej czasu w pozycji siedzącej w porównaniu do półprofesjonalnych. Poziom wydolności tlenowej e-sportowców nie wykazuje zróżnicowania w zależności od poziomu sportowego.

## **2. Metodologia badań własnych**

### **2.1. Materiał badawczy**

Badania zostały przeprowadzone w latach 2020-2023 zgodnie z zasadami Deklaracji Helsińskiej, a protokół badań został zatwierdzony przez Komisję Bioetyczną przy Okręgowej Izbie Lekarskiej w Gdańsku (nr KB-63/22). Wszyscy uczestnicy zostali poinformowani o dobrowolnym przystąpieniu do procedury badawczej oraz wyrazili świadomą pisemną zgodę na uczestnictwo w projekcie.

Grupę badaną stanowili polscy e-sportowcy, reprezentujący poziom profesjonalny i półprofesjonalny w różnych gatunkach gier video (LoL, CS:GO, Starcraft). Kryteriami włączenia do grupy badanej były: płeć męska, dobry ogólny stan zdrowia, wiek w zakresie 18-29 lat oraz co najmniej 3-letni staż treningowy w rozgrywkach na najwyższym poziomie.

Do badań oceniających sposób żywienia zakwalifikowano e-graczy reprezentujących poziom profesjonalny i półprofesjonalny. Częstość spożycia produktów o potencjalnie korzystnym i potencjalnie niekorzystnym wpływie na funkcjonowanie mózgu oraz nawyki żywieniowe i wzory żywieniowe analizowano wśród 233 mężczyzn. Wartość energetyczną i odżywczą diety określono dla 109 e-sportowców (oraz 36 studentów kierunku wychowanie fizyczne i 25 sportowców wyczynowych). Poziom aktywności fizycznej oceniono u blisko dwustu osób, wydolność fizyczną u 141, a do wybranych testów sprawności fizycznej przystąpiło 175 mężczyzn.

Na podstawie uzyskanych wartości masy i wysokości ciała obliczono wskaźnik masy ciała BMI [ $\text{kg}/\text{m}^2$ ]. Odnosząc się do wytycznych WHO (2010) stwierdzono, że większość badanych e-sportowców (62,8%) charakteryzowała się prawidłowym wskaźnikiem BMI, 28,6% stanowiły osoby z nadmierną masą ciała, a u 8,6% wykazano niedowagę.

### **2.2. Metody badań**

2.2.1. Ocena sposobu żywienia, wartości energetycznej i odżywczej diety oraz wyłanianie wzorów żywieniowych polskich e-sportowców - kwestionariusz szybkiej oceny sposobu żywienia (QDS), kwestionariusz do badania poglądów i zwyczajów żywieniowych (Kom-PAN), kwestionariusz częstości spożycia (FFQ) oraz metoda 3-dniowego bieżącego notowania.

Sposób żywienia polskich e-sportowców określono za pomocą metod jakościowych i ilościowych, posługując się metodą sondażu diagnostycznego z zastosowaniem technik ankietowych oraz metodą bieżącego notowania i metodą wagową.

Ocenę sposobu żywienia w zakresie realizacji zaleceń żywieniowych przeprowadzono z zastosowaniem autorskiego, zwalidowanego kwestionariusza do szybkiej oceny diety (ang. QDS - *Quick Diet Survey*) (załącznik 4, str. 175). Pytania w kwestionariuszu dotyczyły różnych zachowań żywieniowych, w tym m.in. liczby i regularności spożywania posiłków, rodzaju spożywanych przekąsek, częstości spożywania wybranych grup produktów spożywczych i napojów, unikania niezdrowej żywności oraz przestrzegania zaleceń w zakresie prawidłowego uzupełniania płynów. Uwzględniając stwierdzone prawidłowości i nieprawidłowości żywieniowe, wyodrębniono trzy poziomy prawidłowości diety: dietę nieodpowiednią (niska realizacja zaleceń żywieniowych), dietę nie w pełni odpowiednią (przeciętna realizacja zaleceń żywieniowych) i dietę prawidłową (wysoka realizacja zaleceń żywieniowych).

W badaniach ankietowych wykorzystano także polski Kwestionariusz do badania poglądów i zwyczajów żywieniowych (Kom-PAN), opracowany przez Komitet Nauki o Żywieniu Człowieka Polskiej Akademii Nauk, przeznaczony dla osób w wieku od 16 do 65 lat. Pytania zawarte w części A kwestionariusza Kom-PAN dotyczyły m.in. liczby, regularności i częstości spożycia posiłków, spożywanych przekąsek, rodzaju preferowanego mleka i produktów mlecznych, technik kulinarnych stosowanych do przygotowywania potraw mięsnych, rodzaju tłuszczu używanego do smarowania pieczywa i smażenia potraw, słodzenia gorących napojów i solenia potraw, rodzaju spożywanej wody i zwyczajowego spożycia płynów (Jeżewska-Zychowicz i wsp. 2014) (załącznik 4, str. 189).

Kolejnym zastosowanym narzędziem badawczym był zmodyfikowany na potrzeby badania kwestionariusz częstości spożycia (ang. FFQ - *Food Frequency Questionnaire*) oparty na międzynarodowych kwestionariuszach częstości spożycia żywności: *Harvard Food Frequency* (Stark 2002) i *National Health and Nutrition Examination Survey* (NHANES) (NHANES Questionnaires, Datasets, and Related Documentation), analizujący spożycie produktów, w tym o potencjalnie korzystnym i niekorzystnym wpływie na funkcjonowanie mózgu. Kwestionariusz FFQ został przetłumaczony z języka angielskiego na język polski przez autorkę pracy i zmodyfikowany poprzez dodanie produktów zwyczajowo spożywanych w Polsce wraz z przypisaniem wielkości porcji (w gramach lub miarach domowych) (załącznik 4, str. 182). Kwestionariusz FFQ zawierał 15 kategorii żywności i napojów: niesłodzone napoje i zupy (7 pozycji); warzywa i przetwory warzywne, w tym soki warzywne (25 pozycji); owoce

i przetwory owocowe, w tym soki owocowe (17 pozycji); rośliny strączkowe i przetwory z roślin strączkowych (7 pozycji); produkty zbożowe, ziemniaki, potrawy mączne i ziemniaczane (14 pozycji); mleko i produkty mleczne (13 pozycji); mięso i produkty mięsne (10); ryby i owoce morza (11 pozycji); jaja (1 pozycja); tłuszcze roślinne, orzechy i nasiona (21 pozycji); tłuszcze zwierzęce (2); cukier i wyroby cukiernicze (2); inne napoje - słodzone, energetyzujące, alkohol (8 pozycji); przyprawy (5 pozycji) i fast food (2 pozycje). Produkty spożywcze zostały sklasyfikowane do 37 grup żywności. Ocena dotyczyła spożycia w ciągu roku poprzedzającego badania. Częstość spożycia produktów i potraw określono w skali porządkowej 7-punktowej: 1\_nigdy/rzadziej niż raz w miesiącu; 2\_1-3 razy w miesiącu; 3\_raz/dwa razy w tygodniu; 4\_kilka razy w tygodniu; 5\_raz dziennie; 6\_2-3 razy dziennie; 7\_4-5 razy dziennie.

Dane uzyskane z kwestionariusza częstości spożycia 37 grup żywności stanowiły także bazę do wyłonienia wzorów żywieniowych (ang. *DPs - Dietary Patterns*). W tym zakresie zastosowano analizę czynnikową (ang. *FA - Factor Analysis*) metodą głównych składowych (ang. *PCA - Principal Component Analysis*), na podstawie, której zidentyfikowano główne czynniki (profile, wzory) żywieniowe, którym nadano odpowiednie nazwy związane z cechami łączącymi produkty charakterystyczne dla danego profilu.

Ocena ilościowa sposobu żywienia e-graczy obejmowała analizę wartości energetycznej i odżywczej diety i została przeprowadzona z zastosowaniem metody 3-dniowego bieżącego notowania i metody wagowej. Uczestnicy prowadzili dziennik żywieniowy, w którym przez trzy losowo wybrane dni zapisywali wszystkie spożyte produkty i napoje, określając ich wielkość w miarach gramaturowych lub domowych (z zastosowaniem tabeli miar domowych i gramatury produktów spożywczych i wybranych potraw). Przed przystąpieniem do monitoringu badani zostali poinstruowani w zakresie prawidłowego zapisu diety, który polegał na dokładnym określeniu posiłków (śniadanie, drugie śniadanie, obiad, podwieczorek, kolacja), godzin ich spożycia oraz produktów spożywczych i potraw (w tym sposobu przygotowywania). W przypadku trudności w oszacowaniu wielkości spożytej porcji wykorzystano metodę zdalnego fotografowania żywności (ang. *RFPM - The Remote Food Photography Method*), która polega na wykonaniu cyfrowych zdjęć żywności przed i po konsumpcji, a następnie przesłaniu ich do autora badania, w celu prawidłowego oszacowania. Wypełnione dzienniki żywieniowe zostały przeanalizowane pod kątem dokładności i poprawności. Następnie wszystkie dane żywieniowe wprowadzono do programu "Aliant Kalkulator - program dla dietetyków" (wersja 2.0). Średnie spożycie makroskładników (białka, tłuszczu, węglowodanów ogółem, kwasów tłuszczowych, błonnika i cholesterolu) odniesiono

do norm dla populacji polskiej (Jarosz i wsp. 2020) oraz zaleceń dla sportowców wyczynowych (Benardot 2012, Thomas i wsp. 2016, Kerkicks i wsp. 2018, EFSA 2017). Średnia podaż wybranych mikroskładników została porównana do właściwych norm żywieniowych (EAR, ang. *Estimated Average Requirement* i AI, ang. *Adequate Intake*) (Martin i wsp. 2009).

#### 2.2.2. Ocena poziomu aktywności fizycznej - Międzynarodowy Kwestionariusz Aktywności Fizycznej (IPAQ)

Do oceny poziomu aktywności fizycznej wykorzystano Międzynarodowy Kwestionariusz Aktywności Fizycznej - IPAQ (ang. *International Physical Activity Questionnaire*) w wersji polskiej (Biernat i wsp. 2007). Pytania odnosiły się do czasu jaki badani przeznaczyli na siedzenie, chodzenie oraz umiarkowany i intensywny wysiłek fizyczny, przez co najmniej 10 minut (bez przerwy) w ciągu ostatnich 7 dni. Wydatek energetyczny (wyrażony w MET-min-tydzień<sup>-1</sup>), obliczono mnożąc liczbę dni wykonywania danej czynności w tygodniu przez odpowiadającą jej wartość współczynnika MET (ang. *Metabolic Equivalent of Task*) oraz średni czas trwania w minutach. Następnie, otrzymane wyniki z zakresu wszystkich aktywności podejmowanych w ciągu tygodnia zsumowano i otrzymano tygodniowy wydatek energetyczny. Na podstawie uzyskanych wyników każdemu uczestnikowi przyporządkowano jeden z trzech poziomów aktywności fizycznej: (1) niewystarczający (niski) - osoby, które nie wykazywały żadnej aktywności fizycznej, bądź nie spełniały warunków dla poziomu wystarczającego i wysokiego; (2) wystarczający (umiarkowany) - osoby, które spełniają jedno z poniższych trzech kryteriów: 3 lub więcej dni intensywnych wysiłków fizycznych nie mniej niż 20 minut dziennie lub 5 lub więcej dni umiarkowanych wysiłków lub chodzenia nie mniej niż 30 minut dziennie lub 5 lub więcej dni którejkolwiek kombinacji aktywności fizycznej (chodzenia, umiarkowanych lub intensywnych wysiłków) przekraczającej 600 MET-min-tydzień<sup>-1</sup>; (3) wysoki - osoby, które spełniają jeden z poniższych dwóch kryteriów: 3 lub więcej dni intensywnych wysiłków fizycznych, łącznie co najmniej 1500 MET-min-tydzień<sup>-1</sup> lub 7 lub więcej dni którejkolwiek kombinacji wysiłków (chodzenia, umiarkowanych lub intensywnych wysiłków) przekraczającej 3000 MET-min-tydzień<sup>-1</sup>.

#### 2.2.3. Ocena wydolności i sprawności fizycznej- test o narastającym obciążeniu oraz zmodyfikowany Międzynarodowy i Europejski Test Sprawności Fizycznej

W celu określenia wydolności tlenowej zastosowano metodę bezpośrednią, polegającą na stopniowym zwiększaniu obciążenia wysiłkowego wykonywanego na ergometrze

rowerowym Monark 894E. Test rozpoczynał się 3-minutową rozgrzewką podczas jazdy na rowerze bez obciążenia, a obciążenie zwiększano o 50 W co 3 minuty, aż do osiągnięcia dobrowolnego wyczerpania. Kadencja wynosiła 60 obr/min. Tętno rejestrowano jednocześnie za pomocą pulsometru (Polar Electro, model S410). Podczas badania, co 30 sekund rejestrowano pobór tlenu ( $\text{VO}_{2\text{max}}$ ), wentylację minutową (VE) i tętno (HR). Na podstawie dynamicznych zmian parametrów oddechowych analizowano progi tlenowe i beztlenowe oraz oceniano następujące wskaźniki: maksymalny pobór tlenu ( $\text{VO}_{2\text{max}}$ ), maksymalne HR ( $\text{HR}_{\text{max}}$ ), HR próg beztlenowy (HR at AeT) i próg beztlenowy (HR at AnT), czas regeneracji HR do AeT (HR at AeT), moc na progu tlenowym (PO at AeT) i próg beztlenowy (PO at AnT), moc maksymalna przy  $\text{VO}_{2\text{max}}$  (PO at  $\text{VO}_{2\text{max}}$ ), praca całkowita (kJ).

Sprawność fizyczną uczestników oceniono za pomocą wybranych testów pochodzących z prób opracowanych przez Międzynarodowy Komitet Standaryzacji Sprawności Fizycznej (ang. ICSPFT - *International Committee on the Standardization of Physical Fitness Tests*) i Europejskiego Testu Sprawności Fizycznej (ang. EUROFIT - *European Fitness Test*) (Talaga 2004). W celu określenia poziomu sprawności ogólnej przeprowadzono serię zmodyfikowanych prób sprawnościowych: wytrzymałości siłowej górnej części ciała (zginanie i prostowanie ramion w podparciu), siły mięśni tułowia/wytrzymałości mięśni brzucha (skłon do przodu z pozycji leżącej do tyłu) i siłę chwytu za pomocą dynamometru (Jamar). Próby poprzedzone były prezentacją prawidłowej techniki wykonywania ćwiczeń oraz właściwą formą rozgrzewki. W ocenie przyjęto następujące kryteria: dla oceny bardzo dobrej - 30 i więcej ugięć ramion/skłonów, dobrej - 20-29 ugięć ramion/skłonów, dostatecznej/niewystarczającej - 10-19 ugięć ramion/skłonów i słabej (<10 ugięć ramion/skłonów). Siłę chwytu prawej i lewej dłoni odniesiono do wartości normatywnych opisanych w literaturze. Przyjęto klasyfikację dla poszczególnych grup wiekowych: 18-19 lat (wynik słaby: <35,7 kg, norma: 35,7-55,5 kg, wynik silny: >55,5 kg); 20-24 lata (wynik słaby: <36,8 kg, norma: 36,8-56,6 kg, wynik silny: >56,6 kg); 25-29 lat (wynik słaby: <37,7 kg, norma: 37,7-57,5kg, wynik silny: >57,5 kg).

#### 2.2.4. Metody analizy statystycznej

Charakterystykę grupy i uzyskane wyniki przedstawiono w postaci danych jakościowych, tj. liczebność (n), procenty (%) i ilościowych (średnia arytmetyczna ( $\bar{x}$ ), odchylenie standardowe (SD) lub mediana (Me). Do analizy statystycznej wyników oraz ich interpretacji wykorzystano oprogramowanie *IBM SPSS* (wersja 21 i 26) oraz *STATISTICA* (wersja 12.0). Uzyskane wyniki w zależności od poziomu sportowego zostały porównane

statystycznie za pomocą testu niezależności *chi*-kwadrat Pearsona, a wyniki istotne statystycznie uznano na poziomie  $p < 0,05$ .

Do empirycznego wyodrębnienia wzorów żywienia wykorzystano analizę czynnikową głównych składowych (FA), stanowiącą wielowymiarową procedurę statystyczną. W celu sprawdzenia spełnienia założeń dla metody FA przeprowadzono test Kaisera-Meyera-Olkina (KMO) oraz test sferyczności Bartletta (Rencher 2002, Hair i wsp. 2010). Wartość współczynnika korelacji KMO wyniosła 0,82, a istotność sferyczności Bartletta była mniejsza niż 0,001, co potwierdziło zasadność zastosowania FA. W celu utrzymania niezależnych czynników, z jednoczesną poprawą interpretowalności przeprowadzono rotację ortogonalną VARIMAX. Na podstawie analizy czynnikowej zidentyfikowano główne czynniki (profile, wzory) i zastosowano wartość własną czynnika ( $<1$ ). Jako metodę selekcji wyrotowanych czynników do interpretacji wykorzystano wykres osypiska (scree plot) i proporcję wariancji wyjaśnioną przez każdy czynnik (Newby 2004). Zidentyfikowano 11 czynników, z których każdy odpowiadał za co najmniej 61,3% wariancji modelu. Produkty spożywcze z bezwzględnymi ładunkami czynnikowymi  $\geq 40$  uznano za reprezentatywne dla każdego DP; wartość graniczna 0,40 oznaczała minimalny wkład dowolnego czynnika w całkowitą wariancję dowolnej grupy żywności. Ostatecznie dalszej analizie poddano 9 dominujących czynników tworzących DP (pozostałe zostały odrzucone, gdyż składały się z pojedynczych produktów). Całkowity udział profili żywieniowych w wyjaśnieniu wariancji modelu wyniósł 54,9% (odpowiednio 9,5%, 9,2%, 7,1 %, 5,8%, 5,6%, 5,3%, 4,6%, 4,1% i 3,7%). Im wyższe wartości ładunków czynnikowych, tym silniejszy był związek między dietą uczestnika a wyłonionym DP.

### 3. Wyniki

#### 3.1. Wyniki badań opublikowane w pracy pt. „Can nutrients and dietary supplements potentially improve cognitive performance also in esports?”

W oparciu o przegląd literatury dokonano charakterystyki wybranych mikroskładników pokarmowych i suplementów diety w kontekście ich potencjalnego wpływu na funkcje poznawcze e-sportowców. Należy podkreślić istotną rolę diety w dostarczaniu pierwiastków śladowych, w tym jodu, żelaza, cynku, magnezu, witamin z grupy B oraz witamin E i C, które pełnią funkcję kofaktorów w kluczowych procesach enzymatycznych. Składniki te odgrywają zasadniczą rolę w metabolizmie neuroprzekazników, strukturalnych i funkcjonalnych lipidów i białek mózgu, DNA i RNA oraz metabolizmie energetycznym. Deficytowe spożycie może powodować niedobory, a w konsekwencji zwiększać ryzyko rozwoju różnych chorób i pogorszenia samopoczucia. Zatem zapewnienie odpowiedniego spożycia mikroelementów jest niezbędnym czynnikiem w promowaniu optymalnego funkcjonowania poznawczego.

Jod ma kluczowe znaczenie dla rozwoju mózgu jako składnik hormonów tarczycy - tyroksyny i trójjodotyroniny. Jego odpowiednie spożycie jest szczególnie ważne w okresie rozwoju neurologicznego (Yehuda i wsp. 2006, Zimmermann i wsp. 2007, Bryan i wsp. 2004, Black i wsp. 2003). Żelazo uczestniczy w wielu procesach fizjologicznych, jest niezbędne do różnicowania i proliferacji neuronów. Niedobór żelaza wywiera negatywny wpływ na procesy neuronalne, takie jak mielinizacja, rozgałęzianie/rozgałęzianie dendrytów i plastyczność neuronów. Niedobór żelaza wpływa także na alokację żelaza w mózgu, zmieniając w ten sposób przedczołowo-podkorowe sieci dopaminergiczne i czołowo-prążkowiowe, które pośredniczą w funkcjach poznawczych (Kaczorowska-Hać i wsp. 2019). Magnez jest niezbędny do prawidłowego funkcjonowania wszystkich komórek, w tym neuronów. Uczestniczy m.in. w reakcjach enzymatycznych (Cowan i wsp. 2002), transmisji wewnątrzkomórkowej (Stangherlin i wsp. 2018), mielinizacji (Seyama i wsp. 2018) oraz tworzeniu i utrzymywaniu synaps (Sun i wsp. 2016), a także w regulacji transmisji serotoninerdycznej, dopaminergicznej i cholinergicznej (Spasov i wsp. 2009). Witaminy z grupy B są niezbędne dla funkcjonowania komórek, działając jako koenzymy w wielu reakcjach enzymatycznych. Ich właściwości są związane z różnymi aspektami funkcjonowania mózgu, w tym z produkcją energii, syntezą i naprawą DNA i RNA, metylacją genomową i niegenomową oraz syntezą neuroprzekazników i cząsteczek sygnalizacyjnych (Kennedy i wsp. 2016). Funkcje metaboliczne witamin z grupy



B i ich rola w syntezie neurochemicznej potwierdzają ich szczególny wpływ na funkcjonowanie mózgu (Kennedy i wsp. 2016). Niedobory żywieniowe takich mikroelementów jak witamina B<sub>12</sub>, kwas foliowy i cynk, mogą wywoływać objawy depresji i demencji, w tym obniżony nastrój, zmęczenie, pogorszenie funkcji poznawczych i drażliwość (Sensi i wsp. 2011, Skarupski i wsp. 2010). Witamina E ( $\alpha$ - i  $\gamma$ - tokoferole), jako antyoksydant, hamuje łańcuchowe reakcje utleniania lipidów, co może wpływać na wielonienasycone kwasy tłuszczowe w błonie komórkowej, wraz ze strukturami neuronalnymi (Traber i wsp. 2012). Witamina D pełni wiele funkcji fizjologicznych, w tym m.in. moduluje rozwój komórek, neurogenezę, neuroprotekcję, detoksykację, funkcje odpornościowe i zmniejsza stan zapalny (Lee i wsp. 2020). Receptor witaminy D w mózgu jest zaangażowany w złożone planowanie, przetwarzanie i tworzenie nowych wspomnień (Buell i wsp. 2008), co wskazuje na znaczenie dla funkcji poznawczych i dobrego ogólnego stanu neurologicznego (Dickens i wsp. 2011). Witamina C uczestniczy w syntezie i modulacji różnych składników regulujących funkcjonowanie układu nerwowego. Jest kofaktorem enzymów katalizujących syntezę katecholamin (noradrenaliny i adrenaliny) oraz biosyntezę neuropeptydów (Ballaz i Rebec wsp. 2019). Poziom witaminy C wpływa na receptory neuroprzekaźników i struktury mózgowe (neurony glutaminergiczne i dopaminergiczne) oraz syntezę komórek glejowych i mieliny (Ballaz i Rebec wsp. 2019, Harrison i May 2009).

Kofeina (alkaloid purynowy) jest bardzo popularnym środkiem psychostymulującym, który wpływa na funkcje poznawcze i fizyczne poprzez blokowanie receptorów adenylinowych A<sub>1</sub> i A<sub>2a</sub> w ośrodkowym i obwodowym układzie nerwowym. Dawki 1-4 mg/kg masy ciała poprawiają czujność, koncentrację i czas reakcji (McLellan i wsp. 2016), a dawki 3-6 mg/kg m.c. mogą poprawić funkcje poznawcze, zdolności motoryczne i wydolność fizyczną sportowców (Maughan i wsp. 2018). L-teanina jest aminokwasem niebiałkowym występującym naturalnie w herbacie, badanym głównie pod kątem wpływu na funkcjonowanie mózgu. Po przekroczeniu bariery krew-mózg L-teanina wpływa na ośrodkowy układ nerwowy (OUN) poprzez neuroprzekaźniki i osłabianie reakcji związanych ze stresem (Nathan i wsp. 2006). Polifenole są wtórnymi metabolitami roślinnymi, które można sklasyfikować jako: kwasy fenolowe, flawonoidy, lignany i stilbeny. Odgrywają rolę ochronną w neurodegeneracji i oddziałują na neuronalne szlaki sygnałowe (Del Rio i wsp. 2013, Shukitt-Hale i wsp. 2008). Polifenole wpływają na obwodowy i mózgowo-naczyniowy przepływ krwi oraz wewnątrzkomórkową sygnalizację neuronalną i glejową, a także chronią neurony przed uszkodzeniem (Williams i wsp. 2004, Spencer 2009, Nagahama i wsp. 2003). Ziarna kakaowca stanowią źródło związków fenolowych o wysokiej zawartości flawanoli (Martín i Ramos

2016). Badania potwierdzają korzystny wpływ kakao i produktów zawierających kakao na funkcje poznawcze. Korzyści poznawcze wynikające ze spożywania czekolady zostały opisane w przeglądzie systematycznym, w którym odnotowano poprawę zdolności poznawczych i efektywności wykonywania zadań wśród dzieci i młodych dorosłych (poniżej 25 lat). Efekt ten przypisuje się polifenolom, w tym flawanolom (Martín i Goya 2020). Luteina i jej analog zeaksantyna należą do grupy karotenoidów, które naturalnie występują w żywności. Aktualne badania sugerują wpływ luteiny na poprawę wzroku i funkcji poznawczych na każdym etapie życia (Johnson i wsp. 2014, Scott i wsp. 2017), co może być związane z jej właściwościami antyoksydacyjnymi i przeciwzapalnymi (Scott i wsp. 2017). Sok z buraków jest suplementem o potwierdzonym działaniu, który był szeroko badany pod kątem wpływu na poprawę zdolności wysiłkowych w czasie długotrwałego treningu submaksymalnego (Bailey i wsp. 2009) oraz intensywnych, przerywanych, krótkotrwałych ćwiczeń (Thompson i wsp. 2015, Wylie i wsp. 2016). Wyniki badań wskazują, że pojedyncze dawki azotanów w diecie mogą modulować odpowiedź przepływu krwi w mózgu na wykonanie zadania i potencjalnie poprawiać wydolność poznawczą, wyjaśniając zarazem jeden z mechanizmów korzystnego wpływu warzyw na funkcjonowanie mózgu (Wightman i wsp. 2015). Kreatyna jest suplementem stosowanym przez sportowców w celu poprawy wydolności, poprzez zwiększenie generowania energii w mięśniach. Jest również składnikiem mózgu, który wspiera procesy poznawcze, zwiększając podaż energii i działając neuroprotekcynie. Suplementacja kreatyną może poprawić wykonywanie zadań wymagających pamięci i inteligencji (Avgerinos i wsp. 2019). Chociaż rola suplementacji kreatyną dla funkcjonowania mózgu jest obiecująca, potrzebne są dalsze badania, ponieważ bariera krew-mózg jest przeszkodą w transporcie kreatyny, co może oznaczać potrzebę wyższych dawek i/lub dłuższych protokołów stosowania w celu zwiększenia stężenia kreatyny w mózgu w porównaniu z mięśniami. Kreatyna może być stosowana w sytuacjach stresowych, kiedy może nastąpić okresowy spadek poziomu kreatyny (Cook i wsp. 2011). W dokonanym przeglądzie badań zaobserwowano wyraźny związek pomiędzy probiotykami a procesami poznawczymi i behawioralnymi, które obejmują neurologiczne, metaboliczne, endokrynologiczne i immunologiczne szlaki sygnałowe. Zmiany w tych systemach mogą powodować zmiany w zachowaniu (dyspozycja psychiczna) i funkcjach poznawczych (uczenie się i pamięć) (Bermúdez-Humarán i wsp. 2019). Oś mikrobiota-jelita-mózg, jako interakcja między mikrobiotą jelitową a mózgiem, wywiera znaczący wpływ na zdrowie człowieka, w tym funkcjonowanie psychiczne (Cryan i Dinan 2012, Long-Smith i wsp. 2020, Gareau 2016). Opublikowano wiele badań koncentrujących się na wpływie fitoskładników na pracę mózgu i funkcje poznawcze. W celu poprawy funkcji poznawczych

zastosowanie znajdują różne suplementy roślinne, w tym żeń-szeń, mięta, miłorząb japoński (*Ginco biloba*), bakoba drobnolistna (*Bacopa monneri*), sopłówka jeżowata (*Lion's Mane*), różeńiec górski (*Rhodiola rosea*), guarana, rozmaryn, szafran, kurkuma, ashwagandha i ksantyny.

### **3.2. Wyniki badań opublikowane w pracy pt. „Nutrition Patterns of Esports players”**

Oceniając zachowania żywieniowe badanej grupy e-sportowców stwierdzono, że tylko 10,4% próby spożywało regularne posiłki, a 45,2% uwzględniało więcej niż 3 posiłki dziennie. Kolację na 2-3 godziny przed snem spożywało zaledwie 31,3% grupy. W ramach podjadania między posiłkami 41,7% badanych sięgało po owoce, ok. 10% po warzywa, a 12,2% wybierało orzechy i nasiona roślin oleistych. Średnio co trzeci badany sięgał po słodycze (39,1%) i słone przekąski (28,7%). E-sportowcy w większym odsetku deklarowali konsumpcję mleka i przetworów mlecznych o standardowej niż obniżonej zawartości tłuszczu (66,1% vs 27,8%). Większość badanych preferowała przyrządzanie potraw mięsnych techniką smażenia (80,8%), pieczenia (53,0%) i gotowania (45,2%). Do smażenia potraw e-sportowcy najczęściej wybierali tłuszcze roślinne (47,8%). Większość badanych (56,9%) deklarowała używanie masła do przygotowywania kanapek. Co drugi zawodnik przyznał, że słodzi gorące napoje co najmniej dwiema łyżeczkami cukru. Podobny odsetek graczy e-sportowych zadeklarował na okazjonalne dosalanie potraw i kanapek (47,8%). Większość e-sportowców (62,6%) wypijała co najmniej 1,5-2 l płynów dziennie, preferując wodę niegazowaną (69,6%).

Oceniając częstość spożycia żywności stwierdzono, że e-sportowcy najczęściej wybierali wodę mineralną, a następnie gorące napoje, owoce, warzywa, mleko, potrawy z białego mięsa i jaja, spożywane przynajmniej kilka razy w tygodniu przez większość e-sportowców (55,4-71,7%). Zarazem jednak warzywa co najmniej 2-3 razy dziennie spożywało zaledwie ok. 10% e-graczy. Ziemniaki, oleje roślinne, soki owocowe, fermentowane napoje mleczne, pełnoziarniste produkty zbożowe i grube kasze e-sportowcy spożywali zazwyczaj raz lub dwa razy w tygodniu. Zarazem tylko co dziesiąty badany wybierał jogurty i kefiry przynajmniej raz dziennie, a ¼ próby spożywała te produkty 1-2 lub kilka razy w tygodniu. Równie niski odsetek deklarował konsumpcję pieczywa pełnoziarnistego przynajmniej raz dziennie (10%). Mniej niż połowa badanych (43,8%) spożywała ryby 1-2 lub kilka razy w tygodniu. Nasiona roślin strączkowych w diecie większości e-sportowców (67,8%) występowały rzadko, tj. 1-3 razy w miesiącu lub nigdy. Zazwyczaj tj. 1-2 razy w tygodniu badani e-sportowcy pili słodkie napoje gazowane lub niegazowane i napoje energetyzujące oraz spożywali produkty fast food i potrawy z mięsa czerwonego.

Na podstawie analizy częstości spożycia żywności zidentyfikowano 9 wzorów żywienia, nadając im odpowiednie nazwy. Wzór 1: „Prawie zdrowy” obejmował biały ryż, standardowy makaron, drobne kasze, pełnoziarniste pieczywo, potrawy z białego mięsa, warzywa i jaja (spożywane średnio kilka razy w tygodniu) oraz ryby, orzechy, nasiona roślin oleistych, potrawy z nasion roślin strączkowych i twarogi (spożywane średnio 1-3 razy w miesiącu). Wzór drugi: „Zachodnia żywność typu fast food /niezdrowa” zawierał następujące produkty: fast food (spożywane średnio 1-2 razy w tygodniu), potrawy z nasion roślin strączkowych, konserwy mięsne i warzywne, marynowane lub kiszone warzywa, soki warzywne lub warzywno-owocowe, zupy w proszku lub zupy gotowe oraz napoje alkoholowe (spożywane średnio 1-3 razy w miesiącu). Wzór 3: „Żywność wysoko przetworzona, mięso i wyroby cukiernicze” składał się z pieczywa jasnego (spożywanego co najmniej raz dziennie), mięsa, kielbas wieprzowych, produktów smażonych (mięsnych lub mącznych) i słodczy (spożywanych średnio kilka razy w tygodniu) oraz mięsa, kielbasy, drobiu i cielęciny (spożywanych średnio 1-2 razy w tygodniu). Wzór 4: „Słodki”, skupiał słodczyce i wyroby cukiernicze (spożywane średnio kilka razy w tygodniu) oraz słodkie napoje gazowane lub niegazowane i napoje energetyzujące (spożywane 1-2 razy w tygodniu). Wzór 5: „Tłuste produkty mleczne” charakteryzował się spożyciem serów (średnio kilka razy w tygodniu), fermentowanych napojów mlecznych (1-2 razy w tygodniu) oraz serów twarogowych (1-3 razy w miesiącu). Wzór 6: „Warzywno-owocowy” obejmował warzywa, owoce i gorące napoje (spożywane średnio kilka razy w tygodniu) oraz soki owocowe (spożywane 1-2 razy w tygodniu). Wzór 7: „Przyprawy i dodatki do żywności/oleje” charakteryzował się spożyciem przypraw (średnio kilka razy w tygodniu) oraz oliwy z oliwek i oleju rzepakowego (1-2 razy w tygodniu). Wzór 8: „Tłuszcze” obejmował margarynę lub mieszanki masła i margaryny oraz smalec/olej kokosowy (spożywane średnio 1-3 razy w miesiącu). Wzór 9: „Zboża” odznaczał się wyższym spożyciem kaszy gryczanej i innych produktów pełnoziarnistych oraz niższym spożyciem smalcu i oleju kokosowego.

### **3.3. Wyniki badań opublikowane w pracy pt. „Evaluation of the eating habits of Polish esports players using the Quick Diet Survey (QDS)”**

Z badań w zakresie oceny sposobu żywienia wynika, że e-sportowcy w najwyższym stopniu realizowali rekomendacje dotyczące przyjmowania odpowiedniej ilości płynów w ciągu dnia (75%) oraz prawidłowego nawadniania w czasie wysiłku fizycznego (72,3%). Większość e-graczy deklarowała spożywanie produktów zbożowych w każdym posiłku głównym (67,6%), konsumpcję przynajmniej 3 posiłków dziennie (62,2%), właściwe

nawadnianie po wysiłku fizycznym (60,1%) oraz preferowanie wody mineralnej do nawadniania (54,8%). Około połowa grupy (50,5%) niemal codziennie spożywała tłuszcze roślinne. Mniej niż połowa badanych deklarowała codzienne spożywanie 1-2 porcji owoców (47,3%), unikanie napojów gazowanych i słodzonych (47,3%) oraz ograniczenie spożywania napojów energetyzujących (45,2%). Średni odsetek racjonalnych wyborów żywieniowych w badanej grupie e-sportowców wyniósł 42,9%. Analiza statystyczna nie wykazała istotnych różnic w zakresie zachowań żywieniowych w zależności od poziomu sportowego (profesjoniści vs półprofesjoniści) ( $p > 0,05$ ).

Wyniki walidacji zastosowanego narzędzia badawczego pozwalają stwierdzić, że kwestionariusz QDS umożliwia efektywne i precyzyjne zbieranie danych dotyczących nawyków żywieniowych, co jest kluczowe dla badań dietetycznych i interwencji zdrowotnych. Stosowanie tego narzędzia jest zalecane w przyszłych badaniach związanych z oceną sposobu żywienia, aby zwiększyć szybkość i dokładność oceny diety oraz identyfikacji wzorców żywieniowych. Ocena sposobu żywienia e-sportowców wykazała, że badani gracze w największym odsetku osiągnęli niski (44,7%) i przeciętny (40,4%) poziom realizacji zaleceń żywieniowych. Jedynie 14,9% ogółu e-graczy wykazywało wysoki poziom prawidłowych zachowań żywieniowych. Analiza statystyczna nie wykazała istotnego zróżnicowania jakości diety (stopnia realizacji rekomendacji żywieniowych) w zależności od poziomu sportowego badanych e-sportowców ( $p > 0,05$ ).

### **3.4. Wyniki badań opublikowane w pracy pt. „Characteristics of the gut microbiome in esports players compared with those in physical education students and professional athletes”**

Ilościowa ocena sposobu żywienia wykazała, że wartość energetyczna diety e-sportowców była istotnie niższa ( $p < 0,01$ ) niż u studentów wychowania fizycznego (2063 kcal vs 2418 kcal). Nieprawidłowe zbilansowanie energii wykazano zarówno w grupie e-graczy (70,5%), jak i w grupie kontrolnej (66,7%). Przeciętna podaż białka i węglowodanów w zwyczajowej diecie e-sportowców była niższa niż u studentów wychowania fizycznego ( $p < 0,001$ ). Nie odnotowano natomiast istotnej różnicy w spożyciu tłuszczu i kwasów tłuszczowych trans w porównywanych grupach. U e-sportowców stwierdzono wyższą podaż nasyconych kwasów tłuszczowych (NKT) (12,0 vs 9,9% energii) oraz niższą podaż wielonienasyconych kwasów tłuszczowych (WNKT), cholesterolu i błonnika niż w grupie kontrolnej.

W omawianych badaniach ocenie poddano także skład mikrobiomu jelitowego oraz krótkołańcuchowe kwasy tłuszczowe (ang. SCFA - *Short Chain Fatty Acids*) i aminokwasy u 109 e-sportowców oraz 25 sportowców wytrzymałościowych i 36 zdrowych studentów wychowania fizycznego. Bakteryjny DNA i metabolity wyizolowane z próbek kału analizowano z zastosowaniem metody sekwencjonowania metagenomicznego typu shoutgun w technologii Illumina i spektrometrii masowej w połączeniu z chromatografią gazową. Omawiane badania wykazały, że pomimo różnic w zakresie wskaźników antropometrycznych, poziomu aktywności fizycznej i sposobu żywienia pomiędzy e-sportowcami i studentami wf, nie stwierdzono różnic w różnorodności bakteryjnej, proporcji bakterii typów *Bacteroidetes/Firmicutes*, rodzajach enterotypów, składzie mikrobiomu i stężeniu SCFA w porównywanych grupach. Stwierdzono natomiast istotne różnice pomiędzy e-sportowcami a studentami wf w odniesieniu do dziewięciu gatunków bakterii i dziewięciu aminokwasów. Jedynym gatunkiem różnicującym badane grupy był *Parabacteroides distasonis*, najmniej liczny u e-graczy, a najbardziej liczny u sportowców dyscyplin wytrzymałościowych. W konkluzji stwierdzono, że różnice w stylu życia i nawykach żywieniowych pomiędzy e-sportowcami i studentami wychowania fizycznego nie mają znaczącego wpływu na mikrobiom jelitowy.

W omawianych badaniach wykazano ponadto, że 253 pary makroskładników i gatunków bakterii wykazywały współczynniki korelacji rang Spearmana w zakresie 0,2 - 0,39. Dziewięć gatunków było powiązanych z przynajmniej siedmioma składnikami odżywczymi. *Veillonella parvula*, *Haemophilus patainfluenzae*, *Bifidobacterium pseudocatenulatum* i *Bacteroides xylanisolvens* korelowały dodatnio odpowiednio z 16, 11, 10 i ośmioma składnikami odżywczymi, a *Desulfovibrio naceabacterium*, *Alistipes putredinis*, *Ruminococcus* sp. CAG330 i *Bilophila muris* korelowały ujemnie z dziewięcioma różnymi składnikami odżywczymi. Wyniki te potwierdzają kluczową rolę diety dla składu funkcjonalnego mikrobioty jelitowej. Korelację pomiędzy liczebnością gatunków a składnikami odżywczymi oceniano również za pomocą LINDA. Dziewięć gatunków (*Bacteroides coprocola*, *Bacteroides faecis*, *Bacteroides* sp CAG443, *Bifidobacterium pseudocatenulatum*, *Lachnospira pectinoschiza*, *Parabacteroides merdae*, *Paraprevotella xylaniphila*, *Prevotellacopri* i *Veillonella parvula*) było skorelowanych z ośmioma miarami składników odżywczych, podczas gdy siedem gatunków korelowało z ilością wody pitnej. Wszystkie związki były pozytywne.

### 3.5. Wyniki badań opublikowane w pracy pt. „Assessment of physical activity, exercise capacity and fitness level of Polish esports players”

Badania dotyczące oceny poziomu aktywności fizycznej pozwoliły na określenie całkowitego wydatku energetycznego w grupie profesjonalnych i półprofesjonalnych e-sportowców, który kształtował się na poziomie 1040 MET-min-tydz<sup>-1</sup>. Obie podgrupy nie różniły się statystycznie pod względem aktywności fizycznej (chodzenie, umiarkowana i intensywna). Wyniki badania wskazują, że e-gracze profesjonalni spędzali znacznie więcej czasu w pozycji siedzącej niż półprofesjoniści (600 vs 400 min,  $X^2 = 60,4$ ;  $p = 0,04$ ). Jedna czwarta graczy e-sportowych prezentowała wysoki, a 38% umiarkowany poziom aktywności fizycznej. Wśród profesjonalistów dominowali zawodnicy o umiarkowanej (54,1%), a wśród półprofesjonalistów - o niskiej aktywności fizycznej (37,9%).

W badaniach własnych, zrelatywizowane względem ciała uzyskane wielkości  $VO_{2max}$  wynosiły  $41,92 \pm 5,41$  mL·kg<sup>-1</sup>·min<sup>-1</sup> i nie wykazywały zróżnicowania pomiędzy podgrupami e-graczy półprofesjonalnych ( $41,98 \pm 5,50$  mL·kg<sup>-1</sup>·min<sup>-1</sup>) i profesjonalnych ( $41,64 \pm 4,91$  mL·kg<sup>-1</sup>·min<sup>-1</sup>). Maksymalne wielkości  $HR_{max}$  badanych mężczyzn wynosiły  $191 \pm 10$  sk·min<sup>-1</sup> i były podobne w każdej z badanych podgrup ( $191 \pm 10$  i  $192 \pm 7$  sk·min<sup>-1</sup>). Osiągnięta moc maksymalna na poziomie  $VO_{2max}$  wśród badanych e-graczy wynosiła  $210,29 \pm 42,63$  W i była zbliżona w podgrupach półprofesjonalnych i profesjonalnych e-sportowców, wynosząc odpowiednio:  $210,73 \pm 43,20$  i  $208,15 \pm 39,70$  W.

Wielkości HR na poziomie progu aerobowego (AeT) nie wykazywały zróżnicowania międzygrupowego pomiędzy zawodnikami półprofesjonalnymi ( $146,00 \pm 7,20$  sk·min<sup>-1</sup>) i profesjonalnymi ( $147,17 \pm 5,38$  sk·min<sup>-1</sup>). Względne wielkości HR wyrażone względem %  $HR_{max}$  na poziomie progu tlenowego wynosiły  $76,47 \pm 2,00$  % i były podobne u graczy półprofesjonalnych i profesjonalnych, wynosząc odpowiednio:  $76,46 \pm 1,97$  i  $76,53 \pm 2,04$ %. Średnia częstość skurczów serca na poziomie progu beztlenowego wynosiła  $174,16 \pm 7,87$  sk·min<sup>-1</sup> i była zbliżona w obu podgrupach ( $174,03 \pm 8,22$  i  $174,83 \pm 5,80$  sk·min<sup>-1</sup>). Zrelatywizowane względem %  $HR_{max}$  wielkości HR na poziomie progu beztlenowego (AnT) wynosiły około  $91,09 \pm 1,10$  % u wszystkich badanych i były niezależne od poziomu gry. Podobnie, wielkości mocy przy AnT były podobne w obu podgrupach ( $149,89 \pm 31,20$  i  $150,04 \pm 22,58$  W), a średnie wielkości dla całej grupy badanych wynosiły  $149,91 \pm 29,91$  W.

W zakresie ocenianych wskaźników sprawności fizycznej, większość uczestników osiągnęła wynik bardzo dobry (45,1%) lub dobry (38,7%). Warto jednak zauważyć, że wśród badanych, którzy wykonali <10 zgięć ramion były osoby, które nie wykonały ani jednego poprawnego powtórzenia (9,2% ogółu). Z kolei, ponad 94% uczestników uzyskało ocenę dobrą

lub bardzo dobrą w próbie skłonów tułowia w przód, a 1,7% nie wykonało żadnego poprawnego technicznie powtórzenia ( $<10$  skłonów). Siła chwytu została oceniona zarówno dla lewej, jak i prawej ręki, jako wynik normatywny w porównaniu do mężczyzn w wieku 18-19 lat (60% i 61,4%) i 20-24 lat (61,4% i 59,3%).



#### 4. Podsumowanie i wnioski

Wraz z postępem technologicznym i wybuchem pandemii COVID-19, w ostatnich latach zaobserwowano wzrost zainteresowania sportami elektronicznymi, co w konsekwencji przyczyniło się do badawczej eksploracji e-sportu przez różne ośrodki akademickie. W dostępnej literaturze znajdują się nieliczne badania poświęcone wybranym aspektom stylu życia, w tym dotyczące snu, aktywności fizycznej i samopoczucia e-sportowców. Problematyka żywienia w e-sporcie nie była dotąd częstym przedmiotem badań, stąd prezentowana rozprawa znacząco wypełnia lukę w tym obszarze. E-sport, podobnie jak sport tradycyjny jest aktywnością, która wymaga połączenia umiejętności fizycznych i mentalnych, choć wydaje się, że główną determinantą osiągnięcia sukcesu w e-sporcie jest wysoki poziom zdolności poznawczych. Aby odnieść sukces, gracze e-sportowi muszą być w najwyższej formie, co wymaga wsparcia poznawczego, fizycznego i psychicznego.

Istotnym czynnikiem wspierającym możliwości graczy e-sportowych jest racjonalna i zbilansowana dieta. Dlatego teoretycznym wprowadzeniem do cyklu publikacji naukowych jest artykuł przeglądowy, dotyczący charakterystyki mikroskładników pokarmowych i suplementów diety (jod, żelazo, magnez, cynk, witaminy z grupy B, witaminy E, D i C, kofeina, L-teanina, kreatyna, sok z buraka, polifenole, flawonole kakaowe, luteina, prebiotyki i probiotyki), w kontekście ich potencjalnego wpływu na funkcje poznawcze e-sportowców. Omawiane w pracy składniki, ze względu na udokumentowane właściwości funkcjonalne, mają potencjalną możliwość wspomagania funkcji umysłowych i poznawczych graczy e-sportowych.

Mikroelementy są pierwiastkami ważnymi dla prawidłowego funkcjonowania mózgu oraz poprawy zdolności poznawczych. Ich niedobór może upośledzać funkcje poznawcze na każdym etapie życia. Podaż witaminy D w diecie jest deficytowa, a synteza skórna pod wpływem UV wymaga specjalnych warunków, dlatego zaleca się stosowanie suplementacji, m.in. z uwagi na zdrowie psychiczne e-sportowców. Kofeina wykazuje właściwości zmniejszania uczucia zmęczenia i poprawy funkcji poznawczych, takich jak czujność, koncentracja, uwaga, czas reakcji, zdolności motoryczne i sprawność fizyczna. L-teanina w połączeniu z kofeiną może pozytywnie wpływać na czas reakcji, pamięć roboczą, uwagę, koncentrację i stan emocjonalny e-sportowców. Polifenole wpływają na wzrost czujności, dokładności, szybkości uwagi wzrokowej i pamięci roboczej, zatem suplementacja polifenolami może być rozważana ze względu na stresujące i rywalizacyjne środowisko

wirtualne, wpisujące się w codzienny tryb życia e-sportowców. Długotrwała ekspozycja na niebieskie światło z ekranu komputera powoduje zmęczenie oraz zaburzenia rytmu dobowego i snu, które można potencjalnie zrekompensować poprzez dostarczanie z dietą flawanoli kakaowych i kreatyny. W trosce o wzrok e-sportowców można rozważyć suplementację luteiny, która oprócz poprawy widzenia, może również wpływać na funkcje poznawcze. Również spożywanie soku z buraków może potencjalnie poprawić zdolności poznawcze e-graczy. Suplementacja kreatyną może z kolei wpływać na redukcję zmęczenia oraz poprawę nastroju, wyników w testach inteligencji, pamięci roboczej i szybkości reakcji, co uzasadnia jej stosowanie przez e-sportowców. Stosowanie probiotyków może wspomagać funkcje poznawcze, poprzez redukcję stresu, który negatywnie oddziałuje na pamięć roboczą. Istnieje wiele suplementów (L-teanina, polifenole, sok z buraków) i składników roślinnych (żeń-szeń, mięta, miłorząb dwuklapowy, bakopa drobnolistna, soplówka jeżowata, rózeniec górski, guarana, rozmaryn, szafran, kurkuma, ashwagandha, ksantyny), które wymagają dalszych badań dotyczących ich wpływu na funkcje poznawcze.

Ważnym zagadnieniem w cyklu publikacji była ocena sposobu żywienia oraz częstości spożycia produktów o potencjalnie korzystnym i negatywnym wpływie na pracę mózgu w grupie profesjonalnych i półprofesjonalnych e-sportowców. W tym zakresie stwierdzono, że polscy e-sportowcy w niskim stopniu realizują jakościowe zalecenia żywieniowe oraz zbyt rzadko spożywają produkty potencjalnie korzystnie wpływające na funkcjonowanie mózgu i poprawę zdolności poznawczych (ryby, orzechy, nasiona roślin oleistych, nasiona roślin strączkowych, soki warzywne i warzywno-owocowe). Jednym z istotnych obszarów badań było wyodrębnienie i określenie wzorów (profilu) żywienia e-sportowców. Większość z wyłonionych wzorów uznano za niezdrowe, cechujące się częstym spożywaniem produktów przetworzonych o wysokiej wartości energetycznej, związanych z modelem diety zachodniej (*Western dietary pattern*), zwiększającej ryzyka zdrowotne i obniżającej funkcje poznawcze. Tylko jeden opisany wzór żywienia wykazywał cechy zdrowej diety. W świetle uzyskanych wyników można przyjąć, że diagnoza sposobu żywienia i nawyków żywieniowych może umożliwić stworzenie spersonalizowanych zaleceń żywieniowych i podjęcie działań edukacyjnych mających na celu racjonalizację sposobu żywienia e-sportowców.

Interesującym poznawczo uzupełnieniem badań była analiza porównawcza diety i mikrobioty jelitowej graczy e-sportowych i osób o zwiększonej aktywności fizycznej, która wykazała brak istotnych różnic w diecie porównywanych grup. Różnice w stylu życia i nawykach żywieniowych e-sportowców i studentów wychowania fizycznego wydają się nie mieć istotnego wpływu na mikrobiom jelitowy. Pomimo zróżnicowania wskaźników

antropometrycznych, poziomu aktywności fizycznej i sposobu żywienia, nie wykazano różnic w różnorodności bakteryjnej, proporcji bakterii typów *Bacteroidetes/Firmicutes*, rodzajach enterotypów, składzie mikrobiomu i stężeniu SCFA u e-sportowców i studentów wf. W porównywanych grupach stwierdzono natomiast istotne różnice dotyczące dziewięciu gatunków bakterii i dziewięciu aminokwasów.

Ostatnim obszarem prezentowanych badań była ocena aktywności, wydolności i sprawności fizycznej polskich e-sportowców. Aktywność fizyczna wraz ze zbilansowaną dietą jest istotnym elementem zdrowego stylu życia. W omawianych badaniach e-sportowcy deklarowali głównie niski i umiarkowany poziom aktywności fizycznej. Profesjonalni gracze istotnie więcej czasu spędzali w pozycji siedzącej w porównaniu do półprofesjonalistów, co jest związane z tym, że są bardziej zaangażowani w treningi i inne dodatkowe działania związane z zawodowym e-sportem. W ramach niniejszej rozprawy dokonano także oceny wydolności krążeniowo-oddechowej ( $VO_{2max}$ ), którą zgodnie z przyjętą klasyfikacją oceniono jako przeciętną, co koresponduje z umiarkowanym i niskim poziomem aktywności fizycznej. Pomiary wydatku energetycznego za pomocą metod wykorzystujących elektroniczne lub mechaniczne czujniki ruchu oraz analizujące przemieszczanie się ciała w przestrzeni (akcelerometry) mogłyby uzupełnić wiedzę w zakresie dobowych wydatków energetycznych e-sportowców.

Wyniki omawianych badań sugerują zasadność podjęcia działań mających na celu zwiększenie wiedzy na temat znaczenia racjonalnego żywienia i regularnej aktywności fizycznej wśród graczy e-sportowych. W przyszłych badaniach można przeprowadzić ocenę składu ciała i monitorowanie stanu odżywienia oraz nawodnienia e-sportowców.

Przeprowadzone w ramach niniejszej rozprawy doktorskiej badania pozwoliły na sformułowanie następujących wniosków.

1. Spośród mikroskładników pokarmowych, szczególne znaczenie w diecie e-sportowców w kontekście zdolności poznawczych, wykazują: jod, żelazo, magnez, cynk, witaminy grupy B oraz witaminy E, D i C. E-sportowcy powinni rozważyć suplementowanie diety kofeiną, L-teaniną, polifenolami, flawonolami kakaowymi, sokiem z buraka, kreatyną, prebiotykami i probiotykami oraz luteiną.
2. Jakościowa ocena sposobu żywienia e-sportowców wykazała ograniczoną skalę realizacji zaleceń żywieniowych. Wśród najbardziej rozpowszechnionych nieprawidłowości żywieniowych należy wskazać niskie spożycie zalecanych grup produktów, w tym warzyw, nasion roślin strączkowych, pełnoziarnistych produktów zbożowych i ryb, co

może mieć wpływ na obniżenie wartości odżywczej i zdrowotnej diety. Ponadto wykazano nieregularne spożywanie posiłków, smażenie potraw mięsnych oraz słodzenie gorących napojów. Prawidłowe zachowania żywieniowe graczy e-sportowych dotyczyły przede wszystkim spożywania zalecanej liczby posiłków, prawidłowego uzupełniania płynów w ciągu dnia, głównie w postaci wody niegazowanej i uwzględniania produktów zbożowych w głównych posiłkach. Poziom realizacji zaleceń żywieniowych nie był zróżnicowany w zależności od poziomu sportowego e-graczy.

3. Stwierdzono niskie spożycie produktów o potencjalnym korzystnym wpływie na funkcjonowanie mózgu, takich jak: ryby, orzechy, nasiona roślin oleistych i strączkowych oraz soki warzywne i warzywno-owocowe.
4. Dietę e-graczy nie można uznać za zbilansowaną, ze względu na niezrównoważony bilans energetyczny i zbyt wysoką podaż nasyconych kwasów tłuszczowych, a także niskie spożycie wielonienasyconych kwasów tłuszczowych oraz błonnika pokarmowego. Zawartość makroskładników pokarmowych, określona jako średni procentowy udział energii w diecie, była odpowiednia, jednak podaż białka (wyrażona w g/kg m. c.) była zbyt wysoka.
5. Wyłoniono i zidentyfikowano 9 wzorów żywienia powiązanych wzajemnymi współzależnościami w zakresie częstości spożycia produktów spożywczych, potraw i napojów. Jeden profil żywienia („Warzywno-owocowy”) został uznany za prozdrowotny, a pozostałe sklasyfikowano jako niezdrowe, związane z modelem diety zachodniej.
6. Polscy e-sportowcy osiągnęli niski i umiarkowany poziom aktywności fizycznej oraz charakteryzowali się przeciętnym poziomem wydolności krążeniowo-oddechowej, a wielkość mocy mięśniowej generowanej na poziomie AeT, AnT,  $VO_{2max}$  była niższa niż u aktywnych fizycznie mężczyzn oraz zdrowych młodych mężczyzn w podobnej grupie wiekowej, których wyniki zostały opisane w literaturze. Sprawność fizyczną e-graczy oceniono jako zadowalającą, ale potrzebne są dalsze badania, aby jednoznacznie potwierdzić uzyskane wstępne dane. Stwierdzono, że gracze profesjonalni istotnie więcej czasu spędzają w pozycji siedzącej w porównaniu do zawodników półprofesjonalnych.
7. Przeprowadzone w ramach rozprawy doktorskiej badania pozwoliły na zaprezentowanie pierwszych, oryginalnych wyników dotyczących oceny wybranych aspektów stylu życia profesjonalnych i półprofesjonalnych graczy e-sportowych. Podjęty problem badawczy ma charakter poznawczy i aplikacyjny. Uzyskane rezultaty wpisują się w rosnące globalne zainteresowanie e-sportem oraz coraz większą świadomość uwarunkowań zdrowia

psychicznego i fizycznego e-sportowców, wskazując na potrzebę racjonalizacji diety oraz edukacji żywieniowej i zdrowotnej tej grupy populacyjnej.

Wyniki uzyskane w ramach przeprowadzonych badań pozwoliły na zweryfikowanie przyjętych hipotez badawczych:

Hipoteza pierwsza została częściowo potwierdzona. Potwierdzono występowanie nieprawidłowości w zakresie analizowanych wybranych aspektów stylu życia w grupie polskich e-sportowców. Stwierdzono bowiem ograniczoną realizację jakościowych zaleceń żywieniowych i niską częstość spożycia produktów pozytywnie wpływających na funkcjonowanie mózgu. Zawodnicy deklarowali niewystarczający poziom aktywności fizycznej oraz charakteryzowali się przeciętnym poziomem wydolności krążeniowo-oddechowej i sprawności fizycznej.

Hipoteza druga została potwierdzona. Ocenione nieprawidłowości żywieniowe wykazały brak istotnych różnic w zakresie zachowań żywieniowych w zależności od poziomu sportowego (profesjoniści vs półprofesjoniści).

Nieprawidłowości żywieniowe stwierdzone w badanej grupie korespondują z tendencjami opisanymi w innych badaniach z udziałem zawodników e-sportowych.

Hipoteza trzecia została potwierdzona. Spośród 9 wyłoniętych wzorów żywienia, osiem z nich charakteryzuje się największą częstością spożycia produktów wysokokalorycznych i przetworzonych, typowych dla modelu diety zachodniej.

Hipoteza czwarta została częściowo potwierdzona. Wykazano, że deklarowany przez e-graczy poziom aktywności fizycznej kształtował się na niskim i umiarkowanym poziomie. Zgodnie z przewidywaniami, zawodnicy e-sportu grający na poziomie profesjonalnym są mniej aktywni i spędzają więcej czasu w pozycji siedzącej w porównaniu do półprofesjonalistów. Nie stwierdzono jednak wysokiego rozpowszechnienia nadmiernej masy ciała. Wydolność krążeniowo-oddechowa nie była istotnie zróżnicowana w zależności od poziomu sportowego badanych e-sportowców.

## 5. Bibliografia

1. Aslanyan G, Amroyan E, Gabrielyan E, Nylander M, Wikman G, Panossian A. Double-blind, placebo-controlled, randomised study of single dose effects of ADAPT-232 on cognitive functions. *Phytomedicine*. 2010 Jun;17(7):494–9.
2. Attia A, Rapp SR, Case LD, D’Agostino R, Lesser G, Naughton M, et al. Phase II study of Ginkgo biloba in irradiated brain tumor patients: effect on cognitive function, quality of life, and mood. *J Neurooncol*. 2012 Sep 15;109(2):357–63.
3. Avgerinos KI, Spyrou N, Bougioukas KI, Kapogiannis D. Effects of creatine supplementation on cognitive function of healthy individuals: A systematic review of randomized controlled trials. *Exp Gerontol*. 2018 Jul 15;108:166–73.
4. Bailey SJ, Winyard P, Vanhatalo A, Blackwell JR, DiMenna FJ, Wilkerson DP, et al. Dietary nitrate supplementation reduces the O<sub>2</sub> cost of low-intensity exercise and enhances tolerance to high-intensity exercise in humans. *J Appl Physiol*. 2009 Oct;107(4):1144–55.
5. Ballaz SJ, Rebec G V. Neurobiology of vitamin C: Expanding the focus from antioxidant to endogenous neuromodulator. *Pharmacol Res*. 2019 Aug;146:104321.
6. Baumann A, Mentzoni RA, Erevik E, Pallesen S. A qualitative study on Norwegian esports students’ sleep, nutritional and physical activity habits and the link to health and performance. *IJESPORTS*. 2022 Oct 25;1(1).
7. Bermúdez-Humarán LG, Salinas E, Ortiz GG, Ramirez-Jirano LJ, Morales JA, Bitzer-Quintero OK. From Probiotics to Psychobiotics: Live Beneficial Bacteria Which Act on the Brain-Gut Axis. *Nutrients*. 2019 Apr 20;11(4):890.
8. Benardot D. Advanced Sports Nutrition. Human Kinetics; 2012.
9. Biernat E, Stupnicki R, Gajewski AK. Międzynarodowy Kwestionariusz Aktywności Fizycznej (IPAQ) – wersja polska. *Wych Fiz Sport*. 2007;51:47–54.
10. Black MM. The Evidence Linking Zinc Deficiency with Children’s Cognitive and Motor Functioning. *J Nutr*. 2003 May;133(5):1473S–1476S.
11. Bryan J, Osendarp S, Hughes D, Calvaresi E, Baghurst K, Klinken JW. Nutrients for Cognitive Development in School-aged Children. *Nutr Rev*. 2004 Aug;62(8):295–306.
12. Buell JS, Dawson-Hughes B. Vitamin D and neurocognitive dysfunction: Preventing “D”ecline? *Mol Aspects Med*. 2008 Dec;29(6):415–22.
13. NHANES Questionnaires, Datasets, and Related Documentation [Internet]. [cited 2022 Oct 15]. Available from: <https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/default.aspx>

14. Chen EYH, Hui CLM. HT1001, A Proprietary North American Ginseng Extract, Improves Working Memory in Schizophrenia: A Double-blind, Placebo-Controlled Study. *Phytother. Res.* 2012 Aug 30;26(8):1166–72.
15. Chiu CC, Su KP, Cheng TC, Liu HC, Chang CJ, Dewey ME, et al. The effects of omega-3 fatty acids monotherapy in Alzheimer's disease and mild cognitive impairment: A preliminary randomized double-blind placebo-controlled study. *Prog Neuropsychopharmacol Biol Psychiatry.* 2008 Aug;32(6):1538–44.
16. Clements AJ, Paul RW, Lencer AJ, Seigerman DA, Erickson BJ, Bishop ME. Analysis of Musculoskeletal Injuries Among Collegiate Varsity Electronic Sports Athletes. *Cureus.* 2022 Nov 14;14(11):e31487.
17. Cook CJ, Crewther BT, Kilduff LP, Drawer S, Gaviglio CM. Skill execution and sleep deprivation: effects of acute caffeine or creatine supplementation - a randomized placebo-controlled trial. *J Int Soc Sports Nutr.* 2011 Feb 4;8(1).
18. Cowan JA. Structural and catalytic chemistry of magnesium-dependent enzymes. *BioMetals.* 2002 Sep;15(3):225–35.
19. Cryan JF, Dinan TG. Mind-altering microorganisms: the impact of the gut microbiota on brain and behaviour. *Nat Rev Neurosci.* 2012 Oct 12;13(10):701–12.
20. Darwish H, Haddad R, Osman S, Ghassan S, Yamout B, Tamim H, et al. Effect of Vitamin D Replacement on Cognition in Multiple Sclerosis Patients. *Sci Rep.* 2017 Apr 4;7(1):45926.
21. de Jager CA, Oulhaj A, Jacoby R, Refsum H, Smith AD. Cognitive and clinical outcomes of homocysteine-lowering B-vitamin treatment in mild cognitive impairment: a randomized controlled trial. *Int J Geriatr Psychiatry.* 2012 Jun 21;27(6):592–600.
22. Del Rio D, Rodriguez-Mateos A, Spencer JPE, Tognolini M, Borges G, Crozier A. Dietary (Poly)phenolics in Human Health: Structures, Bioavailability, and Evidence of Protective Effects Against Chronic Diseases. *Antioxid Redox Signal.* 2013 May 10;18(14):1818–92.
23. Dickens AP, Lang IA, Langa KM, Kos K, Llewellyn DJ. Vitamin D, Cognitive Dysfunction and Dementia in Older Adults. *CNS Drugs.* 2011 Aug;25(8):629–39.
24. DiFrancisco-Donoghue J, Balentine J, Schmidt G, Zwibel H. Managing the health of the eSport athlete: an integrated health management model. *BMJ Open Sport Exerc Med.* 2019 Jan 10;5(1):e000467.
25. DiFrancisco-Donoghue J, Werner WG, Douris PC, Zwibel H. Esports players, got muscle? Competitive video game players' physical activity, body fat, bone mineral content, and muscle mass in comparison to matched controls. *J Sport Health Sci.* 2022 Nov;11(6):725–30.

26. Dysken MW, Sano M, Asthana S, Vertrees JE, Pallaki M, Llorente M, et al. Effect of Vitamin E and Memantine on Functional Decline in Alzheimer Disease. *JAMA*. 2014 Jan 1;311(1):33.
27. European Food Safety Authority (EFSA): Dietary Reference Values for nutrients Summary report. EFSA Supporting Publications. 2017 Dec;14(12):15121.
28. Emara AK, Ng MK, Cruickshank JA, Kampert MW, Piuze NS, Schaffer JL, et al. Gamer's Health Guide: Optimizing Performance, Recognizing Hazards, and Promoting Wellness in Esports. *Curr Sports Med Rep*. 2020 Dec;19(12):537–45.
29. García-Lanzo S, Bonilla I, Chamarro A. The psychological aspects of electronic sports: Tips for sports psychologists. *Int. J. Sport Psychol*. 2020;51(6):613–25.
30. Gareau MG. Cognitive Function and the Microbiome. *Int Rev Neurobiol*. 2016;131:227–46.
31. Giakoni-Ramírez F, Merellano-Navarro E, Duclos-Bastías D. Professional Esports Players: Motivation and Physical Activity Levels. *Int J Environ Res Public Health*. 2022 Feb 16;19(4):2256.
32. Goulart JB, Aitken LS, Siddiqui S, Cuevas M, Cardenas J, Beathard KM, et al. Nutrition, lifestyle, and cognitive performance in esports athletes. *Front Nutr*. 2023 May 18;10.
33. Hair JF, Black, WC, Babin, BJ, Anderson RE. *Multivariate Data Analysis: A Global Perspective*. 7th ed. Pearson Education; 2010.
34. Harrison FE, May JM. Vitamin C function in the brain: vital role of the ascorbate transporter SVCT2. *Free Radic Biol Med*. 2009 Mar;46(6):719–30.
35. Hu J, Jia J, Zhang Y, Miao R, Huo X, Ma F. Effects of vitamin D<sub>3</sub> supplementation on cognition and blood lipids: a 12-month randomised, double-blind, placebo-controlled trial. *J Neurol Neurosurg Psychiatry*. 2018 Dec;89(12):1341–7.
36. Huth C. Nutritional behaviour of (Non-)eSports players – a comparative study. *Qual. Sport*. 2021 Jun 8;7(2):38–44.
37. Jarosz M, Rychlik E, Stoś K, Charzewska J. Normy żywienia dla populacji Polski i ich zastosowanie. Narodowy Instytut Zdrowia Publicznego-Państwowy Zakład Higieny. 2020;
38. Jeżewska-Zychowicz M, Gawęcki J, Wądołowska L, Czarnocińska J, Galiński G, Kołłajtis-Dołowy A, et al. Kwestionariusz do badania poglądów i zwyczajów żywieniowych dla osób w wieku od 16 do 65 lat, wersja 1.1 – kwestionariusz administrowany przez ankietę- badacza. Rozdz. 1. In: Kwestionariusz do badania poglądów i zwyczajów żywieniowych oraz procedura opracowania danych. (red.) Gawęcki J. Wyd. Komitetu Nauki o Żywieniu Człowieka Polskiej Akademii Nauk Warszawa. 2014;23–30.
39. Johnson EJ. Role of lutein and zeaxanthin in visual and cognitive function throughout the lifespan. *Nutr Rev*. 2014 Sep;72(9):605–12.



40. Johnson MR, Woodcock J. Work, play, and precariousness: An overview of the labour ecosystem of esports. *Media Cult Soc*. 2021 Nov 28;43(8):1449–65.
41. Kaczorowska-Hac B, Luszczek M, Antosiewicz J, Kaczor JJ. Iron metabolism and hepcidin concentration in teenagers before and after exercise in relation to the HFE gene status. *Balt J Health Phys Act*. 2019 Jun 30;11(2):26–35.
42. Karpęcka E, Frączek B. Macronutrients and water – do they matter in the context of cognitive performance in athletes? *Balt J Health Phys Act*. 2020 Sep 30;12(3):114–24.
43. Kennedy D. B Vitamins and the Brain: Mechanisms, Dose and Efficacy – A Review. *Nutrients*. 2016 Jan 27;8(2):68.
44. Kerksick CM, Wilborn CD, Roberts MD, Smith-Ryan A, Kleiner SM, Jäger R, et al. ISSN exercise & sports nutrition review update: research & recommendations. *J Int Soc Sports Nutr*. 2018 Jan 5;15(1).
45. Kumar N, Abichandani LG, Thawani V, Gharpure KJ, Naidu MUR, Venkat Ramana G. Efficacy of Standardized Extract of *Bacopa monnieri* (Bacognize®) on Cognitive Functions of Medical Students: A Six-Week, Randomized Placebo-Controlled Trial. *Evid Based Complement Alternat Med*. 2016;2016:1–8.
46. Lam WK, Liu RT, Chen B, Huang XZ, Yi J, Wong DWC. Health Risks and Musculoskeletal Problems of Elite Mobile Esports Players: a Cross-Sectional Descriptive Study. *Sports Med Open*. 2022 Dec 13;8(1):65.
47. Lee DH, Chon J, Kim Y, Seo YK, Park EJ, Won CW, et al. Association between vitamin D deficiency and cognitive function in the elderly Korean population. *Medicine*. 2020 Feb;99(8):e19293.
48. Leher P, Villaseca P, Hogervorst E, Maki PM, Henderson VW. Individually modifiable risk factors to ameliorate cognitive aging: a systematic review and meta-analysis. *Climacteric*. 2015 Sep 3;18(5):678–89.
49. Lewis JE, Melillo AB, Tiozzo E, Chen L, Leonard S, Howell M, et al. A double-blind, randomized clinical trial of dietary supplementation on cognitive and immune functioning in healthy older adults. *BMC Complement Altern Med*. 2014 Dec 4;14(1):43.
50. Lindberg L, Nielsen SB, Damgaard M, Sloth OR, Rathleff MS, Straszek CL. Musculoskeletal pain is common in competitive gaming: a cross-sectional study among Danish esports athletes. *BMJ Open Sport Exerc Med*. 2020 Aug 28;6(1):000799.
51. Long-Smith C, O’Riordan KJ, Clarke G, Stanton C, Dinan TG, Cryan JF. Microbiota-Gut-Brain Axis: New Therapeutic Opportunities. *Annu Rev Pharmacol Toxicol*. 2020 Jan 6;60(1):477–502.

52. Mangelaja E. Economics of Esports. *Electronic Journal of Business Ethics Organization Studies*. 2019;24:34–42.
53. Mariage PA, Hovhannisyan A, Panossian AG. Efficacy of Panax ginseng Meyer Herbal Preparation HRG80 in Preventing and Mitigating Stress-Induced Failure of Cognitive Functions in Healthy Subjects: A Pilot, Randomized, Double-Blind, Placebo-Controlled Crossover Trial. *Pharmaceuticals*. 2020 Mar 29;13(4):57.
54. Martin CK, Kaya S, Gunturk BK. Quantification of food intake using food image analysis. *Annu Int Conf IEEE Eng Med Biol Soc*. 2009;2009:6869–72.
55. Martín MA, Ramos S. Cocoa polyphenols in oxidative stress: Potential health implications. *J Funct Foods*. 2016 Dec;27:570–88.
56. Martin-Niedecken AL, Schättin A. Let the Body’n’Brain Games Begin: Toward Innovative Training Approaches in eSports Athletes. *Front Psychol*. 2020 Feb 19;11.
57. Martín MA, Goya L, de Pascual-Teresa S. Effect of Cocoa and Cocoa Products on Cognitive Performance in Young Adults. *Nutrients*. 2020 Nov 30;12(12):3691.
58. Maughan RJ, Burke LM, Dvorak J, Larson-Meyer DE, Peeling P, Phillips SM, et al. IOC consensus statement: dietary supplements and the high-performance athlete. *Br J Sports Med*. 2018 Apr;52(7):439–55.
59. Maylor EA, Simpson EEA, Secker DL, Meunier N, Andriollo-Sanchez M, Polito A, et al. Effects of zinc supplementation on cognitive function in healthy middle-aged and older adults: the ZENITH study. *Br J Nutr*. 2006 Oct;96(4):752–60.
60. Meeusen R, Decroix L. Nutritional Supplements and the Brain. *Int J Sport Nutr Exerc Metab*. 2018 Mar;28(2):200–11.
61. McLellan TM, Caldwell JA, Lieberman HR. A review of caffeine’s effects on cognitive, physical and occupational performance. *Neurosci Biobehav Rev*. 2016 Dec;71:294–312.
62. Morgan A, Stevens J. Does *Bacopa monnieri* Improve Memory Performance in Older Persons? Results of a Randomized, Placebo-Controlled, Double-Blind Trial. *J Altern Complement Med*. 2010 Jul;16(7):753–9.
63. Nagorsky E, Wiemeyer J. The structure of performance and training in esports. *PLoS One*. 2020 Aug 25;15(8):e0237584.
64. Nagahama Y, Nabatame H, Okina T, Yamauchi H, Narita M, Fujimoto N, et al. Cerebral Correlates of the Progression Rate of the Cognitive Decline in Probable Alzheimer’s Disease. *Eur Neurol*. 2003;50(1):1–9.
65. Nathan PJ, Lu K, Gray M, Oliver C. The Neuropharmacology of L-Theanine( *N* -Ethyl-L-Glutamine). *J Herb Pharmacother*. 2006 Jan 20;6(2):21–30.

66. Newby PK, Tucker KL. Empirically Derived Eating Patterns Using Factor or Cluster Analysis: A Review. *Nutr Rev*. 2004 May 1;62(5):177–203.
67. Paramitha ST, Hasan MF, Ilsya MNF, Anggraeni L, Gilang Ramadhan M. Level of physical activity of Indonesian Esport Athletes in the Piala Presiden Esport 2019. *J. SPORTIF J Penelit. Pembelajaran*. 2021 Apr 15;7(1):71–83.
68. Pedraza-Ramirez I, Musculus L, Raab M, Laborde S. Setting the scientific stage for esports psychology: a systematic review. *Int Rev Sport Exerc Psychol*. 2020 Jan 1;13(1):319–52.
69. Pereira AM, Verhagen E, Figueiredo P, Seabra A, Martins A, Brito J. Physical Activity Levels of Adult Virtual Football Players. *Front Psychol*. 2021 Mar 26;12:596434.
70. Pereira AM, Figueiredo P, Seabra A, Brito J. Evaluation of physical activity levels in FPF eSports eathletes. *Motricidade*. 2019;15:188.
71. Pettersen JA. Does high dose vitamin D supplementation enhance cognition?: A randomized trial in healthy adults. *Exp Gerontol*. 2017 Apr;90:90–7.
72. Pluss MA, Bennett KJM, Novak AR, Panchuk D, Coutts AJ, Fransen J. Esports: The Chess of the 21st Century. *Front Psychol*. 2019 Jan 30;10:156.
73. Rencher AC. Factor Analysis. In: Rencher AC, editor. *Methods of Multivariate Analysis*. New York: John Wiley & Sons, Inc.; 2002. p. 408-447.
74. Ribeiro FJ, Teixeira R, Póinhos R. Dietary Habits and Gaming Behaviors of Portuguese and Brazilian Esports Players. *Nutrients*. 2023 Sep 28;15(19):4200.
75. Rudolf K, Bickmann P, Froböse I, Tholl C, Wechsler K, Grieben C. Demographics and Health Behavior of Video Game and eSports Players in Germany: The eSports Study 2019. *Int J Environ Res Public Health*. 2020 Mar 13;17(6):1870.
76. Scott T, Rasmussen H, Chen O, Johnson E. Avocado Consumption Increases Macular Pigment Density in Older Adults: A Randomized, Controlled Trial. *Nutrients*. 2017 Aug 23;9(9):919.
77. Seng PH, Affandi MABN, Kamaruzzaman NNB, Panierselvam DKA, Mohammed AF. A Cross Sectional Study On The Benefit And Health Issues Among Esports Players. *NVEO*. 2021;31:16076–85.
78. Sensi SL, Paoletti P, Bush AI, Sekler I. Zinc in the physiology and pathology of the CNS. *Nat Rev Neurosci*. 2009 Nov 14;10(11):780–91.
79. Seyama T, Kamei Y, Iriyama T, Imada S, Ichinose M, Toshimitsu M, et al. Pretreatment with magnesium sulfate attenuates white matter damage by preventing cell death of developing oligodendrocytes. *J Obstet Gynaecol Res*. 2018 Apr 23;44(4):601–7.
80. Shukitt-Hale B, Lau FC, Joseph JA. Berry Fruit Supplementation and the Aging Brain. *J Agric Food Chem*. 2008 Feb;56(3):636–41.

81. Skarupski KA, Tangney C, Li H, Ouyang B, Evans DA, Morris MC. Longitudinal association of vitamin B-6, folate, and vitamin B-12 with depressive symptoms among older adults over time. *Am J Clin Nutr.* 2010 Aug;92(2):330–5.
82. Spasov AA, Iezhitsa IN, Kravchenko MS, Kharitonova M V. Features of Central Neurotransmission in Animals in Conditions of Dietary Magnesium Deficiency and After Its Correction. *Neurosci Behav Physiol.* 2009 Sep 21;39(7):645–53.
83. Spencer JPE. The impact of flavonoids on memory: physiological and molecular considerations. *Chem Soc Rev.* 2009 Apr;38(4):1152.
84. Stangherlin A, O'Neill JS. Signal Transduction: Magnesium Manifests as a Second Messenger. *Curr Biol.* 2018 Dec;28(24):R1403–5.
85. Stark A. An historical review of the Harvard and the National Cancer Institute food frequency questionnaires: Their similarities, differences, and their limitations in assessment of food intake. *Ecol Food Nutr.* 2002 Jan;41(1):35–74.
86. Sun Q, Weinger JG, Mao F, Liu G. Regulation of structural and functional synapse density by L-threonate through modulation of intraneuronal magnesium concentration. *Neuropharmacology.* 2016 Sep;108:426–39.
87. Szot M, Frączek B, Tyrała F. Nutrition Patterns of Polish Esports Players. *Nutrients.* 2022 Dec 28;15(1):149.
88. Talaga J. *Sprawność Fizyczna Ogólna-Testy.* Poznań: Wyd. Zysk i S-ka; 2004.
89. Tartar JL, Kalman D, Hewlings S. A Prospective Study Evaluating the Effects of a Nutritional Supplement Intervention on Cognition, Mood States, and Mental Performance in Video Gamers. *Nutrients.* 2019 Oct 1;11(10):2326.
90. Thomas DT, Erdman KA, Burke LM. American College of Sports Medicine Joint Position Statement. Nutrition and Athletic Performance. *Med Sci Sports Exerc.* 2016 Mar;48(3):543–68.
91. Thomas CJ, Rothschild J, Earnest CP, Blaisdell A. The Effects of Energy Drink Consumption on Cognitive and Physical Performance in Elite League of Legends Players. *Sports.* 2019 Aug 22;7(9):196.
92. Thompson C, Wylie LJ, Fulford J, Kelly J, Black MI, McDonagh STJ, et al. Dietary nitrate improves sprint performance and cognitive function during prolonged intermittent exercise. *Eur J Appl Physiol.* 2015 Sep 7;115(9):1825–34.
93. Traber MG. Vitamin, E. Present Knowledge in Nutrition. In: Erdman JW, Macdonald IA, Zeisel SH, editors. *Washington: Wiley-Blackwell; 2012. p. 214–29.*

94. Trotter MG, Coulter TJ, Davis PA, Poulus DR, Polman R. The Association between Esports Participation, Health and Physical Activity Behaviour. *Int J Environ Res Public Health*. 2020 Oct 8;17(19):7329.
95. Truong P, Truong L, Le T, Kuklova K. Orthopedic Injuries from Video Games: A Literature Review and Implications for the Future. *Int Arch Orthop Surg*. 2020 Aug 31;3(2).
96. Wightman EL, Haskell-Ramsay CF, Thompson KG, Blackwell JR, Winyard PG, Forster J, et al. Dietary nitrate modulates cerebral blood flow parameters and cognitive performance in humans: A double-blind, placebo-controlled, crossover investigation. *Physiol Behav*. 2015 Oct;149:149–58.
97. Williams RJ, Spencer JPE, Rice-Evans C. Flavonoids: antioxidants or signalling molecules? *Free Radic Biol Med*. 2004 Apr;36(7):838–49.
98. Wylie LJ, Bailey SJ, Kelly J, Blackwell JR, Vanhatalo A, Jones AM. Influence of beetroot juice supplementation on intermittent exercise performance. *Eur J Appl Physiol*. 2016 Feb 27;116(2):415–25.
99. Yehuda S, Rabinovitz S, Mostofsky D. Nutritional Deficiencies in Learning and Cognition. *J Pediatr Gastroenterol Nutr*. 2006 Dec;43(S3).
100. Yin K, Zi Y, Zhuang W, Gao Y, Tong Y, Song L, et al. Linking Esports to health risks and benefits: Current knowledge and future research needs. *J Sport Health Sci*. 2020 Dec;9(6):485–8.
101. Zimmermann MB. The Adverse Effects of Mild-to-Moderate Iodine Deficiency during Pregnancy and Childhood: A Review. *Thyroid*. 2007 Sep;17(9):829–35.
102. Zwibel H, DiFrancisco-Donoghue J, DeFeo A, Yao S. An Osteopathic Physician’s Approach to the Esports Athlete. *J Am Osteopath Assoc*. 2019 Nov 1;119(11):756–62.

## 6. Streszczenie i Abstract

### Streszczenie

Gry rywalizacyjne (sport elektroniczny lub e-sport) stanowią konkurencyjne rozgrywki zawodów gier video, które w ostatnim czasie cieszą się dużym zainteresowaniem. Wiedza na temat stylu życia graczy jest wciąż niewielka i brakuje naukowego potwierdzenia znaczenia czynników, które mogą przyczynić się do osiągania lepszych wyników w rozgrywkach na wysokim poziomie. W tym kontekście celem badań była ocena wybranych elementów stylu życia polskich e-sportowców, w szczególności sposobu żywienia (częstości spożycia i zachowań żywieniowych), wartości energetycznej i odżywczej diety, częstości spożycia składników pokarmowych o potencjalnie korzystnym wpływie na funkcje poznawcze, profili żywieniowych (modeli żywieniowych), a także poziomu aktywności, wydolności i sprawności fizycznej e-graczy. Wprowadzeniem teoretycznym do cyklu publikacji naukowych był artykuł przeglądowy nt. charakterystyki mikroskładników pokarmowych i suplementów diety w kontekście ich potencjalnego wpływu na funkcje poznawcze e-sportowców.

W przeprowadzonych badaniach wzięli udział profesjonalni i półprofesjonalni polscy e-sportowcy ( $n = 233$ ) w wieku 18-29 lat. Narzędziami badawczymi były trzy kwestionariusze żywieniowe: standaryzowany kwestionariusz do badania poglądów i zwyczajów żywieniowych (Kom-PAN), zmodyfikowany kwestionariusz częstości spożycia produktów i potraw (FFQ), oparty na międzynarodowych kwestionariuszach częstości spożycia oraz autorski kwestionariusz szybkiej oceny sposobu żywienia (QDS), zwalidowany w Zakładzie Medycyny Sportowej i Żywienia Człowieka AWF w Krakowie. Zastosowano również Międzynarodowy Kwestionariusz Aktywności Fizycznej (IPAQ). W celu określenia wartości energetycznej i odżywczej diety zastosowano metodę 3-dniowego bieżącego notowania i wagową. Profile żywieniowe wyłoniono wykorzystując analizę czynnikową. Wydolność fizyczną oceniono z zastosowaniem zmodyfikowanego testu o narastającym obciążeniu, a sprawność fizyczną w oparciu o wybrane testy opracowane przez Międzynarodowy Komitet Standaryzacji Sprawności Fizycznej oraz Europejski Test Sprawności Fizycznej.

Na podstawie przeprowadzonych badań wykazano, że spośród mikroskładników pokarmowych, szczególne znaczenie w diecie e-sportowców wykazują: jod, żelazo, magnez, cynk, witaminy grupy B oraz witaminy E, D i C. W celu uzupełnienia diety rozważyć można także suplementację kofeiną, L-teaniną, polifenolami, flawonolami kakaowymi, sokiem z buraka, kreatyną, prebiotykami i probiotykami oraz luteiną. Większość zawodników,

niezależnie od poziomu sportowego, nie realizowała jakościowych zaleceń żywieniowych. Stwierdzono niskie spożycie produktów o potencjalnie korzystnym wpływie na funkcjonowanie mózgu, takich jak: ryby, orzechy, nasiona oleiste i roślin strączkowych, soki warzywne i warzywno-owocowe. Zawartość makroskładników pokarmowych, określona jako udział energii w diecie, była odpowiednia, jednak podaż białka (wyrażona w g/kg m. c.) była zbyt wysoka. Dieta zawodników e-sportowych była niebilansowana ze względu na nie zrównoważony bilans energetyczny i zbyt wysoką podaż nasyconych kwasów tłuszczowych, a także niskie spożycie wielonienasyconych kwasów tłuszczowych i błonnika pokarmowego. Wyłoniono i zidentyfikowano 9 wzorów żywienia powiązanych wzajemnymi współzależnościami w zakresie częstości spożycia produktów spożywczych, potraw i napojów. Za ledwie jeden profil żywienia („Warzywno-owocowy”) uznano za prozdrowotny, a pozostałe sklasyfikowano jako niezdrowe, związane z modelem diety zachodniej. Stwierdzono, że polscy e-sportowcy cechują się niskim i umiarkowanym poziomem aktywności fizycznej, a profesjonalni gracze spędzają istotnie więcej czasu w pozycji siedzącej w porównaniu do półprofesjonalnych. Gracze charakteryzowali się przeciętnym poziomem wydolności krążeniowo-oddechowej, a wielkość mocy mięśniowej generowanej na poziomie AeT, AnT,  $VO_{2max}$  była niższa niż u aktywnych fizycznie mężczyzn oraz zdrowych młodych mężczyzn w podobnej grupie wiekowej. Sprawność fizyczną e-graczy oceniono jako zadowalającą, jednak potrzebne są dalsze badania, aby jednoznacznie potwierdzić uzyskane wstępne dane.

Przeprowadzone w ramach rozprawy doktorskiej badania pozwoliły na zaprezentowanie pierwszych, oryginalnych wyników dotyczących oceny wybranych aspektów stylu życia profesjonalnych i półprofesjonalnych graczy e-sportowych. Podjęty problem badawczy ma charakter poznawczy i aplikacyjny. Uzyskane rezultaty wpisują się w rosnące globalne zainteresowanie e-sportem oraz coraz większą świadomość uwarunkowań zdrowia.

# **Akademia Wychowania Fizycznego i Sportu im. Jędrzeja Śniadeckiego w Gdańsku**



**Monika Szot MSc**

## ***Evaluation of selected lifestyle elements of a group of Polish esports players***

Ph.D. thesis under the supervision of:

prof. dr hab. Barbara Frączek

Co-supervisor:

dr Paulina Mazur Kurach

**Gdańsk 2024**



## **Abstract**

Competitive gaming (electronic sports or esports) refers to competitive gameplay in video game tournaments that have recently garnered significant interest. Despite the growing popularity of esports, there is still a lack of knowledge about the lifestyles of players. Furthermore, there is a paucity of scientific evidence regarding the factors that may contribute to achieving better results in high-level gameplay. The objective of this research was to assess selected elements of the lifestyle of Polish esports players in relation to dietary habits (frequency of consumption and dietary behaviours), energy and nutritional value of the diet, frequency of consumption of dietary components potentially beneficial for cognitive functions, dietary profiles (dietary patterns) of players, as well as their level of physical activity, endurance, and physical fitness. The theoretical introduction to the scientific publication cycle was a review article on the characteristics of dietary micronutrients and dietary supplements in the context of their potential impact on the cognitive functions of esports players.

The study included professional and semi-professional Polish esports players ( $n = 233$ ) aged between 18-29 years. The research tools consisted of three dietary questionnaires: a standardised nutritional questionnaire for assessing dietary beliefs and habits (Kom-PAN), a modified Food Frequency Questionnaire (FFQ) based on International Food Frequency Questionnaires, and proprietary Quick Diet Survey (QDS) validated at the Department of Sports Medicine and Human Nutrition at the University School of Physical Education in Krakow and the International Physical Activity Questionnaire (IPAQ) for assessing physical activity.

To determine the energy and nutritional value of the diet, a method of three-day current diary recording and weighing was employed. Dietary patterns were identified using factor analysis. exercise capacity was assessed using a modified incremental load test, while physical fitness was evaluated by selected tests from protocols developed by the International Committee for Physical Fitness Standardization and the European Physical Fitness Test.

Based on the studies conducted, it has been shown that among the micronutrients, iodine, iron, magnesium, zinc, B group vitamins, vitamins E, D and C play a particularly important role in the diet of esports players. In addition, it is advisable to consider supplementing the diet with caffeine, L-theanine, polyphenols, cocoa flavonols, beetroot juice, creatine, prebiotics, probiotics and lutein. Most esports players, regardless of their level of involvement in sport, did not adhere to the dietary quality recommendations. Low intakes of foods potentially beneficial to brain function were observed, such as fish, nuts, oilseeds,

legumes, vegetable juices, and fruits and vegetables. The macronutrient content, expressed as the average percentage of energy in the diet, was adequate; however, the protein intake (expressed in g/kg body weight) was excessive. The diet of esports players was unbalanced due to an imbalanced energy intake and an excessive intake of saturated fatty acids and a low intake of polyunsaturated fatty acids and dietary fibre. Nine dietary patterns were identified and classified according to interdependencies in the frequency of consumption of foods, dishes and beverages. One dietary profile ("Vegetable-Fruit") was classified as health-promoting, while the others were classified as unhealthy and associated with a Western dietary pattern. Polish esports players were found to have low to moderate levels of physical activity, with professional players spending significantly more time in a sedentary position than non-professionals. Players showed an average level of cardiorespiratory fitness, and muscle performance in terms of AeT, AnT and  $VO_{2max}$  was lower than that of physically active men and healthy young men of a similar age group. The physical fitness of esports players was judged to be satisfactory, but further research is needed to definitively confirm the preliminary data obtained.

The research carried out as part of the doctoral thesis allowed the presentation of the first original results on the assessment of selected aspects of the lifestyle of professional and semi-professional esports players. The research problem addressed has both cognitive and applied characteristics. The results obtained are in line with the growing global interest in esports and the increasing awareness of health determinants.

## 7. Załączniki

### Załącznik 1. Kopie publikacji wchodzących w skład rozprawy doktorskiej



Review

## Can Nutrients and Dietary Supplements Potentially Improve Cognitive Performance Also in Esports?

Monika Szot <sup>1</sup>, Ewa Karpecka-Gaika <sup>2</sup>, Remigiusz Dróżdż <sup>3</sup> and Barbara Frączek <sup>4,\*</sup>

<sup>1</sup> Department of Sports Dietetics, Gdansk University of Physical Education and Sport, 80-336 Gdansk, Poland; szotmonika@hotmail.com

<sup>2</sup> Doctoral School of Physical Culture Sciences, University School of Physical Education in Krakow, Jana Pawła II 78, 31-571 Cracow, Poland; karpeckaewa@gmail.com

<sup>3</sup> Department of Economics and Business, Gdansk University of Physical Education and Sport, 80-336 Gdansk, Poland; remigiusz.drozd@awf.gda.pl

<sup>4</sup> Department of Sports Medicine and Human Nutrition, Institute of Biomedical Sciences, University School of Physical Education in Krakow, Jana Pawła II 78, 31-571 Cracow, Poland

\* Correspondence: barbara.fraczek@awf.krakow.pl; Tel.: +48-126831002

**Abstract:** Factors influencing brain function and cognitive performance can be critical to athletic performance of esports athletes. This review aims to discuss the potential beneficial effects of micronutrients, i.e., vitamins, minerals and biologically active substances on cognitive functions of e-athletes. Minerals (iodine, zinc, iron, magnesium) and vitamins (B vitamins, vitamins E, D, and C) are significant factors that positively influence cognitive functions. Prevention of deficiencies of the listed ingredients and regular examinations can support cognitive processes. The beneficial effects of caffeine, creatine, and probiotics have been documented so far. There are many plant products, herbal extracts, or phytonutrients that have been shown to affect precognitive activity, but more research is needed. Beetroot juice and nootropics can also be essential nutrients for cognitive performance. For the sake of players' eyesight, it would be useful to use lutein, which, in addition to improving vision and protecting against eye diseases, can also affect cognitive functions. In supporting the physical and mental abilities of e-athletes the base is a well-balanced diet with adequate hydration. There is a lack of sufficient evidence that has investigated the relationship between dietary effects and improved performance in esports. Therefore, there is a need for randomized controlled trials involving esports players.

**Keywords:** esports; cognitive performance; cognition; video game; esports athletes; nutrition habits



**Citation:** Szot, M.; Karpecka-Gaika, E.; Dróżdż, R.; Frączek, B. Can Nutrients and Dietary Supplements Potentially Improve Cognitive Performance Also in Esports? *Healthcare* **2022**, *10*, 186. <https://doi.org/10.3390/healthcare10020186>

**Academic Editors:** Akira Sekikawa and Chrysi Koliaki

Received: 10 November 2021

Accepted: 14 January 2022

Published: 18 January 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

### 1. Introduction

The increasingly frequent incidence of neurodegenerative diseases and the lack of an effective method for their treatment have resulted in an increased interest in dietary supplements to improve cognitive functions and prevent their decline [1]. A micronutrient deficit can lead to a decrease in cognitive abilities, which also deteriorate with age. Not only the elderly but also young and middle-aged people are exposed to micronutrient deficiencies due to their demanding lifestyles and insufficient diets [2]. Therefore, it is suggested that e-athletes may also be at risk.

In general opinion, esports (electronic sport) is a relatively new and rapidly growing sport involving players competing in video game tournaments. Although the genesis of e-tournaments was in the 1970s, the first professional competition started in 1997 [3]. Currently, this discipline is becoming more and more popular among players and viewers [4]. The global audience for esports competitions in 2019 had 443 million viewers, which translated into a market value of USD 68.2 billion [5]. It is estimated that the popularity of esports will grow in subsequent years [6]. Although women participate in esports, men continue to dominate the field [7]. Mainly due to the competitive nature of esports, but

also due to the “physicality” and “skill” necessary to play at a high level, it was found that esports have characteristics similar to traditional sports. Additionally, the current organizational structure of esports and social interest in this discipline contributed to its acceptance by the sports community [8]. Esports has been considered a sport since 2003 in China, but in the USA, players also have official status as athletes [6].

### 1.1. Division and Characteristics of Games and Organization of Esports

All esports are video games, but not all games are esports. Esports refers to a classification of video games shaped around competition [9] involving amateur players, semi-professionals, and professionals, with substantial interest, income, and profit offered to support the best players [10].

Video games (especially action video games) can influence the cognitive domains of esports players [11]. Competitive video games also require the ability to engage in physical actions (e.g., clicking, typing, and button-mashing) within the virtual environment; these actions are called “mechanics” [12]. Many video games also contain theatrical and fictional elements, which are a part of the attraction. The game-playing experience of esports involves a unique combination of motor, cognitive, strategic, and mimetic skills [13]. The model of game competence is relevant for professional esports players because of certain features that are unique to the esports domain [6]. Currently, however, there is no scientific evidence available to create a model in this discipline. Esports can be divided into specific genres, each of which demand exceptional skills used in competitive games [14] that include multiplayer online battlefield arenas (MOBA), first-person shooters (FPS), real-time strategy games [6,15], and sports simulations [6]. Each genre involves different game characteristics, mechanics, competition policies [6], and relevant cognitive functions [16]. Examples of popular esports games include League of Legends, Counter Strike: Global Offensive, and Player Unknown’s Battlegrounds (PUBG). Competitive esports tournaments are organized for many people, mostly between professional players, and can take place in front of a live audience, via television broadcasting, or online [17]. During gameplay, the gamers must connect their perceptual–cognitive skills (e.g., anticipation, visual behavior, pattern recall, and action) and domain-specific skills (e.g., mouse and mouse movements) [15].

### 1.2. Health Risk and Dangers of Esports

Potentially adverse effects of esports games can arise from stressful, long-lasting training, as well as from the fierce competition that affects high-level players. According to Johnson and Woodcock (2021), world-class professionals are an integral part of the esports environment, but in the context of work, they are unstable, as they cannot maintain their highest skill levels after their thirties [10]. Interest in professional esports is especially prevalent among young people [18], as it is known that people over twenty years of age are not able to compete at the highest level because their reaction speed is slowed down [8]. Professional esports requires the playing of video games for several hours in order to improve skills such as gamepad and keyboard operation, game knowledge, strategy, and tactics [16]. Prolonged sitting may increase the risk of obesity and promote inappropriate eating behaviors [9]. Other esports requirements can also lead to serious health complications such as injury; eye strain; and neck, back, and wrist pain. Mental condition (depression and burnout symptoms) and elements of the psychosocial sphere (social anxiety, sleep disorders, and problems with personal hygiene) may also significantly deteriorate [16]. There are other games (e.g., exergaming) that, in their rules, require one to expend energy or physical activity, thereby improving the gamer’s physical condition and fitness. However, the level of energy expenditure is unknown among those participating in such games at a high level [18].

### 1.3. Potential Factors Affecting Success in Esports

Despite the ongoing development of the esports industry, there is a lack of scientific understanding regarding the determinants of high-level performance. Experts say there



is a need for large-scale research to clearly determine the personal characteristics and factors that are important precursors to achieving satisfactory results in competition [3]. Recent studies in the field of esports psychology have identified the characteristics of successful players, including knowledge of the game, decision-making ability, motivation, the ability to separate private life from sports activity, concentration, emotional control, positive attitude, commitments to mental and physical warm-ups before training sessions, and flexibility in the relevant procedures and playing conditions. Moreover, to meet the requirements of esports, players improve their skills by training in various areas related to overcoming obstacles, teamwork, and/or individual physical effort, including the cognitive, psychological, physical, technical, and tactical domains [19]. Currently, the scientific literature indicates several cognitive domains such as attention (division and switching of attention), perception and processing of information (fast reaction time), and visual-spatial skills (navigation in a virtual environment) [16]. The selected physical characteristics (physical abilities) and health can also be considered important factors for success in sports [20].

Cognition is a key factor in athletic performance, and there is mounting evidence that select dietary ingredients, hydration levels, and supplements can affect brain function [21]. In the case of esports, the dominant role is played by cognitive processes, particularly executive functions, which help maintain long-term performance [22] and affect the achievement of satisfactory results [23]. To date, cognitive functions have been extensively studied for the prevention and support of treatments in neurodegenerative diseases [24–31], as well as to support healthy people [32–37]. Despite the high popularity of esports, there are still no publications in the field of physical culture sciences that explicitly and directly indicate the mechanism underlying the influence of nutrients and dietary supplements on the cognitive abilities and concentration of players. This review aims to characterize the relevant micronutrients and dietary supplements based on the available literature data to indicate what potential impact these micronutrients and dietary supplements may have on the cognitive functions of e-athletes. The first part of the article, published in 2020, describes the role of macronutrients and water in the context of cognitive functions in sport [38]. This review is a continuation of work in the field of micronutrients, i.e., vitamins, minerals, and biologically active substances.

## 2. Materials and Methods

A search was carried out using the following databases: PubMed and Medline, SPORT-Discus, Academic Search Ultimate, Scopus, and ScienceDirect for studies published in English from January 2011 to August 2021. The search terms contained keywords related to: “brain”, “nutrition”, “micronutrients”, “minerals”, “vitamins”, “supplements”, “e-sport”, “ESports”, “esports”, “esports science”, “cognition”, “cognitive functions”, “cognitive control”, “cognitive skills”, “video games”, “computer games”, and “physical activity”. The search resulted in 1727 articles that included randomized, double-blind, placebo-controlled trials, narrative review articles, systematic reviews, and meta-analyses. Then, the studies were selected based on the following criteria: studies published within 5 years (meta-analyses, systematic reviews, randomized control studies) and works examining cognitive functions. Based on the titles and abstracts, studies evaluating the use of dietary components in the prophylaxis of neurodegenerative or other neurological diseases, especially in the elderly, were excluded. Then, the databases were searched, taking into account dietary components such as: iodine, iron, zinc, magnesium, B vitamins, and vitamins C, D, and E, in addition to caffeine, L-theanine, polyphenols, beetroot juice, creatine, probiotics, lutein, and nootropic substances.

## 3. Results

### 3.1. The Influence of Dietary Micronutrients on Cognitive Functions

The diet provides trace elements, including iodine, iron, zinc, magnesium, B vitamins, and vitamins E and C, which play the role of cofactors in key enzymatic processes. They

play an essential role in the metabolism of neurotransmitters, structural and functional brain lipids and proteins, DNA and RNA, and energy metabolism. Some micronutrients are necessary already at the stage of prenatal development for the proper development of the nervous system (iodine, iron, folic acid), which is related to the need to supplement the diet of pregnant women. Inadequate intake of micronutrients in adulthood leads to deficiencies, and in case of long-term insufficient supply of a given ingredient, it may lead to the development of many diseases or deterioration of well-being. Given that certain deficiencies, such as iron and iodine, are fairly common even in developed countries [39,40], ensuring adequate micronutrient intake is an essential step in promoting optimal cognitive functioning.

### 3.1.1. Minerals

#### Iodine

Iodine is critical to the developing brain as a component of the thyroid hormones thyroxine (T4) and triiodothyronine (T3) [41,42]. The importance of adequate consumption of this micronutrient is especially important during neurological development [43–46]. Iodine deficiency can cause a decrease in brain mass and a greater cell mass in the cortex, and a lower cell mass in the baby's cerebellum. Neurological cretinism mainly begins with maternal hypothyroidism due to iodine deficiency. Even moderate or mild hypothyroxinemia during pregnancy increases the risk of neurodevelopmental deficits in the offspring [47]. Sufficient iodine intake is needed for the synthesis of adequate amounts of thyroid hormones. There is evidence to suggest that low levels of T4 may adversely affect the development of the fetal brain and, subsequently, the cognitive functions of children and adults [48].

Santiago-Fernandez et al. conducted a study to assess the intelligence quotient (IQ) of students aged 6 to 16 living in a province with mild to moderate iodine deficiency in Spain. The children were divided according to the concentration of iodine in the urine. The obtained results showed that children with urine iodine concentration <100 µg/L had a lower IQ compared with children with urine iodine concentration above 100 µg/L [49] (Table 1).

Two randomized, double-blind, placebo-controlled studies have shown an association between iodine deficiency and cognition in school-age children. Zimmermann et al. conducted a study among children from 10 to 12 years of age from Southeast Albania with moderate iodine deficiency. Initially, the iodine concentration in the urine of the children was evaluated and seven cognitive tests were performed. Children were provided with iodized poppy seed oil (containing 400 mg of potassium iodate) or a placebo (sunflower oil). After six months, it was observed that iodine nutritional status in the iodine supplementation group improved from moderate deficiency to adequate concentration, while the control group was moderately deficient in iodine throughout the study period. The experimental group experienced significant improvement in four out of seven cognitive tests compared with the placebo group [50] (Table 1).

A similar study was conducted by Gordon et al. in children aged 10 to 13 with mild iodine deficiency living in New Zealand. The children were randomly split into two groups: supplementing them daily for 28 weeks, iodine in the form of tablets containing 150 µg/L of iodine, and the control group receiving a placebo. Initially, cognitive function was evaluated using the four subtests of the Wechsler Intelligence Scale for Children. After the end of the intervention, members of the iodine supplementation group had an increase in iodine concentration to a sufficient amount, while participants in the control group were still moderately deficient in iodine. A significant therapeutic effect was found in two out of four cognitive tests in the iodine supplement group compared with the placebo group, which suggests that iodine deficiency affects the development of cognitive functions until at least 13 years of age [51] (Table 1).

**Table 1.** Impact of minerals on cognitive function [32,49–61].

| Factor | Subjects and Methods                                                                                          | Results                                                                                                                                                                                                                                                                                         | Conclusion                                                                                                                                                                                                                             | References |
|--------|---------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Iodine | Cross-sectional study; 1221 children (6–16 years)                                                             | IQ was higher in children with urine iodine >100 µg/L. The intake of non-iodized salt and drinking milk less than once a day was related to the risk of having an IQ below the 25th percentile. The risk of having an IQ below 70 was greater in children with urinary iodine levels <100 µg/L. | Intake of iodine in children in the developed world may affect IQ. The IQ of children with mild iodine deficiency can be improved by adequate iodine intake through the diet until the urinary iodine concentration is above 100 µg/L. | [49]       |
|        | Randomized, placebo-controlled, double-blind trial; 184 children (10–13 years)                                | Iodine supplementation improved scores for 2 of the 4 cognitive subtests (picture concepts and matrix reasoning but not for letter-number sequencing or symbol search).                                                                                                                         | Mild iodine deficiency could prevent children from attaining their full intellectual potential. Iodine supplementation in children with deficiency improves perceptual reasoning.                                                      | [51]       |
|        | Randomized, placebo-controlled, double-blind intervention trial; 310 children (10–12 years)                   | Iodine treatment improved performance on 4 of 7 tests: rapid target marking, symbol search, rapid object naming, and Raven’s Coloured Progressive Matrices compared with placebo.                                                                                                               | Iodine supplementation in schoolchildren with moderate deficiency improves information processing, motor skills, and visual problem solving.                                                                                           | [50]       |
| Iron   | Review                                                                                                        | Children and young adults who had iron deficiency anemia in infancy showed poorer inhibitory control and executive functioning as assessed by neurocognitive tasks.                                                                                                                             | There is a need to prevent iron deficiency in infancy due to persistent poorer cognitive, motor, affective, and sensory system functioning.                                                                                            | [52]       |
|        | Systematic review and meta-analysis; 32 studies including 7089 children (5–12 years)                          | Iron supplementation improved global cognitive scores, intelligence quotient among anemic children and measures of attention and concentration.                                                                                                                                                 | In young players with anemia, it is worth using iron supplementation to improve cognitive functions.                                                                                                                                   | [55]       |
|        | Systematic review; 10 randomized controlled trials and 1 non-randomized controlled trial; women (12–55 years) | Improvement in aspects of mood and cognition after iron supplementation (in 7 studies). Iron supplementation appeared to improve memory and intellectual ability in participants, regardless of whether the participant was initially iron insufficient or iron-deficient with anemia.          | Adequate iron levels are a key factor in intellectual performance.                                                                                                                                                                     | [57]       |
|        | Review; 89 studies                                                                                            | Iron deficiency had a negative impact on cognition, behavior, and motor skills.                                                                                                                                                                                                                 | There is some evidence that iron supplementation improves cognition.                                                                                                                                                                   | [54]       |
|        | Observational study, 39 children (7–11 years)                                                                 | Positive relationship between spatial IQ and mean iron content in the basal ganglia and in the caudate specifically.                                                                                                                                                                            | Iron content in specific regions of the iron-rich deep nuclei of the basal ganglia influences spatial intelligence.                                                                                                                    | [53]       |



Table 1. Cont.

| Factor | Subjects and Methods                                                                                                                                                          | Results                                                                                                                                                                                                                                                                                                                                                | Conclusion                                                                                                                                              | References |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
|        | Double-blind, randomized, intervention study; 140 Indian boys (12–16 years)                                                                                                   | Daily iron intake from pearl millet was higher in those consuming biofortified (19.6 mg/d) compared with conventional pearl millet (4.8 mg/d). Compared with conventional pearl millet, the consumption of biofortified pearl millet resulted in greater improvement in attention and memory.                                                          | Consuming iron-biofortified pearl millet improves iron status and some measures of cognitive performance in Indian adolescents.                         | [56]       |
|        | Cohort trial; 428 adolescents ( $12.0 \pm 0.4$ years) from China                                                                                                              | Iron deficiency was associated with slower performance of tasks that measured abstraction, mental flexibility, and spatial processing capacity. High serum iron levels were associated with lower accuracy in the spatial processing ability task and longer reaction time in the abstraction and mental flexibility task compared with normal levels. | Both iron deficiency and high iron levels lead to decreased neurocognitive performance in a domain-specific manner in early teens.                      | [58]       |
|        | Review; 41 human studies                                                                                                                                                      | Increased iron levels in caudate nuclei correlated with worse memory and general cognitive performance in adulthood. The increase in iron levels in the hippocampus and thalamus was associated with poorer memory performance. The increased iron level in the putamen and globus pallidus affects general cognition.                                 | Brain iron is detrimental to cognitive health.                                                                                                          | [59]       |
|        | Randomized double-blind placebo-controlled trial; 387 healthy adults aged 55–87 years                                                                                         | 3-month zinc supplementation at a dose of 15 or 30 mg/day had a positive effect on spatial working memory, while a dose of 15 mg/day had a negative effect on the measurement of attention. Younger adults (<70 years old) performed significantly better on all tests than older adults (>70 years old).                                              | Zinc supplementation can have a positive effect on spatial working memory.                                                                              | [32]       |
| Zinc   | Systematic review and meta-analysis; 18 studies; 12 randomized controlled trials (11 in children and 1 in adults) and 6 observational studies (2 in children and 4 in adults) | A correlation between zinc intake or status with one or more measure of cognitive function was shown (9 of analyzed 18 studies). Meta-analysis of data from the adult studies was not possible because of the limited number of studies.                                                                                                               | There is no significant effect of zinc supplementation on cognition in children. Supplementation may improve executive functions and motor development. | [60]       |



Table 1. Cont.

| Factor    | Subjects and Methods           | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | Conclusion                                                              | References |
|-----------|--------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------|------------|
| Magnesium | Systematic review; 32 articles | Magnesium supplementation showed positive results in depressive symptoms (12 studies). The decreased level of magnesium in the plasma correlated with the occurrence of depression, assessed using psychometric scales (7 studies). Consumption of magnesium improved the symptoms of depression (2 studies). The consumption of magnesium in combination with antidepressants improved the symptoms of depression (2 studies). Concentration of magnesium in the raw material had no significant influence on the occurrence of panic or anxiety disorders (2 studies). Higher serum magnesium levels in depressed and stressed patients correlated with a lower Hamilton anxiety score (2 studies). Low levels of magnesium correlated with attention deficit hyperactivity disorder (ADHD) (2 studies). Lower levels of magnesium were observed in autism spectrum disorder (1 out of 3 studies). Eating disorders and schizophrenia were associated with differences in magnesium levels in some aspects of the disease. | Supplementation with magnesium could be beneficial in mental disorders. | [61]       |

Apart from studies on pregnant women and the effects of iodine nutrition on fetal development and cognitive function of the newborn, there have been few studies involving adults. In adults, thyroid hormones affect mood, may induce affective disorders and dementia, and could potentially be associated with cognitive functions including memory and attention [62]. Both in healthier, older adults with regular thyroid function and in older adults with hypothyroidism, a positive relationship has been found between the level of thyroid hormones and the results of cognitive functions [63,64].

The best sources of iodine in your diet are sea fish and seafood, algae, and dairy products, including milk, cheese, yogurt, and eggs. In connection with people's personal food choices, iodization of table salt is a useful method for preventing deficiencies in this nutrient [65–67].

### Iron

Iron is a trace mineral that participates in many physiological processes, such as oxygen transport, oxidative metabolism, energy production, cell growth and differentiation, DNA synthesis, cellular immune response, and many others [68]. It is also a key mineral that is essential for the differentiation and proliferation of neurons. Iron deficiency affects neuronal processes such as myelination, dendritic branching/branching, and neuronal plasticity. Moreover, iron deficiency influences iron allocation in the brain, thus altering the prefrontal-subcortical dopaminergic and frontal striatal networks that mediate cognitive functions [69]. Disturbances in dopaminergic systems, therein the nigrostriatal and mesocortical pathways, may contribute to the formation of cognitive deficits, in particular difficulties in visual-spatial processing related to iron deficiency [52] (Table 1). This was confirmed in a study by the Carpenter team. Researchers found a positive relationship between spatial IQ and the average amount of iron in the basal ganglia, and in particular in the caudate, suggesting that the presence of iron in certain regions of iron-rich deep basal ganglion nuclei influences spatial intelligence [53] (Table 1).

Iron deficiency in the neonatal period and infancy is considered a factor predisposing to the development of cognitive development disorders. According to the results of experimental studies, iron deficiency may cause cognitive deterioration in animals and humans [70,71], with damage to the brain's mitochondria as the basis for these changes [72]. In addition, there are presumed changes in dopamine metabolism in the brain, as well as altered serotonergic neurotransmission and changes in dopamine receptors. In fact, iron deficiency or anemia causes severe changes in dopamine synthesis in key areas of the brain [73]. The cognitive disorders caused by iron deficiency include mainly those related to concentration of attention, intelligence, and sensory perception function, as well as those related to emotions associated with iron deficiency anemia. Moreover, iron deficiency beyond anemia could possibly cause cognitive impairment [54] (Table 1).

A meta-analysis of 32 studies involving 7089 children aged 5–12 years by Low et al. showed that iron supplementation improved general cognitive functions and IQ in addition to attention and concentration measures in children with anemia [55] (Table 1). In another study in 140 Indian teens, intake of iron-biofortified pearl millet resulted in greater improvements in attention and memory compared with the group consuming regular pearl millet. Reaction time on attention-assessment tasks was doubled in adolescents consuming biofortified millet for 6 months compared with conventional millet [56] (Table 1). In their systematic review, Lomongo and co-authors analyzed 10 randomized controlled trials and 1 non-randomized control trial in premenopausal women between 12 and 55 years of age. Among the analyzed studies, as many as seven showed an improvement in mood and cognitive functions after iron supplementation [57] (Table 1). Conversely, a study of 428 Chinese 12-year-olds showed that both iron deficiency and high iron levels contributed to the reduction in neurocognitive performance in a discipline-specific way in early adolescents. Iron deficiency com-

pared with the normal group was associated with slower performance of tasks that measured abstraction, mental flexibility, and spatial processing capacity. High serum iron concentration was associated with lower accuracy in the task of measuring spatial processing abilities and a longer reaction time in the task evaluating abstraction and mental flexibility compared with normal serum levels [58] (Table 1). These results show that it is important to maintain an adequate level of iron in the serum for the proper functioning of the brain. Disruption of the iron homeostasis may result in its accumulation in the brain and interaction that enhances oxidative damage [59] (Table 1). Cognitive dysfunction associated with high iron levels is likely due to iron cytotoxicity to brain function [74]. The source of heme iron is red meat, poultry, liver, offal, fish, and egg yolk. Non-heme iron comes from plant products—vegetables, legumes, and whole grains, especially millet and amaranth, pumpkin seeds, and cocoa and cocoa products [67].

### Zinc

Zinc is an essential trace element that plays a vital role in brain function. Free zinc ion ( $Zn^{2+}$ ) neurons are found in various areas of the brain, including the cerebral cortex, amygdala, olfactory bulb, and hippocampal neurons. Zinc plays a key role in enzymatic activity, cell signaling, and modulation of neurotransmitter activity [75]. It is considered essential for the formation and migration of neurons and for the formation of neuronal synapses [76]. Adult brain neurogenesis is dependent on the presence of zinc, which has wide-ranging implications for hippocampal function, including learning and memory, as well as emotional and mood control [75]. One of the few studies available on the relationship of zinc and cognitive performance in adults examined zinc supplementation (15 or 30 mg/day) in 387 healthy adults aged 55–87 years and found that each dose of zinc used for 3 months had a beneficial effect on spatial working memory. However, the benefits of supplementation were not observed in the case of other examined indicators [32] (Table 1). Warthon-Medina et al. conducted a meta-analysis of 18 studies that showed no significant effect of zinc supplementation on cognition in children, although there were some modest signs of improvement in aspects of executive function and motor development after the supplementation began [60] (Table 1).

The products rich in zinc include oysters, beef, legumes (e.g., beans, chickpeas), yoghurts, ripening cheeses, and cereals [67].

### Magnesium

Magnesium is a mineral vital to the proper functioning of all human cells, including neurons. It takes part, among others, in many enzymatic reactions [77], intracellular transmission [78], myelination [79], and synaptic formation and maintenance [80] and in the regulation of serotonergic, dopaminergic, and cholinergic transmission [81]. In the nervous system, magnesium is therefore essential for neuromuscular coordination and optimal nerve transmission. It plays a role in protecting against overstimulation that leads to cellular death: It interacts with the aspartate receptor to block the calcium channel at that receptor and must be cleared for glutamatergic excitatory signaling to occur. Low levels of magnesium may theoretically increase glutamatergic neurotransmission, which may lead to oxidative stress and nerve cell death [82]. The vast majority of studies conducted so far have focused on depression, due to the recognized role of magnesium in several basic mechanisms of the pathophysiology of depression, including inflammation and oxidative stress [61] (Table 1). The majority of preliminary symptoms of a magnesium deficiency include neurological or neuromuscular symptoms. Neuromuscular hyperactivity, including muscle cramps, is a prevalent characteristic of magnesium deficiency, but latent tetany, generalized seizures, dizziness, and muscle weakness may also occur [83]. Other symptoms of magnesium deficiency can manifest as tiredness, lethargy, lightheadedness, and appetite deficit [84].



The products are obtained from magnesium include: hard water, bananas, soybeans, nuts, spices, green leafy vegetables, apricots, and whole grains [67].

### 3.1.2. Vitamins

#### B Vitamins

The group of B vitamins includes eight water-soluble vitamins that are vital in the context of cell function, acting as coenzymes in many enzymatic reactions. Their joint action is well known in many aspects of brain function—that is, energy production, DNA and RNA synthesis and repair, genomic and non-genomic methylation, and the synthesis of diverse neurotransmitters and signaling molecules [85]. The body has no other organ so active metabolically than the brain. Though it accounts for just 2% of body weight, it is responsible for more than 20% of total energy consumption [86]. Therefore, the metabolic functions of B vitamins and their role in neurochemical synthesis can be viewed as having a special impact on the functioning of the brain [85].

Thiamin (vitamin B1) is a part of synaptic formation, axonal growth, and myelin genesis, leading to the formation of functional neuroglia. It also can maintain the membrane of newly formed neurons during embryogenesis and can control apoptosis [87]. It is essential for the synthesis of fatty acids, steroids, nucleic acids, and aromatic amino acids, which are the precursors of a number of neurotransmitters, therein acetylcholine, glutamate, and gamma-aminobutyric acid [88]. Food sources of thiamine are liver, pork, eggs, nuts, oats, oranges, dry pulses, yeast, and powdered milk [67]. Folic acid (vitamin B9) is important in the maintenance of the lipids of the neuronal and glial membranes, which can affect brain function. This may manifest as changes in mood, sleep rhythm, and irritability [89,90]. Food sources of folic acid are avocado, dark vegetable leaves, spinach, pawpaw, oranges, seeds, and nuts [67]. Pyridoxine (vitamin B6), folic acid (vitamin B9), and cobalamin (vitamin B12) are essential cofactors for the synthesis of myelin and neurotransmitters [91]. Food sources of pyridoxine are potatoes, fruit, fish, beef liver, and other parts of meat [67].

Deficiency of folic acid, mainly caused by low intake, is associated with a number of physiological irregularities during development and adulthood. Proper folate levels are essential for brain function, and insufficient folate supply can lead to neurological disorders such as depression and cognitive decline. Folate supplementation, alone or in combination with other B vitamins, has proven effective in prevention of cognitive decline and dementia during aging and in enhancing the effects of antidepressants. The results of a randomized clinical trial showed that a 3-year folic acid supplementation can positively influence the reduction in aging-related cognitive decline [92] (Table 2).

**Table 2.** Impact of vitamins on cognitive function [35,92–105].

| Factor     | Subjects and Methods                                                                                 | Results                                                                                                                                                                                                                                                                                                                                                                            | Conclusion                                                                                                                                                                                                                                                                   | References |
|------------|------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| B vitamins | Systematic review and meta-analysis of 31 English-language, randomized placebo-controlled trials     | B-vitamin supplementation did not show an improvement in Mini-Mental State Examination scores for individuals with and without cognitive impairment compared with placebo.                                                                                                                                                                                                         | Elevated plasma homocysteine levels increase the risk of cognitive impairment and dementia. There is no clear evidence confirming the beneficial effect on cognitive functions resulting from lowering the level of homocysteine with B vitamins (heterogeneity of studies). | [93]       |
|            | Multicenter study; 1398 blacks and 1738 whites (25.1 ± 3.6 years)                                    | Higher consumption of vitamin B6 and vitamin B12 correlated with better psychomotor speed assessed by Digit Symbol Substitution Test (DSST) scores.                                                                                                                                                                                                                                | Higher intake of B vitamins in early adult years was associated with improved cognitive function in later adult life.                                                                                                                                                        | [94]       |
|            | Study; 317 children (11.8 ± 3.3 years)                                                               | Vitamin B1 consumption had a positive effect on the results of the numerical tasks and modalities of symbolic digits (neurocognitive tests). The consumption of vitamin B6 showed a positive correlation with the results of the digit range tasks. The consumption of vitamins B1, B2, B6, and niacin was negatively correlated with omission errors, which indicate inattention. | A diet high in B vitamins correlates with better neurocognitive test results. Diet is closely related to the cognitive functions of healthy children and adolescents.                                                                                                        | [95]       |
|            | Study; 72 adolescents (10–16 years)                                                                  | Controls who followed the standard diet from birth without eliminating meat products scored better on most psychological tests compared with those following the macrobiotic diet with low or normal cobalamin status.                                                                                                                                                             | Cobalamin deficiency without hematologic signs can possibly cause impaired cognitive performance in adolescents.                                                                                                                                                             | [96]       |
|            | Review; 17 studies: 3 cross-sectional, 1 case-control, and 12 cohort studies and 1 randomized trial. | Observational studies to date have demonstrated associations between vitamin B-12 status or dietary intake and cognitive outcomes in children.                                                                                                                                                                                                                                     | A diet rich in vitamin B12 is recommended in adolescence due to its positive influence on cognitive functions.                                                                                                                                                               | [97]       |
|            | Randomized, double blind, placebo controlled study; 818 adults (50–70 years)                         | 3 years of folic acid supplementation improved memory, information processing speed, and sensorimotor speed compared with the placebo group.                                                                                                                                                                                                                                       | 3 years of folic acid supplemented intake significantly improved cognitive functions that most often decline with age.                                                                                                                                                       | [92]       |
|            | Systematic Review, Meta-Analysis, and Meta-Regression; 53 randomized trials                          | No evidence for an effect of B12 alone or B complex supplementation on any subdomain of cognitive function outcomes.                                                                                                                                                                                                                                                               | Vitamin B12 supplementation possibly does not improve cognitive function or depressive symptoms in patients without advanced neurological disorders.                                                                                                                         | [98]       |

Table 2. Cont.

| Factor    | Subjects and Methods                                                                                                                                                            | Results                                                                                                                                                                                                                                                                                                                                        | Conclusion                                                                                                                                                                   | References |
|-----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Vitamin E | Systematic Review and Meta-Analysis; 24 trials (6 omega-3 fatty acids, 7 B vitamins, 3 vitamin E, 8 other interventions)                                                        | The vitamin E studies did not show any meaningful impact on cognitive outcomes.                                                                                                                                                                                                                                                                | Vitamin E supplementation had no effect on cognition in mentally healthy middle-aged and older adults.                                                                       | [99]       |
|           | Meta-analysis; 5 trials (vitamin B); 1 trial vitamin E; 1 trial (vitamin C and E)                                                                                               | No significant effect of three years of supplementation with vitamin E (1000 IU of alpha-tocopherol twice daily) on overall cognitive function, episodic memory, speed of processing, clinical global impression, functional performance, adverse events, or mortality.                                                                        | Three years of major vitamin E supplementing suggested scarce possibilities of reduced risk of progression to dementia.                                                      | [100]      |
| Vitamin D | Mendelian randomization study; 17 cohorts: 172349 participants                                                                                                                  | Associations of serum [25(OH)D] with global and memory-related cognitive function were non-linear (lower cognitive scores for both low and high [25(OH)D]).                                                                                                                                                                                    | No evidence for serum [25(OH)D] concentration as a causal factor for cognitive performance in mid- to later life.                                                            | [101]      |
|           | Systematic review and meta-analysis; 17 articles                                                                                                                                | Vitamin D deficiency (<25 nmol/L or 7–28 nmol/L) was associated with an increased risk of dementia compared with people with sufficient vitamin D intake ( $\geq 50$ nmol/L or 54–159 nmol/L) (meta-analysis of 5 studies).                                                                                                                    | Low vitamin D levels might contribute to the development of dementia.                                                                                                        | [102]      |
|           | Systematic review and random effect meta-analysis; 26 observational and 3 intervention studies                                                                                  | Low vitamin D was associated with deteriorated cognitive performance and cognitive decline; with cross-sectional studies yielding a stronger effect compared with longitudinal studies. Vitamin D supplementation showed no significant benefit on cognition compared with control.                                                            | Low vitamin D levels deteriorate cognitive functions. There is no clear benefit from vitamin D supplementation.                                                              | [103]      |
|           | Randomized placebo controlled trial; 128 participants (at least 18 years of age)                                                                                                | Vitamin D supplementation (5000 IU of cholecalciferol) did not cause changes in working memory, inhibition of reaction, cognitive flexibility, or secondary symptoms (predisposition to hallucinations, psychotic experiences, and the assessment of depression, anxiety, and anger) despite a significant increase in serum vitamin D levels. | Vitamin D supplementation has no impact on cognitive or emotional functioning in healthy young adults.                                                                       | [104]      |
|           | Randomized trial; 82 healthy adults                                                                                                                                             | Supplementation with a high dose of vitamin D (4000 IU/d) improved the efficiency of non-verbal (visual-spatial) memory, and in the group with lower baseline [25(OH)D] levels (<75 nmol/L), it improved significantly.                                                                                                                        | A higher level of [25(OH)D] is especially important for a higher level of cognitive functioning, especially non-verbal (visual) memory, which also uses executive processes. | [35]       |
| Vitamin C | Systematic Review; 50 studies, with randomized controlled trials (RCTs, $n = 5$ ), prospective ( $n = 24$ ), cross-sectional ( $n = 17$ ), and case-control ( $n = 4$ ) studies | Studies demonstrated higher mean vitamin C concentrations in the cognitively intact groups of participants compared with cognitively impaired groups.                                                                                                                                                                                          | No correlation between vitamin C concentrations and cognitive function was apparent in the cognitively impaired individuals.                                                 | [105]      |



Nutritional deficiencies of micronutrients such as vitamin B12, folate, and zinc may cause symptoms of depression and dementia, including depressed mood, fatigue, cognitive decline, and irritability [106,107]. Vitamin B12, vitamin B6, and folic acid play an important role in the metabolism of plasma homocysteine (tHcy), and vitamin deficiency hyperhomocysteinemia is associated with cognitive decline later in life. Cross-sectional, case-control, and long-term observational studies have indicated that high tHcy raises the risk of cognitive impairment with or without dementia, but the nature of these studies makes it challenging to conclude whether these associations are actually causal. Increased tHcy is associated with an increased risk of cognitive impairment and dementia, although the available evidence from RCTs does not indicate any obvious cognitive benefit from lowering tHcy with B vitamins [93] (Table 2).

A study of 3136 American adults aged 18 to 30 was conducted. Study participants were followed for 20 years. People with the highest dietary niacin intake at baseline (i.e., median intake 24.7 mg/day) scored better in cognitive tests 20–25 years later than those with the lowest dietary niacin intake (median 8.6 mg/day, so below the US recommendations, set at 15 mg per day). The study participants with the highest dietary intake of pyridoxine at baseline (i.e., mean intake of 3.0 mg/day) performed better in psychomotor speed tests 20–25 years later compared with those with the lowest dietary pyridoxine intake (median 0.7 mg/day). Young adults consuming large amounts of dietary folate (mean consumption: 384 g/day) showed better cognitive functions 20–25 years later in middle age, compared with those with the lowest dietary folate intake (mean consumption: 152 g/day). Those with the highest dietary intake of vitamin B12 at baseline (i.e., mean intake of 8.7 g/day) surpassed those with the lowest dietary cobalamin intake (median 2.2 g/day) in psychomotor speed 20 to 25 years later [94] (Table 2).

In a group of 317 healthy Korean children without prior diagnosis of neurological or psychiatric disorders, analyses suggested that vitamin B1, B2, B6, and niacin intake was negatively correlated with omission errors that indicated inattention [95] (Table 2). Louwman et al. conducted a study to assess whether cognitive functions in adolescents (10–16 years old) with marginal cobalamin status were impaired because of a macrobiotic diet up to 6 years of age. Control subjects who followed a standard diet since birth, without elimination of meat products, achieved better results on most psychological tests than macrobiotic subjects with low or normal cobalamin status [96] (Table 2). Cross-sectional studies in older children or adolescents most often showed that lower levels of biochemical vitamin B12 were correlated with deterioration of academic performance and mental and social development, as well as poorer short-term memory and attention [97] (Table 2). A systematic review published in 2021, focusing on vitamin B12 supplementation in elderly patients with regular or subclinical serum levels of vitamin B12 and without advanced neurological disorders, found no effect of treatment on cognitive functioning and symptoms of depression [98] (Table 2).

#### Vitamin E

Vitamin E ( $\alpha$ - and  $\gamma$ -tocopherols) is an essential fat-soluble vitamin and antioxidant. It inhibits the propagation of the lipid oxidation chain reaction, which may particularly affect polyunsaturated fatty acids in the cell membrane, along with neuronal structures [108]. It affects cognitive performance, and a decrease in serum vitamin E levels was associated with poor memory performance in the elderly [109]. A meta-analysis of randomized controlled trials did not show a significant effect of vitamin E on cognitive functions in middle-aged and elderly people without dementia [99] (Table 2). A meta-analysis of randomized controlled trials investigating oral vitamin or mineral supplements in participants diagnosed with mild cognitive impairment showed that three years of treatment with high doses of vitamin E probably did not reduce the risk of progression to dementia. However, only one study was included in the analysis, which analyzed the effect of vitamin E supplementation on cognitive functions, which requires confirmation in further studies in the future [100]

(Table 2). The sources of vitamin E are nuts (almonds, hazelnuts, peanuts), vegetable oils, soybean oil, wheat germ, safflower, sunflower seeds, spinach, and broccoli [67].

#### Vitamin D

Vitamin D plays a key role in the metabolism of bone and calcium in the human body. It also serves other functions in the body, including modulation of cell development, neurogenesis, neuroprotection, detoxification, immune function, and reduction in inflammation [110]. The vitamin D receptor located in the brain is involved in the complex planning, processing, and formation of new memories [111], which would herald the importance of cognitive functions and a better overall neurological state [112]. The occurrence of vitamin D deficiency is a major global public health challenge. Based on their research, scientists have linked vitamin D to disorders affecting multiple body parts, such as cardiovascular diseases, cancer, stroke, and metabolic disorders, not to mention diabetes [113]. In a randomized trial conducted, Mendel Maddock et al. showed that there is no evidence that serum [25(OH)D] concentration is a factor influencing cognitive functions in middle and later life [101] (Table 2). Concentrations of [25(OH)D] below 25 nmol/L increase the risk of dementia, especially in adults and patients over 65 years of age [102] (Table 2). According to a meta-analysis by Goodwill et al., low vitamin D levels are associated with poorer cognitive functions; however, interventional studies have not shown clear benefits of vitamin D supplementation [103] (Table 2). In a study involving younger, healthy adults, 128 people were divided into two groups. The first group (63 people) took 5000 IU/day of cholecalciferol for 6 weeks, while the second group (65 people) took placebo for 6 weeks. The aim of the study was to assess the effect of supplementation on cognitive functioning and secondary emotional measures. Subjects were assessed for working memory, response inhibition, and cognitive flexibility at baseline and at 6 weeks. As a result of the intervention, the group receiving vitamin D significantly developed serum levels of [25(OH)D], while no difference was observed in the group receiving placebo. No measure of cognitive functioning improved after 6 weeks of follow-up [104] (Table 2).

In another clinical study in healthy adults, 82 patients with a baseline value of [25 (OH)D]  $\leq 100$  nmol/L were randomized to one of two groups. The first group received a high dose (4000 IU/day;  $n = 42$ ) of vitamin D3 for 18 weeks, and the second group received a low dose (400 IU/day;  $n = 40$ ) to assess the effects of supplementation on cognitive functions according to the Symbol Digit Modalities test, assessing verbal fluency and digit span, and the Cambridge Automated Neuropsychological Test Battery (CANTAB) battery. Serum [25(OH)D] levels increased significantly more in the high-dose group. Improvement in non-verbal (visual-spatial) memory performance in the high-dose group and in the group with lower baseline [25-(OH)-D] levels ( $<75$  nmol/L) improved significantly. The results suggest that elevated [25(OH)D] levels are crucial for executive functions such as non-verbal memory [35] (Table 2). Sources of vitamin D in food are fortified milk, cheese, cereals, egg yolk, salmon, and fortified margarine [67].

#### Vitamin C

Vitamin C participates in the synthesis and modulation of various hormonal components of the nervous system. It is a catalyst for enzymes that catalyze the formation of catecholamines (noradrenaline and adrenaline) and enzymes active in the biosynthesis of neuropeptides [114]. A group of components of the nervous system are adjusted by ascorbate (vitamin C) levels, therein neurotransmitter receptors and brain cell structures (such as glutamatergic and dopaminergic neurons) and the synthesis of glial cells and myelin [114,115]. Travica et al. reviewed a systematic review of 50 randomized controlled trials to find the relationship between vitamin C status and cognitive efficiency in both healthy (cognitively intact) and disabled individuals. Of these, 36 studies were conducted in healthy participants and 14 in people with cognitive impairment (including Alzheimer's disease and dementia). Vitamin C status was measured using meal frequency questionnaires or direct assessment of vitamin C in plasma. Cognitive function was studied using



various tests, mainly the Mini-Mental-State-Examination (MMSE). The results of the study showed higher mean vitamin C concentrations in the groups of cognitively intact participants compared with the groups with cognitive impairment. There was no correlation between vitamin C concentration and the cognitive function of MMSE in people with cognitive impairment. MMSE was not adequate to detect cognitive variance in the healthy group. An analysis of studies that used different cognitive assessments in cognitively intact subjects was not the subject of this review; however, a qualitative assessment showed a potential relationship between vitamin C levels in plasma and cognitive function [105] (Table 2). Sources of vitamin C are citrus fruits (lemons, oranges, limes), papaya, red and green peppers, tomatoes, kiwi, strawberries, cantaloupes, leafy vegetables and their juices, fortified cereals, and potatoes [67].

### 3.2. The Influence of Dietary Supplements on Cognitive Functions

There is growing evidence that certain dietary supplements may positively influence cognitive performance. These include caffeine, L-theanine, creatine, polyphenols, beetroot juice, probiotics, lutein, nootropics, and other plant supplements.

#### 3.2.1. Caffeine

Caffeine is a purine alkaloid and a very popular psychostimulant that is widely used by people all over the world. It is found in coffee beans, cola nuts, tea leaves, and yerba mate, as well as guarana seeds and cocoa beans [116]. It has been classified as a supplement with a very well documented effect, used to improve exercise performance. The benefits of its supplementation are observed in terms of sports performance in situations requiring endurance and in short-term, supra-maximum, or repeated sprint tasks [117]. Caffeine influences cognitive and physical functions by blocking adenosine A1 and A2a receptors in the central nervous system and peripheral tissues. Doses of 1–4 mg/kg body weight improve alertness, concentration, and reaction time [118] (Table 3), while doses of 3–6 mg/kg b.w. caffeine can enhance cognitive performance, motor skills, and physical performance in many types of sports [117] (Table 3).

The effect of caffeine on cognitive performance is also being investigated. This term covers executive functioning (EF), decision making, and creativity. Zhang et al. investigated the effects of low, moderate, and high doses of caffeine on cognitive performance and brain activation. Low dose caffeine intake (3 mg/kg b.w.) had a greater effect on cognition and brain activation than moderate and high doses of caffeine (6 and 9 mg/kg b.w.), suggesting low-dose caffeine can be a discriminating supplement in enhancing function executive and prefrontal activity [119] (Table 3).

Lorenzo Calvo et al. investigated the relationship between caffeine consumption and cognitive performance during sports. The systematic review included 13 studies assessing the effect of caffeine on objective measures of cognitive performance or cognitive function. Five of these studies were also meta-analyzed. After collecting the data in a meta-analysis, a significant effect of caffeine was only revealed in terms of attention, accuracy, and speed. However, the results of 13 studies suggest that consuming a low to moderate dose of caffeine prior to and/or during exercise may enhance mood and cognitive functions such as attention; it may also increase simple reaction time, choice reaction time, memory, or fatigue, but this is dependent on research protocols [120] (Table 3).

**Table 3.** Impact of supplements on cognitive function [20,117–153].

| Factor   | Subjects and Methods                                                                                          | Results                                                                                                                                                                                                                                                                                                                                                                                                | Conclusion                                                                                                                                                                                                                                                                 | References |
|----------|---------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Caffeine | Review                                                                                                        | Caffeine doses of around 0.5–4.0 mg/kg b.w. (~40–300 mg) improved cognitive function in well-rested individuals, while doses of 3–7 mg/kg b.w. (~200–500 mg) taken approximately 1 h before exercise improved physical performance. The dose–response exhibited high interindividual variability.                                                                                                      | Doses of 1–4 mg/kg b.w. improve alertness, concentration, and reaction time, but there is less consistent impact on memory and executive functions, such as assessing the situation and making decisions.                                                                  | [118]      |
|          | International Olympic Committee consensus statement                                                           | Doses of 3–6 mg/kg b.w. caffeine improved cognitive, motor skills, and exercise performance in many types of sports.                                                                                                                                                                                                                                                                                   | Caffeine supplementation may improve cognitive, motor skills, and exercise performance.                                                                                                                                                                                    | [117]      |
|          | Randomized, double-blind, placebo-controlled crossover trial; 9 elite League of Legends (LoL) esports players | The administration of a supplement (AI Reload (118 mL) that included 150 mg caffeine ( $1.9 \pm 0.3$ mg/kg b.w.) designed to improve performance demonstrated no ergogenic effects relative to the indices examined in this study (measures of attention, reaction time, working memory, and fatigue).                                                                                                 | Three LoL games do not accumulate mental fatigue in elite LoL players. The administration of a supplement containing caffeine does not have a positive effect on the cognitive functions of LoL players.                                                                   | [20]       |
|          | Crossover, double-blind study; 10 male subjects                                                               | Intake of 3 mg/kg of caffeine boosted performance on the Stroop task under both incongruent and congruent conditions and increased mean oxygenated hemoglobin under the congruent condition. Ingestion of 6 mg/kg of caffeine increased efficiency on the Stroop task under the incongruent condition.                                                                                                 | Low-dose caffeine intake proved to have greater effects on cognition and brain activation compared with midrange and high caffeine doses, implying that small doses of caffeine may be the supplement of choice in enhancing executive function and prefrontal activities. | [119]      |
|          | Double-blind, crossover, randomized experimental trial; 15 professional e-gamers (age = $22 \pm 3$ years).    | The acute ingestion of 3 mg/kg of caffeine improved both reaction time and accuracy in hitting targets.                                                                                                                                                                                                                                                                                                | Caffeine consumption (3 mg/kg b.w.) can be considered an ergogenic aid for esports players (in first person shooters) due to its effect on increasing accuracy and hit time.                                                                                               | [152]      |
|          | Systematic Review and Meta-Analysis; 13 studies, of which 5 studies were included in the meta-analysis        | Caffeine showed beneficial effects in tasks requiring attention, accuracy, and speed (meta-analysis). Supplementation with a low/moderate dose of caffeine before and/or during exercise helped raise mood, energy, and attention, but also enhanced simple reaction and response time, as well as augmenting memory and easing fatigue, though this may have depended on test protocols (13 studies). | Caffeine supplementation in sports requiring attention and focus may be considered, but more research is needed.                                                                                                                                                           | [120]      |

Table 3. Cont.

| Factor                                          | Subjects and Methods                                                                                                                | Results                                                                                                                                                                                                                                                                                                                                                                                                                      | Conclusion                                                                                                                                                                                                  | References |
|-------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Combination of caffeine and theanine            | Randomized, placebo-controlled, double-blind, balanced crossover study; 24 participants (9 male and 15 female, mean age 21.3 years) | A combination of 250 mg of L-theanine and 150 mg of caffeine improved reaction time, working memory, and accuracy of task verification.                                                                                                                                                                                                                                                                                      | The combination of caffeine and L-theanine seems to be justified in sports that require quick response, memory, and accuracy.                                                                               | [121]      |
|                                                 | Systematic review and meta-analysis (11 randomized placebo-controlled human studies)                                                | The combination of L-theanine with caffeine increased alertness, increased the accuracy of switching attention, slightly increased the accuracy of non-sensory visual attention, and slightly increased the accuracy of non-sensory auditory attention.                                                                                                                                                                      | Caffeine in combination with L-theanine had a beneficial effect on the cognitive function and mood.                                                                                                         | [122]      |
|                                                 | Systematic review (49 studies)                                                                                                      | Caffeine in a dose of 40 mg improved performance in demanding long-term cognitive tasks as well as self-reported alertness, agitation, and vigor. L-Theanine alone improved relaxation, tension and calmness reported by patients themselves, starting with 200 mg. The combination of L-theanine and caffeine improved performance in attention-switching and alertness tasks, but to a lesser extent than caffeine itself. | L-Theanine and caffeine both have apparent advantageous effects on continued alertness, memory, and improved attention. L-Theanine helped to relax by curbing arousal stimulated by caffeine.               | [123]      |
|                                                 | Systematic review of controlled trials, crossover studies cross-sectional studies, and cohort study (21 studies)                    | Green tea influenced psychopathological symptoms (e.g., reduction in anxiety), cognition (e.g., benefits in memory and attention), and brain function (e.g., activation of working memory seen in functional MRI).                                                                                                                                                                                                           | Caffeine in combination with L-theanine has a beneficial effect on cognition, while the separate use of both substances has a smaller effect.                                                               | [124]      |
| Combination of caffeine, theanine, and tyrosine | Randomized, double-blind, placebo-controlled crossover trial; 20 current or former male collegiate athletes (age: 20.5 ± 1.4 years) | The combination of a low dose of caffeine with theanine and tyrosine improved the accuracy of athletes' movements and reaction time during a series of grueling exercises.                                                                                                                                                                                                                                                   | Supplementation recommended in exercises demanding accurate movements and quick reaction time.                                                                                                              | [125]      |
| Polyphenols                                     | Systematic review and meta-analysis; 18 studies                                                                                     | The acute consumption of polyphenols enhanced processing of fast-paced visual stimuli in young participants.                                                                                                                                                                                                                                                                                                                 | Acute polyphenol consumption might improve speed in rapid visual information processing task, a higher order task with elements of vigilance, working memory, and executive function, in young participants | [128]      |

Table 3. Cont.

| Factor                   | Subjects and Methods                                                      | Results                                                                                                                                                                                                                                                                                             | Conclusion                                                                                                                                                                                                                                             | References |
|--------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Cocoa                    | Randomized, double-blind, crossover study; 12 healthy men                 | At rest, cocoa flavanol intake increased cerebral oxygenation, but not brain-derived neurotrophic factor concentrations, and no impact on executive function was detected.                                                                                                                          | Positive influence of cocoa flavanol on brain oxygenation during rest was revoked by a strong increase in perfusion and brain oxygenation caused by exertion.                                                                                          | [126]      |
|                          | 98 healthy young adults ( $n = 57$ females) aged 18–24 years              | Dark chocolate consumption (70% cocoa) was associated with better verbal memory performance for several outcome measures of the Rey Auditory Verbal Learning Test relative to the white chocolate consumption; however, there were no effects on mood.                                              | 70% cocoa dark chocolate consumption can benefit verbal episodic memory two hours post consumption in healthy young adults relative to a white chocolate control. A daily serving (35 g) of dark chocolate can benefit the brain of healthy consumers. | [127]      |
|                          | Review; 11 intervention studies that involved a total of 366 participants | After acute consumption, these beneficial effects seemed to be accompanied by an increase in cerebral blood flow or cerebral blood oxygenation. After chronic intake of cocoa flavanols in young adults, a better cognitive performance was found, together with increased levels of neurotrophins. | The beneficial effect of cocoa flavanols on cognitive function and neuroplasticity was supported and indicates that such benefits are possible in early adulthood.                                                                                     | [129]      |
|                          | Review, 15 human studies                                                  | Regular consumption of flavanols had a neuroprotective effect and also improved cerebrovascular and metabolic functions.                                                                                                                                                                            | Consuming cocoa flavanols may have beneficial effects in maintaining cognitive performance by improving indicators of general cognition, attention, processing speed, and memory.                                                                      | [130]      |
|                          | Systematic Review; 18 studies                                             | Consuming chocolate or cocoa products improved lipid (triglyceride) profiles. The effect of chocolate on all other outcome parameters did not differ significantly (including cognitive functions).                                                                                                 | There is no evidence that cocoa and cocoa-containing products may be beneficial for cognition.                                                                                                                                                         | [131]      |
| Beetroot juice (nitrate) | Randomized, double-blind, crossover study, 16 male team-sport players     | The total work done during the sprints was greater in the nitrate-rich beetroot juice group compared with the placebo group. The response time to cognitive tasks in the second half of the sprint improved in the nitrate-containing beet juice group compared with the placebo group.             | Dietary $\text{NO}_3^-$ enhances repeated sprint performance and may attenuate the decline in cognitive function (and specifically reaction time) that may occur during prolonged intermittent exercise.                                               | [132]      |



Table 3. Cont.

| Factor   | Subjects and Methods                                                                                                                                                                           | Results                                                                                                                                                                                                                                                                                                                                     | Conclusion                                                                                                                                                                                  | References |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
|          | Randomized, double-blind, placebo-controlled trial, 40 healthy adults (18–27 years)                                                                                                            | Dietary nitrate modulated the hemodynamic response to task performance, with an initial increase in prefrontal cortex cerebral blood flow at the start of the task period, followed by consistent reductions during the least demanding of the three tasks utilized. Cognitive performance was improved on the serial 3 s subtraction task. | Single doses of dietary nitrates may modulate the cerebral blood flow response to task performance and potentially improve cognitive performance.                                           | [133]      |
|          | Double-blind, placebo controlled, crossover trial; thirteen younger (18–30 years) and 11 older (50–70 years)                                                                                   | Response time improved in the Stroop test after beetroot juice supplementation for both groups. Acute BR supplementation increased plasma nitrite levels and to a greater extent reduced diastolic BP in the elderly; while systolic BP was lowered in both older and younger subjects.                                                     | Acute supplementation with beetroot juice can reduce blood pressure and improve aspects of cognitive performance; thus, having potential health benefits for both younger and older adults. | [134]      |
|          | Double-blind placebo-controlled trial; 24 healthy volunteers (19 men and five women, 24.3 ± 9.1 years old)                                                                                     | After taking the creatine supplement, task-evoked increase in cerebral oxygenated hemoglobin in the brains of subjects measured by near infrared spectroscopy was significantly reduced, which is compatible with increased oxygen utilization in the brain.                                                                                | Dietary supplement of creatine (8 g/day for 5 days) reduces mental fatigue when subjects repeatedly perform a simple mathematical calculation.                                              | [136]      |
| Creatine | Double-blind, placebo-controlled, crossover trial; 25 vegan or vegetarian subjects (12 males (median age of 27.5, range of 19–37 years), 33 females (median age of 24.9, range of 18–40 years) | Oral creatine supplementation (5 g/day for six weeks) improved IQ scores and working memory performance in 45 young adult vegetarians. Creatine supplementation had a positive effect on both working memory (digit spread) and intelligence (Raven's Advanced Progressive Matrices), both tasks requiring processing speed.                | These findings underline a dynamic and significant role of brain energy capacity in influencing brain performance.                                                                          | [137]      |
|          | Clinical trial; volunteer male ( $n = 17$ ) and female ( $n = 3$ ) sports science and adventure education majors (mean age: 21.11 years)                                                       | At 24 h, the creatine group (20 g/day for 7 days) demonstrated significantly less change in performance in random movement generation (RMG), choice reaction time, balance, and mood state.                                                                                                                                                 | Following 24 h sleep deprivation, creatine supplementation had a positive effect on mood state and tasks that place a heavy stress on the prefrontal cortex.                                | [138]      |
|          | Double-blind, placebo-controlled study; 34 participants (including 12 females); mean age of 21 years (SD: 1.38; range: 18–24).                                                                 | Creatine ethyl ester supplementation (5 g/day for 15 days) improved cognition on some tasks. Creatine dosing led to an improvement over the placebo condition on several measures.                                                                                                                                                          | Although creatine seems to facilitate cognition on some tasks, these results require replication using objective measures of compliance.                                                    | [139]      |

Table 3. Cont.

| Factor | Subjects and Methods                                                                                                                                                                  | Results                                                                                                                                                                                                                                                                                                                                                                                                                                              | Conclusion                                                                                                                                                                                                                                      | References |
|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
|        | Randomized, double-blind, placebo-controlled trial; Female undergraduates ( $n = 121$ ), mean age 20.3 (SE 2.1) years, meat-eaters ( $n = 51$ ) and vegan or vegetarian ( $n = 70$ ). | Creatine supplementation (20 g of creatine supplement for 5 d) did not affect the indicators of verbal fluency and alertness. However, in vegetarians, supplementation with creatine resulted in better memory compared with the group consuming meat.                                                                                                                                                                                               | For vegetarians, it is worth using creatine supplementation to improve memory.                                                                                                                                                                  | [140]      |
|        | Systematic review of randomized controlled trials; 6 studies (281 individuals)                                                                                                        | Short-term memory and intelligence/reasoning can be improved by administering creatine. Effect of creatine on other cognitive domains, i.e., long-term memory, spatial memory, memory scanning, attention, executive functions, reaction inhibition, word fluency, reaction time, and mental fatigue was not clear cut. Vegetarians responded better than meat eaters to memory tasks, but no differences were observed for other cognitive domains. | Oral creatine administration may improve short-term memory and intelligence/reasoning of healthy individuals, but its effect on other cognitive domains remains unclear. Findings suggest potential benefit for aging and stressed individuals. | [135]      |
|        | Pilot trial in healthy men ( $n = 5$ )                                                                                                                                                | Guanidinoacetic acid (GAA, 3 g·day <sup>-1</sup> ), a naturally occurring creatine precursor, was reported to have a superior influence on brain creatine content when compared with an equimolar dose of creatine.                                                                                                                                                                                                                                  | GAA as a preferred alternative to creatine for improved bioenergetics in energy-demanding tissues.                                                                                                                                              | [141]      |
|        | Blinded, placebo-controlled crossover design; 10 rugby backs (mean $\pm$ SD, age; 20 $\pm$ 0.5 years)                                                                                 | No fall in skill performance was seen with caffeine doses of 1 or 5 mg/kg, and the two doses were not significantly different in effect. Similarly, no deficit was seen with creatine administration at 50 or 100 mg/kg, and the performance effects were not significantly different.                                                                                                                                                               | Creatine can be used in stressful situations in which there may be a temporary decrease in creatine levels and may offset the negative cognitive effects of sleep deprivation.                                                                  | [142]      |
| Review |                                                                                                                                                                                       | It appears that creatine was most likely to exert an influence in situations whereby cognitive processes were stressed, e.g., during sleep deprivation, experimental hypoxia, or during the performance of more complex, and thus more cognitively demanding tasks.                                                                                                                                                                                  | In situations of sleep deprivation and performing more complex tasks, creatine supplementation may turn out to be beneficial.                                                                                                                   | [143]      |
| Review |                                                                                                                                                                                       | There was a potential for creatine supplementation to improve cognitive processing, especially under conditions characterized by brain creatine deficits, which could be induced by acute stressors (e.g., exercise, sleep deprivation) or chronic, pathologic conditions (e.g., creatine synthesis enzyme deficiencies, mild traumatic brain injury, aging, Alzheimer's disease, depression).                                                       | The optimal creatine protocol able to increase brain creatine levels is still to be determined.                                                                                                                                                 | [144]      |

Table 3. Cont.

| Factor                                    | Subjects and Methods                                                                                        | Results                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | Conclusion                                                                                                                                                                                                          | References |
|-------------------------------------------|-------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Prebiotics, probiotics and fermented food | A meta-analysis of randomized controlled trials; 22 studies ( $n = 1551$ )                                  | Despite several individual studies (14 of 22) reporting significant improvements in specific cognitive domains, results of the pooled meta-analysis found no significant effect for any intervention for global cognition.                                                                                                                                                                                                                                                                    | These results do not support the use of probiotic, prebiotic, and fermented food interventions for cognitive outcomes.                                                                                              | [147]      |
|                                           | Narrative review; 14 studies, (5 randomized, crossover trials, 3 double-blind, and 2 nonblinded studies)    | Chronic prebiotic interventions (>28 d) improved affect and verbal episodic memory compared with a placebo. Acute prebiotic interventions (<24 h) were more efficient in improving cognitive variables (e.g., verbal episodic memory).                                                                                                                                                                                                                                                        | Acute prebiotic interventions (<24 h) can be used to improve cognitive variables. However, more research is needed.                                                                                                 | [146]      |
| Prebiotics                                | Randomized, double-blind, crossover, controlled trial; 18 healthy female participants                       | Polydextrose improved cognitive flexibility (reducing the number of errors made in the Intra-Extra Dimensional Set Shift task). Better performance in terms of retention of attention was observed due to the greater number of correct answers and rejections in the quickly processing visual information task. Although there was no change in microbial diversity, <i>Ruminiclostridium 5</i> abundance increased significantly after polydextrose supplementation compared with placebo. | Supplementation with the polydextrose resulted in a modest improvement in cognitive performance. The results indicate that polydextrose could benefit gut-to-brain communication and modulate behavioral responses. | [148]      |
| Probiotics                                | Randomized controlled trial; healthy female subjects, (aged 18–40 years)                                    | Subjects with a higher increase in Ruminococcaceae_UCG-003 abundance after probiotics were also more protected from negative effects of stress on working memory after probiotic supplementation.                                                                                                                                                                                                                                                                                             | Gut microbial alterations, modulated through probiotics use, are related to improved cognitive performance in acute stress circumstances.                                                                           | [149]      |
|                                           | Randomized, double-blind, placebo-controlled trial, 45 right-handed healthy participants (aged 20–40 years) | Functional connectivity changes were observed in the default mode network, salience network, and middle and superior frontal gyrus network in the probiotic group as compared with the placebo and control groups.                                                                                                                                                                                                                                                                            | The results demonstrated that there is a close relationship between the effects of probiotic intervention on behavioral and neuroimaging readouts.                                                                  | [145]      |
| Lutein                                    | Review                                                                                                      | Dietary sources of lutein (avocado, spinach) had an influence of serum level of lutein and could lead to the accumulation of lutein in retinal neural tissue and may maintain eye and brain health.                                                                                                                                                                                                                                                                                           | Dietary intake and supplementation of lutein can improve cognitive and vision abilities.                                                                                                                            | [150]      |
|                                           | Randomized controlled trial; 20 healthy subjects                                                            | In a study, the elderly (mean age 63) consumed avocados (high source of lutein), which increased MPOD (macular pigment optical density) and was associated with the improvement in cognitive functions.                                                                                                                                                                                                                                                                                       | Dietary intake of lutein has significant impact on the improvement in cognitive functions.                                                                                                                          | [151]      |
|                                           | Randomized double blind, placebo-controlled trial; 37 healthy subjects (aged 22–30 years)                   | Lutein supplementation for 12 weeks increased levels of serum lutein and improved contrast sensitivity in both groups.                                                                                                                                                                                                                                                                                                                                                                        | Higher intake of lutein may be beneficial for visual performance.                                                                                                                                                   | [153]      |



### 3.2.2. L-Theanine

Tea, a drink made from the leaves of *Camellia sinensis*, has enjoyed wide consumption throughout human history. Many studies show that tea intake is associated with beneficial effects on brain health, including a reduced incidence of cognitive deterioration and decreased incidence of depression and mental stress [154,155].

L-Theanine is a non-protein amino acid found naturally in tea and has been mainly studied for its effects on the brain. After crossing the blood–brain barrier, L-theanine influences the central nervous system (CNS) by affecting neurotransmitters and attenuating stress-related CNS responses [156]. Haskell et al. investigated that a combination of 250 mg of L-theanine and 150 mg of caffeine improved reaction time, working memory, and accuracy of task verification in a group of volunteers aged 18–34 years [121] (Table 3). The meta-analysis by Camfield et al. collected 11 human studies that investigated the effects of L-theanine alone or in combination with caffeine on cognitive ability and mood. Caffeine in combination with L-theanine had a beneficial effect on the concentration and emotional state of the study participants [122] (Table 3). Dietz and Dekker reviewed the available studies, concluding that L-theanine and caffeine had beneficial effects on continuous attention, memory, and distraction suppression. In contrast, L-theanine leads to relaxation by reducing caffeine-induced arousal [123] (Table 3). The cognitive effects of green tea are related to the combined effects of caffeine and L-theanine, while separate administration of each substance has been shown to have a smaller effect [124] (Table 3). In another study, Zaragoza et al. attempted to test the effect of supplementation with a low-dose combination of caffeine, theanine, and tyrosine on sport-specific cognition in tests where accuracy of movement and reaction time are important. The results obtained in the study showed that the combination of low-dose caffeine with theanine and tyrosine can improve athletes' accuracy of movement and reaction time during a series of strenuous exercises [125] (Table 3).

### 3.2.3. Polyphenols

Polyphenols are secondary metabolites of plants and can be divided into four categories: phenolic acids, flavonoids, lignans, and stilbenes. They play a protective role in neurodegeneration and interact with neuronal signaling pathways [157,158]. Fruits and drinks such as tea, red wine, cocoa, and coffee are the main sources of dietary polyphenols. They affect peripheral and cerebrovascular blood flow, interact with intracellular neuronal and glial signaling, and help protect neurons from damage [159–161]. Research results show that polyphenols have a positive effect on cognition and memory and reduce neuronal damage [162–164].

Polyphenols such as flavonoids and resveratrol have been shown to exert many important effects on the brain, including modulation of cellular pathways involved in gene expression, neuroprotection, neuroplasticity, and endogenous antioxidant defense and increasing cerebral blood flow [165,166]. The intake of polyphenols with the diet is associated with a reduced risk of developing dementia, improving cognitive abilities in the aging process [167]. The mechanisms of action of polyphenols include the reduction in oxidative stress and inflammation and the improvement in cerebral perfusion [126,127] (Table 3). Later studies suggested that berry polyphenols may have multiple effects in addition to their anti-inflammatory and antioxidant functions [168]. Additionally, it has been shown that anthocyanins contained in blueberries penetrate the brain, and their concentration has been correlated with cognitive performance [169].

Hepsomali et al. conducted a systematic review and meta-analysis to investigate whether polyphenol consumption might have a beneficial effect on cognition, especially on accuracy and speed of attention. A total of 18 placebo-controlled human intervention studies were included in the meta-analysis. The results of the study indicate that acute polyphenol consumption may improve the speed of processing visual information, a higher-



order task with vigilance elements, working memory, and executive functions in young participants [128] (Table 3).

### 3.2.4. Cocoa Flavanols

Cocoa beans are commonly known for being a primary source of phenolic compounds with unmatched content of flavanols of any food on a per weight basis [170]. More and more studies confirm the beneficial effects of cocoa and cocoa-containing products on human cognition. The cognitive benefits of consuming chocolate are identified in a systematic review that reported improvements in cognitive or task performance among young adults (under the age of 25) and children who regularly consumed chocolate. This effect is attributed to polyphenols, including flavanols [129] (Table 3). Decroix showed in a conducted study involving 12 healthy men that the beneficial effect of cocoa flavanols on brain oxygenation at rest was offset by a strong increase in brain perfusion and oxygenation induced by exercise. Cocoa-derived flavanols had no additional effect on exercise-induced cognitive enhancement and the associated increased brain oxygenation and perfusion [126]. A study in 98 healthy adults found that consuming 35 g of dark chocolate with a cocoa content of 70% may have a positive effect on episodic verbal memory compared with an equal-calorie bar of white chocolate of 35 g two hours after ingestion in healthy young adults [171]. According to a review by Socci et al., the ad hoc supply of cocoa flavanols may result in an immediate improvement in cognitive functions, as well as maintaining the efficiency of cognitive functions under situations of fatigue and insufficient sleep. [130] (Table 3). Tan et al. conducted a systematic review of 18 studies to assess the health effects of cocoa and cocoa-containing products. The consumption of chocolate or cocoa products significantly improved lipid (triglyceride) profiles, while the effects of chocolate in all other outcome parameters did not differ significantly, including no significant effect on cognitive functions [131] (Table 3).

### 3.2.5. Beetroot Juice

Beetroot juice is a scientifically proven supplement. It is a popular additive that has been widely studied for its effects on improving the ability to perform long-term submaximal training [172] and intense, intermittent, short-term exercise [132,173] (Table 3). Its beneficial effect in the context of sports is due to the high content of nitrates ( $\text{NO}_3^-$ ), compounds found naturally in vegetables. Dietary nitrates are reduced endogenously to nitric oxide. Most studies suggest that beetroot juice supplementation is vital in modulating skeletal muscle function [174], increases exercise capacity through increased function of type II muscle fibers [175], reduces ATP cost of muscle strength production, increases mitochondrial respiration efficiency, and increases blood flow through blood vessels [176].

One study found that dietary nitrates increase performance during repeated sprints and may ameliorate the cognitive decline (particularly in reaction time) that may occur with prolonged repetitive exercise [132]. In another randomized, double-blind, placebo-controlled, parallel group study, 40 healthy adults received a placebo or 450 mL of beetroot juice. The results of the study show that single doses of dietary nitrate can modulate the brain's blood flow response to task performance and potentially improve cognitive performance and suggest one possible mechanism by which vegetable consumption may have a beneficial effect on brain function [133] (Table 3). Stanaway et al. conducted a study to assess whether supplementation with nitrate-rich beetroot juice would improve cardiovascular and cognitive functions in elderly people (50–70 years old) and young adults (18–30 years old). The results indicate that beetroot juice supplementation can lower blood pressure and boost some aspects of cognitive performance, thus providing potential health benefits for both age groups [134] (Table 3).

### 3.2.6. Creatine

Creatine is a supplement used by athletes to improve efficiency in sports by increasing the energy supply of muscle tissues. It is also a crucial component of the brain, and accord-

ing to research, it supports cognitive processes, enhancing energy supply and influencing neuroprotection [135]. Brain cells use adenosine triphosphate (ATP) to produce energy. The phosphocreatine and creatine (PCr/Cr) system is linked to adenine nucleotides through the creatine phosphokinase reaction [135] (Table 3). Overall, creatine is involved in cellular energy homeostasis [177,178]. The results of many studies have shown that creatine supplementation increases the PCr content in the brain by 5–15%, and thus improves the brain's bioenergetics [179]. Watanabe et al. found that dietary supplementation with creatine (8 g/day for 5 days) reduces mental fatigue when subjects repeatedly perform simple mathematical calculations [136]. Rea et al. investigated whether oral creatine supplementation (5 g per day for six weeks) increased IQ scores and working memory performance in 45 young adult vegetarians. Creatine supplementation had a significant positive effect on both working memory and intelligence. Both tasks required processing speed [137] (Table 3). McMorris et al. found that creatine supplementation (20 g/day for 7 days) had a positive effect on the mood state and performance of tasks that affect the prefrontal cortex in sleep-deprived participants [138] (Table 3). Ling et al. investigated whether creatine ethyl ester supplementation (5 g/day for 15 days) might improve cognitive functions in some tasks [139] (Table 3). Creatine supplementation may improve the performance of tasks that require memory and intelligence [135] (Table 3). While the role of creatine supplementation in brain function is promising, more research is needed, as evidence suggests that the blood–brain barrier is an obstacle to the circulation of creatine, which may require higher doses and/or longer protocols to increase the concentration of creatine in the brain in comparison with the muscles. Not all research results are unequivocal. Benton et al. showed that creatine supplementation did not affect the indicators of verbal fluency and alertness. However, in vegetarians, supplementation with creatine resulted in better memory compared with the group consuming meat [140] (Table 3).

Studies show that guanidinoacetic acid (GAA, 3 g/day), a naturally occurring creatine precursor, shows superior results in increasing brain creatine content compared with an equimolar dose of creatine [141] (Table 3), although it should be noted that this finding was based on a study involving five participants.

Creatine may be used in stressful situations when a temporary decrease in creatine levels may occur to potentially offset the negative cognitive effects of sleep deprivation [142] (Table 3). The effect of creatine supplementation on brain function seems to be greater under stressful conditions that lead to temporary (e.g., mental fatigue, exhausting exercise) or chronic (e.g., aging, depression) creatine depletion, while the effect is absent or minimal in healthy people under non-stressful conditions [143]. A review by Roschel et al. concluded that supplementation with creatine may enhance cognitive processing, especially in circumstances of creatine deficits in the brain that may be caused by acute stressors (e.g., exercise, sleep deprivation) or chronic pathological conditions (e.g., deficiencies of creatine synthesis enzymes, mild traumatic brain injury, aging, Alzheimer's disease, depression). Nevertheless, the optimal creatine protocol capable of increasing brain creatine levels remains to be determined [144] (Table 3).

### 3.2.7. Probiotics and Prebiotics

There is a clear relationship between probiotics, psychobiotics, and cognitive and behavioral processes that include neurological, metabolic, endocrine, and immune signaling pathways. Changes in these systems can cause changes in behavior (mental disposition) and cognitive level (learning and memory) [180]. The microbiota–gut–brain axis is the interaction between the gut microbiota and the brain. This combination has a great impact on human health, including on mental illness and on behaviors that affect mental health and cognitive performance [181–183].

Intestinal colonization begins at birth and continues through the first 3 years of life. The initial interaction between the gut microbiota and the host is essential for the maturation of the nervous system, the immune system, and development regulation of intestinal physiology [184–186]. At this stage, the intestinal microbiota is also able to modulate the



angiogenesis process [187]. In addition, the microorganisms also exhibit antimicrobial activity, thus maintaining a stable intestinal ecosystem. It has been shown that changes in the microbial colonization of human intestines early in life influence the risk of developing diseases [188]. Later in life, microbial colonization of the gut has significant effects on the host's neurophysiology, behavior, and nervous system function [181,189,190]. The gut microbiota, thanks to its immunomodulatory properties, influences brain function and human behavior through various immune pathways, inside and outside the central nervous system (CNS). It has been shown that microbial neuroimmune modulation may contribute to etiopathogenesis or show important signs and symptoms in neurodegenerative and behavioral disorders such as autism spectrum disorders, anxiety, depression, Alzheimer's disease, and Parkinson's disease [189]. Probiotic interventions provide specific strains of bacteria that can influence composition and activity of the gut microflora. In a study of 45 healthy adults, a 4-week administration of a multi-strain probiotic intervention ( $7.5 \times 10^6$  CFU/g) modulated functional activity in areas of the brain associated with higher-order cognitive processes such as problem-solving, reasoning, attention, decision-making, learning, and creativity [145] (Table 3).

Prebiotics, as defined by the International Scientific Association for Probiotics and Prebiotics, are "a substrate that is selectively used by host microorganisms to provide health benefits" [191]. Dietary ingredients with prebiotic properties provide substrates for the metabolism of commensal bacteria, unlike probiotics, which provide external strains of probiotic bacteria. The prebiotic preparations include, among others carbohydrate-based compounds such as fructooligosaccharides and inulin, as well as polyphenols and polyunsaturated fatty acids [192]. An additional intervention aimed at providing probiotics and prebiotics, as well as bioactive metabolites produced during fermentation processes, is the use of fermented products such as yogurt, kefir, and sauerkraut. Certain probiotic bacteria found in fermented foods can initiate the production of the neurotransmitter gamma-aminobutyric acid [193].

A systematic review of 14 prebiotic intervention studies aimed to evaluate the available prebiotic intervention studies in humans on cognition and affective functions, highlighting the potential mediating role of microbiota. Some chronic prebiotic interventions (>28 days) improved affect and episodic verbal memory compared with placebo. Acute prebiotic interventions (<24 h) were more effective in improving cognitive variables (e.g., verbal episodic memory). [146] (Table 3). A meta-analysis by Marx et al. aimed to evaluate randomized control trials that investigated the use of probiotic, prebiotic, and fermented food interventions to improve cognitive function. The results of the analysis do not show a benefit of using probiotic, prebiotic, and fermented food interventions for cognitive outcomes. However, this could be due to the great diversity of the population, types of cognitive tests, and introduced interventions; therefore, there is a need for further research [147] (Table 3). A randomized control study in 18 women was designed to test the effectiveness of dietary fiber, polydextrose, in improving cognitive performance and acute stress responses by manipulating the gut microflora in a healthy population. Supplementation with polydextrose caused a slight improvement in cognitive performance. The results indicate that polydextrose may positively influence communication between the gut and the brain and may modulate behavioral responses [148] (Table 3).

Exposure to chronic psychosocial stress reduces the level of *Bacteroides* spp. and increases the level of *Clostridium* spp. in the caecum, while increasing the level of circulating interleukin IL-6 and CCL2 (monocyte chemotactic protein, MCP-1), indicating immune activation. Levels of IL-6 and CCL2 correlate with changes in the levels of *Coprococcus* spp., *Pseudobutyrvibrio* spp., and *Dorea* spp. induced by stressors directly in the intestine [194]. The aim of the probiotic intervention undertaken by Bloemendaal et al. was to evaluate how probiotics can buffer the detrimental effects of stress on cognition by studying the association with probiotic-induced changes in the gut microbiota. Intestinal microbiological changes after 28-day supplementation with multi-strain probiotics (ecologic barrier consisting of *Lactobacilli*, *Lactococci*, and *Bifidobacteria* in healthy women (probiotic group

$n = 27$ , placebo group  $n = 29$ ) were analyzed. People with a higher increase in the number of Ruminococcaceae\_UCG-003 after probiotics were better protected against the negative effects of stress on working memory after probiotic supplementation [149] (Table 3).

### 3.2.8. Lutein

Lutein and its analogue zeaxanthin belong to the group of carotenoids that occur naturally in food. Rich sources of lutein include einkorn, Khorasan, and durum wheat and maize, as well as the food products that contain these substances. These carotenoids are also found in green leafy vegetables and egg yolks [195]. Lutein is responsible for processes related to vision, as well as for protecting the eyes against the development of diseases. Current evidence suggests that lutein may have a beneficial effect on the optimization of vision and cognitive functions at every stage of life [150,151] (Table 3). It is presumed that the substance's antioxidant and anti-inflammatory effects are responsible for this activity [151] (Table 3).

### 3.2.9. Other Plant Supplements

There is a lot of research on the influence of phytonutrients on the work of the brain and on cognitive functions. There are many plant products, herbal extracts, or phytonutrients such as ginseng, mint, *Ginkgo biloba*, *Bacopa monnieri*, lion's mane, *Rhodiola rosea*, guarana, rosemary, saffron, turmeric, ashwagandha, and xanthines, which are sold as tonic supplements to enhance cognitive functions. Many of the dietary ingredients listed appear to have promising effects on cognition. Several studies have shown positive effects of these products [1,21], but more research is needed.

Nootropics ("smart drugs") have a documented effect on cognition. Their mechanism of action strengthens mental functions such as memory, creativity, motivation, attention [196], concentration, and speed [197], which are important from the perspective of esports. The competitive nature of esports has led players to choose various nootropics or drugs that improve cognitive abilities in order to gain an advantage [20]. The safest options seem to be herbal medicines available in the form of dietary supplements, which contain vitamins, minerals, fatty acids, and other ingredients. According to research, herbs that show procognitive effects include *Ginkgo biloba*, *Siberian ginseng*, *Rhodiola rosea*, Brahmi rasayana, *Mucuna pruriens*, Royal Jelly, caffeine, and curcumin [197].

## 4. Discussion

Esports is a rapidly developing discipline that requires the selection of appropriate nutritional solutions, as well as a holistic approach for the player, to ensure that the player maintains appropriate physical and mental conditioning, both during and after the player's competitive period. Esports athletes want to improve their skills in the selected games in which they specialize and often spend several hours a day in a forced position, usually in front of computer screens [16]. Therefore, such athletes are exposed to the risk of deteriorating health; vision problems; and pain in the neck, back, or wrists [198]. From a mental perspective, esports athletes are also at high risk of developing depression and burnout symptoms [199]. Regular training can, moreover, lead to addiction, personal hygiene problems, sleep disorders, and social anxiety [198], which can negatively affect the physical, cognitive, and mental health of esports athletes. Thus, appropriate actions should be taken to counteract the negative effects of training.

The training of professional athletes is based on patterns drawn from scientific studies; however, the training involved in esports training is not yet adequately described in the literature. To develop their skills in esports, e-athletes use training in various areas related to overcoming obstacles, teamwork, or individual physical effort, including the cognitive, psychological, physical, technical, and tactical domains [19]. There is a special need for video game players to take care of their cognitive functions due to the competitive practices of video games, which require motor skills, including aiming and manual dexterity [200]; cognitive motor speed, i.e., reaction time and speed of action [200,201]; memory; intel-



ligence [202]; concentration [203]; visual-spatial attention [204]; and many other skills. Understanding the importance of factors influencing brain function and cognitive performance can be critical to athletic performance and the well-being of esports athletes. It seems that a proper diet, energy balance (resulting in an appropriate body structure), an optimal level of physical efficiency and physical activity, and a good state of physical and mental health can help ensure the proper preparation of an esports competitor for competition.

There is a lot of research available on the effects of dietary ingredients on cognition, brain activity, reaction time, and working memory. There have also been many studies focused on the effects of nutrients in preventing or relieving symptoms of neurodegenerative diseases. The mechanisms of the influence of dietary components on cognitive functions are known, but there is a lack of well-developed studies that would assess the relationship between the effect of diet and improvement in esports performance.

#### 4.1. The Potential Role of Minerals in Esports

Iodine is a good solution for the proper functioning of the body (i.e., brain function and target hormones) and can improve cognitive functions at every stage of life [43–48]. Iodine deficiency may also correlate with a lower IQ index in children and adolescents [49], as well as cognitive declines among school-age children [50,51]. On the other hand, in adults, iodine affects the proper functioning of the thyroid gland, which in turn correlates with an improvement in cognitive functions, such as memory and attention, as well as a proper mood [62–64]. Moreover, the development of skills necessary for improving in esports is important during adolescence because, according to current reports, people over twenty years of age have a reduced reaction rate [8]; thus, it is worth considering the appropriate dietary supply of iodine or possible iodine supplementation in the event of a deficiency.

Both an iron deficiency and excess iron may contribute to inadequate functioning of the brain and the formation of cognitive disorders related to difficulties in visual-spatial processing, longer reaction times, and impaired attention and concentration [45,54,58,59,70–74]. All these features are of great importance in esports. Iron supplementation improves general cognitive function, IQ, and measures of attention and concentration in children with anemia [55], and the consumption of iron-fortified foods in adolescents was shown to improve attention, reaction time, and memory [56]. Iron supplementation in middle-aged women was found to improve mood and cognitive functions [57]. Therefore, as with iodine, it is worth ensuring an adequate supply of iron in one's diet or, in the event of a deficiency, implementing iron supplementation due to the work requirements of e-athletes, which include high concentration, good memory, fast reaction time, and ease of visual-spatial processing. These features are particularly important in multiplayer online battlefield arena games (including LOL, DOTA2) [10,11,14,205,206] and first-person shooters (Overwatch, Counter Strike, Global Offensive CS: GO) [11,14,205,207].

Zinc is a mineral essential for neurogenesis in the brain [76] and is important in the context of learning and memory, as well as emotional and mood control [75]. Zinc supplementation in adults improves spatial working memory [32]. As emphasized by Kowal et al., memory, attention control, and inhibitory skills are particularly important in multiplayer online battlefield arena games and first-person shooters [11]. Hence, it is important to supply zinc within one's diet in order to cover the daily requirements for this ingredient. In the event of a deficiency, zinc supplementation may be beneficial in improving executive functions and motor development [38], which are also used in multiplayer online battlefield arena games and first-person shooters [11,206].

Esports athletes are a group of players with a high mental load, accompanied by various emotional experiences [208]. The characteristics of esports indicate that the mental condition of players may deteriorate, leading to depression and burnout symptoms, along with deterioration in the psychosocial sphere due to social anxiety, sleep disorders, and problems with personal hygiene [16]. The results of the present research indicate that magnesium deficiency may contribute to weakening of the body, manifested, e.g., by dizziness, fatigue, lethargy, lightheadedness, and loss of appetite [83,84]. Additionally,

magnesium deficiency may lead to the formation of oxidative stress, thereby increasing the risk of depression, as well as problems with concentration, working memory, and attention, which are required for gaming [61,82]. Therefore, it is worth ensuring an adequate supply of magnesium in the diets of e-athletes to prevent the negative effects of a deficiency of this element.

#### 4.2. The Potential Role of Vitamins in Esports

B vitamins are essential for the proper functioning of the nervous system and the brain, including energy production, DNA and RNA synthesis and repair, genomic and non-genomic methylation, and the synthesis of numerous neurotransmitters and signaling molecules [85]. Nutritional deficiencies in micronutrients such as vitamin B12, folate, and zinc can cause symptoms of depression and dementia, including depressed mood, fatigue, cognitive decline, and irritability [76,107]. The supply of B vitamins within one's diet, which can cover the demand for these ingredients, has a positive effect on cognitive functions in children and adolescents [95,96]. Moreover, a lower level of vitamin B12 was correlated with deterioration in academic performance and mental and social development, as well as weaker short-term memory and attention in older children or adolescents [97]. Moreover, a properly balanced diet rich in B vitamins may contribute to an improvement in cognitive functions at a later age [94]. The importance of B vitamins in one's diet should also be emphasized in e-athletes, which represent a group that needs particular support for cognitive functions and proper functioning of the nervous system.

Vitamin E has antioxidant activities [108] that exert a positive influence on cognitive functions [209,210]. Thus, the diets of e-athletes should be rich in vitamin E due to stress, which is a common factor among athletes. Research results indicate that low vitamin E concentrations in the elderly reduce memory performance [109], but another study did not show a significant effect of vitamin E on the cognitive functions of middle-aged and elderly people [99]. There remains a lack of studies that assess the cognitive abilities of healthy young and middle-aged people.

Vitamin D has many important functions in the body, including the modulation of cell growth, neurogenesis, neuroprotection, detoxification, immune function, and reduction in inflammation [110]. Because supplying vitamin D within one's diet is difficult, and skin synthesis as a result of contact with UV radiation requires special conditions (appropriate clothing enabling skin synthesis, no sunscreen on the skin, and the right time depending on latitude and season) [211], e-athletes are recommended to engage in vitamin D supplementation. Elevated serum vitamin D levels are important for executive functions, such as non-verbal memory [35]. The supplementation and optimal concentration of vitamin D in blood serum may, but does not have to, positively influence cognitive functions, and current scientific reports are contradictory [102–104]. However, due to the functions of vitamin D in the body, maintaining an appropriate vitamin D level is necessary for the proper development and functioning of the body. Vitamin D supplementation is especially important for improving mental health. The research results indicate that these components have a beneficial effect on the mental health of healthy people, and meta-analyses confirm the effectiveness of supplementation in reducing depression symptoms [211–214] and relieving negative emotions [215]. Due to the high mental burden of esports players, vitamin D supplementation seems to be necessary [199].

Vitamin C is an essential component for the functioning of the nervous system due to its modulation of neurotransmitter receptors, brain cell structures, and the synthesis of glial cells and myelin [114,115]. Due to the antioxidant effects of vitamin C and the positive effects of antioxidant components on cognitive functions, the diets of e-athletes should be rich in vitamin C due to stress, which is a factor that often occurs in athletes.

#### 4.3. The Potential Role of Dietary Supplements in Esports

Due to the well-documented effect of caffeine in sport, especially in the context of reducing fatigue [120], and improving cognitive functions, such as alertness, concentration,



attention, and reaction time [118,120], as well as cognitive performance, motor skills, and physical fitness [117], this supplement is recommended by nutritionists and coaches and used by athletes in esports. To date, two studies on caffeine have been conducted in esports, one involving nine players and the other involving fifteen players [20,152].

Thomas et al. conducted a randomized, double-blind, placebo-controlled, crossover study of nine elite League of Legends players to investigate the cognitive and physical changes associated with consuming an energy drink. The main outcomes included measures of attention, reaction time, and working memory, while the secondary outcomes were based on fatigue. On the basis of the obtained results, it can be concluded that elite esports athletes did not show mental or physical improvement in their results due to the introduced supplementation [20].

Sainz et al. also conducted a study to determine the effects of caffeine on esports performance. A double-blind, cross-randomized, experimental trial was conducted on fifteen professional e-athletes. The aim of this study was to determine the effects of caffeine consumption at a dose of 3 mg/kg b.w. by measuring the simple reaction time during the color test and the hit accuracy and reaction time while playing a first-person shooter. Caffeine consumption at a dose of 3 mg/kg b.w. also improved the accuracy of hitting the target in a first-person shooter among professional e-players [152]. There remains a need for randomized controlled trials with larger study groups. In addition to requiring strong reaction times, esports demands that players be particularly focused, concentrated, and vigilant, necessitating the implementation of all possible measures to improve these skills. Caffeine appears to be a supplement with potentially beneficial effects in esports, and its use may be particularly significant in multiplayer online battlefield arena games and first-person shooters [11,206].

L-Theanine has a positive effect on cognitive functions. When combined with caffeine, L-theanine can improve reaction time, working memory, and the accuracy of task verification [121]; L-theanine also has beneficial effects on concentration, emotional state [122], and attention and can suppress distraction [123]. The combination of a low dose of caffeine with L-theanine and tyrosine may improve athletes' accuracy of movement and reaction time during strenuous exercise [125]. Due to the aforementioned factors, the use of L-theanine in esports may be a legitimate practice that brings benefits to the player. Training in esports requires attention, memory and focus, accuracy of movement, and quick reaction times from the player. Therefore, it is worth considering L-theanine supplementation, preferably in combination with caffeine, especially for e-athletes who play in multiplayer online battlefield arena games (including LOL, DOTA2) [10,11,14,205,206] and first-person shooters (Overwatch, Counter Strike, Global Offensive CS: GO) [11,14,205,207].

To maintain proper cognitive functions at a high level, one's diet should be rich in antioxidant ingredients, specifically polyphenols, which have positive effects on cognition and memory and reduce neuronal damage [162–164]. The dietary intake of polyphenols can improve visual processing speed, alertness, working memory, and executive functions [128]. Polyphenols should thus be taken into account by e-athletes when planning their diets due to their stressful lifestyles caused by competition. Additionally, polyphenols seem to improve accuracy and speed of attention, which are especially important in both multiplayer online battlefield arena games (including LOL, DOTA2) [10,11,14,205,206] and first-person shooters (Overwatch, Counter Strike, Global Offensive CS: GO) [11,14,205,207].

Cocoa flavanols may also improve cognitive functions, including episodic verbal memory [114]. Due to the positive effect of flavanols on cognitive functions, it is worth introducing products with a high cocoa content into the diets of e-athletes. The addition of flavanols to the diets of e-athletes could be used in multiplayer online battlefield arena games (including LOL, DOTA2) and first-person shooters (Overwatch, Counter Strike, Global Offensive CS: GO) due to the need to develop working memory [11]. Playing for a few hours in front of a computer screen may cause fatigue and sleep disturbances. Screen light can influence the natural circadian rhythm, and this in turn can also influence sleep behavior [216]. The possible impairment of e-athletes' attention due to the above



aspects could potentially be compensated by supplying of cocoa flavanols within athletes' diets [130].

Beet juice may also have positive effects on cognition and reaction time during prolonged repetitive exercise [132]. The player's reaction time is particularly important in multiplayer online battlefield arena games (including LOL, DOTA2) [11] and first-person shooters (Overwatch, Counter Strike, Global Offensive CS: GO) [11,14,207]. Therefore, e-athletes should include beetroot juice in their diets to improve cognitive function and reaction time, especially during prolonged training sessions and tournaments.

Creatine supplementation reduces mental fatigue; improves IQ scores; improves working memory performance [135,137] and reaction speed [137]; and affects the state of mood. The use of creatine is recommended in stressful situations, as well as when one's amount of sleep is limited, due to creatine's compensatory effects on the cognitive effects of sleep deprivation [138,142–144]. The use of creatine supplementation among vegetarians resulted in better memory compared with results in the group consuming meat [140]. The described features are important in esports, especially in multiplayer online battlefield arena games (including LOL, DOTA2) [10,11,14,205,206] and first-person shooters (Overwatch, Counter Strike, Global Offensive CS: GO) [11,14,205,207]. Due to the potential sleep disorders and deficiencies among esports players, in addition to their stressful lifestyles, it is worth considering the use of creatine in esports.

Esports athletes are exposed to mental deterioration, which is associated with the high stress resulting from the competitiveness of esports. Such athletes also face increased social attention and pressure at competitions [217,218]. Thus, the use of probiotic therapy would be beneficial to reduce the negative effects of stress on the structure of the microbiota [149], which, thanks to its immunomodulatory properties, affects the functions of the brain [189]. The use of multi-strain probiotic therapy can modulate functional activity in areas of the brain related to cognitive processes such as problem solving, reasoning, attention, decision-making, learning, and creativity [145]. These features are especially important in multiplayer online battlefield arena games (including LOL, DOTA2) [10,11,14,205,206] and first-person shooters (Overwatch, Counter Strike, Global Offensive CS: GO) [11,14,205,207].

Lutein, due to its anti-inflammatory functions and beneficial effect on eyesight [151], may be a useful ingredient in the diet of e-athletes who spend many hours in front of computer screens [16]. In a study conducted by Ma et al., eyesight improved in healthy people who supplemented with lutein. In particular, the sensitivity to contrast was improved, which may mean that a higher supply of lutein may have a positive effect on visual efficiency [153] (Table 3). Supplements that should be considered in the diet of e-athletes include nootropic substances. Their mechanism contributes to the strengthening of mental functions such as memory, creativity, motivation, attention [196], concentration, and speed [197], which are important from the point of view of esports. The competitive nature of esports causes players to be guided by the choice of various nootropics or drugs that improve cognitive abilities in order to gain an advantage [20]. The safest here seem to be herbal medicines available in the form of dietary supplements, which contain vitamins, minerals, fatty acids, and other ingredients. According to research, herbs that show a procognitive effect are, among others: *Ginkgo biloba*, *Siberian ginseng*, *Rhodiola rosea*, *Brahmi rasayana*, *Mucuna pruriens*, Royal Jelly, caffeine, and curcumin [197].

In cooperation with e-athletes, it is worth relying on dietary ingredients and supplements that have documented effects in the scientific literature. These supplements include lutein, caffeine, creatine, beetroot juice, and probiotics. In addition to the listed ingredients, there is a need for vitamin D supplementation, especially under limited access to sunlight, as it is impossible to meet the demand for this ingredient within one's daily diet. Every effort should be made to ensure that the dietary supply of minerals and vitamins does not lead to deficiencies, and the level of ingredients that may be deficient (due to illness, diet, or lifestyle) should be regularly controlled through appropriate tests in order to introduce appropriate supplementation.

#### 4.4. Health Behaviors as an Essential Part of Esports Lifestyle

Spending a long period of time sitting position in front of a TV or computer screen may be associated with weight gain and the development of obesity, especially abdominal obesity [219–221]. The development of abdominal obesity among those who play video games is particularly worrying due to the associated increased risk of cardiovascular diseases [221–223]. The results of studies conducted on the participation of e-athletes indicate that the majority of players either have adequate body weight or are overweight [4,9]. Among the studied esports athletes, there was also a group of people with type 2 and 3 obesity, which suggests that it is necessary to develop appropriate recommendations to facilitate weight reduction, as well as a permanent change in eating habits among this group of players [9]. To counteract the development of overweight and obesity among esports players, nutritional education should be utilized, thereby promoting healthy eating habits and the consumption of balanced meals.

#### 4.5. Diet and Nutritional Habits

Proper nutrition is a key factor influencing physical performance [38] and improving mental health. Inadequate diet can lead to an increased risk of obesity [224] and the development of other disorders such as diabetes, cardiovascular diseases, or hypertension [225]. Scientific reports increasingly suggest that health-promoting behaviors such as physical activity, eating a Mediterranean-style diet, and cognitive training protect cognitive functions [226–228]. The Mediterranean diet is suggested to have a positive effect on cognitive functions and episodic memory and is associated with a lower risk of cognitive disorders and neurodegenerative diseases [38]. There is, moreover, a relationship between the consumption of vegetables and fruits and an improvement in cognitive functions, especially memory, resulting from the ingredients with antioxidant properties contained in those foods [229]. On the other hand, the influence of the Western diet, which is rich in saturated fatty acids, sugar, and proteins, contributes to the development of diet-dependent diseases such as type 2 diabetes, obesity, dementia, and depression. The Western diet also impairs cognitive abilities. Following the guidelines of the Mediterranean diet thus seems to be an important element of care for the health of e-athletes who seek to improve their cognitive functions. A well-rounded diet includes balanced meals that provide essential nutrients such as proteins, fats, and carbohydrates [38].

An important practice that should be implemented by e-athletes is eating breakfast. Skipping breakfast may lead to a shortened reaction time and short-term memory, in addition to weakening executive functions due to inadequate blood glucose levels [230–232]. Every day, e-athletes should also pay attention to adequate hydration, which significantly affects cognitive functions. Dehydration in a situation where water loss exceeds 2% of one's body weight worsens cognitive performance, attention, executive functions, and coordination [38,233]. Previous studies confirmed that e-athletes eagerly use stimulants such as energy drinks to improve their performance.

The studies conducted so far show that there is no relationship between the consumption of energy drinks and significant improvements in performance [20]. Alcohol is consumed most often by those with a low level of play [234].

#### 4.6. Sleep

The quality and duration of sleep also significantly affect the regeneration of athletes. These factors also have an impact on the brain's performance and ability to cope with immune, emotional, neurological, and psychological factors [38]. Sleep is thus a significant factor that can affect mental health and performance in esports. Scientific research confirms that sleep deprivation negatively affects various cognitive functions and mood [235], thus reducing the chance of victory [236]. E-athletes are particularly vulnerable to lack of sleep due to their many hours of training, high consumption of caffeinated drinks, travel (and the related changes in time zones), and the competitive nature of the discipline [235]. As light-emitting devices are the primary tools in esports, there is an increased risk of sleep



disturbances among e-athletes compared with traditional athletes. Existing studies on the general population suggest that the use of electronic devices in the evening hours may cause disturbances in melatonin secretion and thus impair sleep quality and performance during the day [237].

#### 4.7. Physical Activity

Physical activity can contribute to meeting the physical requirements of esports. A previous study found that physical exercise can help improve long-term memory, learning, and the ability to acquire motor skills even in the case of extreme effort. Moreover, the effect of exercise is related to an improvement in neural performance in the prefrontal cortex and promotes neurogenesis and plasticity of the brain. The available evidence suggests that physical activity among young people can support cognitive functions and provide such individuals with a competitive advantage, especially in a professional esports career [23]. A study by Trotter et al. indicates that the highest performing e-athletes are also more physically active, with the top 10% of players being significantly more physically active than the bottom 90% of players [9]. Additionally, regular physical activity can be an effective remedy in the treatment of symptoms of depression and stress-induced disorders [238].

#### 4.8. Research Limitations

One limitation of the study is that this review is not a systematic review. Considering the currently available literature related to nutrition, there is a need for randomized controlled trials with esports players. Along with the development of scientific research in this area, which may lead to studying the effects of dietary ingredients and supplements on the cognitive abilities of e-athletes, it is worth preparing statistical reviews and meta-analyses.

### 5. Conclusions

1. Micronutrients are important to optimize cognitive performance and prevent brain disease. A deficit in micronutrients may impair cognitive functions, which are important at every stage of life.
2. Providing vitamin D within one's diet is problematic, and skin synthesis as a result of UV radiation requires one to meet many restrictive conditions. Thus, supplementation is important to prevent deficiencies and take care of the mental health of e-athletes.
3. Caffeine is a supplement with potentially beneficial effects in esports due to its documented abilities to reduce fatigue and improve cognitive functions such as alertness, concentration, attention, reaction time, cognitive performance, motor skills, and physical fitness.
4. L-Theanine in combination with caffeine can positively impact features such as reaction time, working memory, attention, concentration, and emotional state among e-athletes.
5. The dietary intake of polyphenols can improve alertness, accuracy, speed of visual attention, working memory, and executive functions. Thus, supplementation with polyphenols should be considered by e-athletes due to the stressful and competitive lifestyle of esports.
6. The possible distraction of an e-athlete related to long-term exposure to blue light from the computer screen and the resulting fatigue, disturbances in circadian rhythm, and sleep could potentially be compensated for by supplying cocoa flavanols and creatine within one's diet. For the sake of players' eyesight, it would be useful to also use lutein, which, in addition to improving vision and protecting against eye diseases, can also affect cognitive functions.
7. Drinking beetroot juice can potentially improve cognitive performance when performing tasks.
8. Creatine supplementation can affect mood; reduce mental fatigue; and improve intelligence test results, working memory performance, and reaction speed. Thus, creatine could also be potentially used by e-athletes.

9. The use of probiotics seems to support cognitive functions due to the reduction in stress, which negatively affects working memory.
10. There are many supplements (L-theanine, polyphenols, beetroot juice) and plant ingredients (ginseng, mint, *Ginkgo biloba*, *Bacopa monnieri*, lion's mane, *Rhodiola rosea*, guarana, rosemary, saffron, turmeric, ashwagandha, xanthines) that require further research regarding their effects on cognitive functions.
11. There is a lack of well-designed studies that have investigated the relationship between dietary effects and improved performance in esports. The information presented in this review could, in the future, be used to create specific esports nutritional recommendations that are currently lacking. Therefore, there is a need for randomized controlled trials with esports players.
12. To be successful, esports players need to be in top form, which requires cognitive, physical, and mental support. The most important factor for supporting the abilities of esports players is a rational and proper diet with adequate hydration.

**Author Contributions:** Conceptualization, B.F.; contributed to the design of the review, B.F. and M.S.; investigation, M.S. and E.K.-G.; performed the literature search, M.S., E.K.-G. and R.D.; contributed to the writing (review and editing), M.S., E.K.-G. and B.F. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

## References

1. Munoz, P.; Humeres, A. Iron deficiency on neuronal function. *Biometals* **2012**, *25*, 825–835. [CrossRef] [PubMed]
2. Lewis, J.E.; Poles, J.; Shaw, D.P.; Karhu, E.; Khan, S.A.; Lyons, A.E.; Sacco, S.B.; McDaniel, H.R. The effects of twenty-one nutrients and phytonutrients on cognitive function: A narrative review. *J. Clin. Transl. Res.* **2021**, *7*, 575–620.
3. Huskisson, E.; Maggini, S.; Ruf, M. The role of vitamins and minerals in energy metabolism and well-being. *J. Int. Med. Res.* **2007**, *35*, 277–289. [CrossRef]
4. Pedraza-Ramirez, I.; Musculus, L.; Raab, M.; Laborde, S. Setting the scientific stage for esports psychology: A systematic review. *Int. Rev. Sport Exerc. Psychol.* **2020**, *13*, 1–34. [CrossRef]
5. Rudolf, K.; Bickmann, P.; Froböse, I.; Tholl, C.; Wechsler, K.; Grieben, C. Demographics and Health Behavior of Video Game and eSports Players in Germany: The eSports Study 2019. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1870. [CrossRef]
6. Available online: <https://newzoo.com/key-numbers> (accessed on 25 March 2020).
7. Nagorsky, E.; Wiemeyer, J. The structure of performance and training in esports. *PLoS ONE* **2020**, *15*, e0237584. [CrossRef]
8. Rogstad, E.T. Gender in eSports research: A literature review. *Eur. J. Sport Soc.* **2021**, 1–19. [CrossRef]
9. Hallmann, K.; Giel, T. eSports—Competitive sports or recreational activity? *Sport Manag. Rev.* **2018**, *21*, 14–20. [CrossRef]
10. Trotter, M.G.; Coulter, T.J.; Davis, P.A.; Poulus, D.R.; Polman, R. The Association between Esports Participation, Health and Physical Activity Behaviour. *Int. J. Environ. Res. Public Health* **2020**, *17*, 7329. [CrossRef] [PubMed]
11. Johnson, M.R.; Woodcock, J. Work, play, and precariousness: An overview of the labour ecosystem of esports. *Media Cult. Soc.* **2021**, *43*, 1–17. [CrossRef]
12. Kowal, M.; Toth, A.J.; Exton, C.; Campbell, M.J. Different cognitive abilities displayed by action video gamers and non-gamers. *Comput. Hum. Behav.* **2018**, *88*, 255–262. [CrossRef]
13. Ferrari, S. eSport and the Human Body: Foundations for a popular aesthetics. In Proceedings of the DiGRA Conference, Atlanta, GA, USA, 26–29 August 2013.
14. Hilvoorde, I.V.; Pot, N. Embodiment and fundamental motor skills in eSports. *Sport Ethics Philos.* **2016**, *10*, 14–27. [CrossRef]
15. Sousa, A.; Ahmad, S.L.; Hassan, T.; Yuen, K.; Douris, P.; Zwibel, H.; DiFrancisco-Donoghue, J. Physiological and Cognitive Functions Following a Discrete Session of Competitive Esports Gaming. *Front. Psychol.* **2020**, *11*, 1030. [CrossRef] [PubMed]
16. Pluss, M.A.; Bennett, K.J.M.; Novak, A.R.; Panchuk, D.; Coutts, A.J.; Franssen, J. Esports: The Chess of the 21st Century. *Front. Psychol.* **2019**, *10*, 156. [CrossRef] [PubMed]
17. Martin-Niedecken, A.L.; Schättin, A. Let the Body'n'Brain Games Begin: Toward Innovative Training Approaches in eSports Athletes. *Front. Psychol.* **2020**, *11*, 138. [CrossRef] [PubMed]



18. Chung, T.; Sum, S.; Chan, M.; Lai, E.; Cheng, N. Will esports result in a higher prevalence of problematic gaming? A review of the global situation. *J. Behav. Addict.* **2019**, *8*, 384–394. [\[CrossRef\]](#) [\[PubMed\]](#)
19. Yin, K.; Zi, Y.; Zhuang, W.; Gao, Y.; Tong, Y.; Song, L.; Liu, Y. Linking Esports to health risks and benefits: Current knowledge and future research needs. *Sport Health Sci.* **2020**, *9*, 485–488. [\[CrossRef\]](#) [\[PubMed\]](#)
20. Garcia-Lanzo, S.; Bonilla, I.; Chamarro, A. The psychological aspects of electronic sports: Tips for sports psychologists. *Int. J. Sport Psychol.* **2020**, *51*, 613–625.
21. Thomas, C.J.; Rothschild, J.; Earnest, C.P.; Blaisdell, A. The Effects of Energy Drink Consumption on Cognitive and Physical Performance in Elite League of Legends Players. *Sports* **2019**, *7*, 196. [\[CrossRef\]](#)
22. Meeusen, R.; Decroix, L. Nutritional Supplements and the Brain. *Int. J. Sport Nutr. Exerc. Metab.* **2018**, *28*, 200–211. [\[CrossRef\]](#)
23. Tartar, J.L.; Kalman, D.; Hewlings, S. A Prospective Study Evaluating the Effects of a Nutritional Supplement Intervention on Cognition, Mood States, and Mental Performance in Video Gamers. *Nutrients* **2019**, *11*, 2326. [\[CrossRef\]](#)
24. Toth, A.J.; Ramsbottom, N.; Kowal, M.; Campbell, M.J. Converging Evidence Supporting the Cognitive Link between Exercise and Esport Performance: A Dual Systematic Review. *Brain Sci.* **2020**, *10*, 859. [\[CrossRef\]](#) [\[PubMed\]](#)
25. Chiu, C.C.; Su, K.P.; Cheng, T.C.; Liu, H.C.; Chang, C.J.; Dewey, M.E.; Stewart, R.; Huang, S.Y. The Effects of Omega-3 Fatty Acids Monotherapy in Alzheimer's Disease and Mild Cognitive Impairment: A Preliminary Randomized Double-blind Placebo-controlled Study. *Prog. Neuropsychopharmacol. Biol. Psychiatry* **2008**, *32*, 1538–1544. [\[CrossRef\]](#) [\[PubMed\]](#)
26. Morgan, A.; Stevens, J. Does *Bacopa monnieri* Improve Memory Performance in Older Persons? Results of a Randomized, Placebo-controlled, Double-blind Trial. *J. Altern. Complement. Med.* **2010**, *16*, 753–759. [\[CrossRef\]](#)
27. De Jager, C.A.; Oulhaj, A.; Jacoby, R.; Refsum, H.; Smith, A.D. Cognitive and Clinical Outcomes of Homocysteine-lowering B-Vitamin Treatment in Mild Cognitive Impairment: A Randomized Controlled Trial. *Int. J. Geriatr. Psychiatry.* **2012**, *27*, 592–600. [\[CrossRef\]](#)
28. Dysken, M.W.; Sano, M.; Asthana, S.; Vertrees, J.E.; Pallaki, M.; Llorente, M.; Love, S.; Schellenberg, G.D.; McCarten, J.R.; Malphurs, J.; et al. Effect of Vitamin E and Memantine on Functional Decline in Alzheimer Disease: The Team-ad VA Cooperative Randomized Trial. *JAMA* **2014**, *311*, 33–44. [\[CrossRef\]](#)
29. Attia, A.; Rapp, S.R.; Case, L.D.; D'Agostino, R.; Lesser, G.; Naughton, M.; McMullen, K.; Rosdhal, R.; Shaw, E.G. Phase II Study of *Ginkgo biloba* in Irradiated Brain Tumor Patients: Effect on Cognitive Function, Quality of Life, and Mood. *J. Neurooncol.* **2012**, *109*, 357–363. [\[CrossRef\]](#)
30. Chen, E.Y.; Hui, C.L. Ht1001, a Proprietary North American Ginseng Extract, Improves Working Memory in Schizophrenia: A Double-blind, Placebo-controlled Study. *Phytother. Res.* **2012**, *26*, 1166–1172. [\[CrossRef\]](#)
31. Darwish, H.; Haddad, R.; Osman, S.; Ghassan, S.; Yamout, B.; Tamim, H.; Khoury, S. Effect of Vitamin D Replacement on Cognition in Multiple Sclerosis Patients. *Sci. Rep.* **2017**, *7*, 45926. [\[CrossRef\]](#)
32. Hu, J.; Jia, J.; Zhang, Y.; Miao, R.; Huo, X.; Ma, F. Effects of Vitamin D3 Supplementation on Cognition and Blood Lipids: A 12-Month Randomised, Double-Blind, Placebo-controlled Trial. *J. Neurol. Neurosurg. Psychiatry* **2018**, *89*, 1341–1347. [\[CrossRef\]](#) [\[PubMed\]](#)
33. Maylor, E.A.; Simpson, E.E.; Secker, D.L.; Meunier, N.; Andriollo-Sanchez, M.; Polito, A.; Stewart-Knox, B.; McConville, C.; O'Connor, J.M.; Coudray, C. Effects of Zinc Supplementation on Cognitive Function in Healthy Middle-aged and Older Adults: The Zenith Study. *Br. J. Nutr.* **2006**, *96*, 752–760. [\[PubMed\]](#)
34. Lewis, J.E.; Melillo, A.B.; Tiozzo, E.; Chen, L.; Leonard, S.; Howell, M.; Diaz, J.; Gonzalez, K.; Woolger, J.M.; Konefal, J.; et al. A Double-blind, Randomized Clinical Trial of Dietary Supplementation on Cognitive and Immune Functioning in Healthy Older Adults. *BMC Complement. Altern. Med.* **2014**, *14*, 43. [\[CrossRef\]](#)
35. Kumar, N.; Abichandani, L.G.; Thawani, V.; Gharpure, K.J.; Naidu, M.U.; Venkat Ramana, G. Efficacy of Standardized Extract of *Bacopa monnieri* (Bacognize(r)) on Cognitive Functions of Medical Students: A Six-week, Randomized Placebo-controlled Trial. *Evid. Based Complement. Alternat. Med.* **2016**, *2016*, 4103423. [\[CrossRef\]](#) [\[PubMed\]](#)
36. Pettersen, J.A. Does high dose vitamin D supplementation enhance cognition?: A randomized trial in healthy adults. *Exp. Gerontol.* **2017**, *90*, 90–97. [\[CrossRef\]](#) [\[PubMed\]](#)
37. Mariage, P.A.; Hovhannisyann, A.; Panossian, A.G. Efficacy of *Panax ginseng* Meyer Herbal Preparation hrg80 in Preventing and Mitigating Stress-induced Failure of Cognitive Functions in Healthy Subjects: A Pilot, Randomized, Double-blind, Placebo-controlled Crossover Trial. *Pharmaceuticals* **2020**, *13*, 57. [\[CrossRef\]](#)
38. Aslanyan, G.; Amroyan, E.; Gabrielyan, E.; Nylander, M.; Wikman, G.; Panossian, A. Double-blind, Placebo-controlled, Randomised Study of Single Dose Effects of Adapt-232 on Cognitive Functions. *Phytomedicine* **2010**, *17*, 494–499. [\[CrossRef\]](#)
39. Karpecka, E.; Frączek, B. Macronutrients and water—do they matter in the context of cognitive performance in athletes? *Balt. J. Health Phys. Act.* **2020**, *12*, 114–124. [\[CrossRef\]](#)
40. Kraemer, K.; Zimmermann, M.B. *Nutritional Anemia*; Sign Life Press: Basel, Switzerland, 2007.
41. Anderson, M.; de Benoist, B.; Darnton-Hill, I.; Delange, F. *Iodine Deficiency in Europe: A Continuing Public Health Problem*; WHO Press: Geneva, Switzerland, 2007.
42. Chung, H.R. Iodine and thyroid function. *Ann. Pediatr. Endocrinol. Metab.* **2014**, *19*, 8–12. [\[CrossRef\]](#)
43. Smyth, P. Iodine, Seaweed, and the Thyroid. *Eur. Thyroid J.* **2021**, *10*, 101–108. [\[CrossRef\]](#)
44. Yehuda, S.; Rabinovitz, S.; Mostofsky, D.I. Nutritional deficiencies in learning and cognition. *J. Pediatr. Gastroenterol. Nutr.* **2006**, *43*, 22–25. [\[CrossRef\]](#)

45. Zimmermann, M.B. The adverse effects of mild-to-moderate iodine deficiency during pregnancy and childhood: A review. *Thyroid* **2007**, *17*, 829–835. [\[CrossRef\]](#)
46. Bryan, J.; Osendarp, S.; Hughes, D.; Calvaresi, E.; Baghurst, K.; van Klinken, J.W. Nutrients for cognitive development in school-aged children. *Nutr. Rev.* **2004**, *62*, 295–306. [\[CrossRef\]](#) [\[PubMed\]](#)
47. Black, M.M. The evidence linking zinc deficiency with children's cognitive and motor functioning. *J. Nutr.* **2003**, *133*, 1473–1476. [\[CrossRef\]](#) [\[PubMed\]](#)
48. Vermiglio, F.; Lo Presti, V.P.; Moleti, M.; Sidoti, M.; Tortorella, G.; Scaffidi, G.; Trimarchi, F. Attention deficit and hyperactivity disorders in the offspring of mothers exposed to mild-moderate iodine deficiency: A possible novel iodine deficiency disorder in developed countries. *J. Clin. Endocrinol. Metab.* **2004**, *89*, 6054–6060. [\[CrossRef\]](#) [\[PubMed\]](#)
49. Redman, K.; Ruffman, T.; Fitzgerald, P.; Skeaff, S. Iodine Deficiency and the Brain: Effects and Mechanisms. *Crit. Rev. Food Sci. Nutr.* **2016**, *56*, 2695–2713. [\[CrossRef\]](#) [\[PubMed\]](#)
50. Santiago-Fernandez, P.; Torres-Barahona, R.; Muela-Martínez, A.; Rojo-Martínez, G.; García-Fuentes, E.; Garriga, M.J.; León, G.; Soriguer, F. Intelligence quotient and iodine intake: A cross-sectional study in children. *J. Clin. Endocrinol. Metab.* **2004**, *89*, 3851–3857. [\[CrossRef\]](#)
51. Zimmermann, M.B.; Connolly, K.; Bozo, M.; Bridon, J.; Rohner, F.; Grimci, L. Iodine supplementation improves cognition in iodine-deficient schoolchildren in Albania: A randomized, controlled, double-blind study. *Am. J. Clin. Nutr.* **2006**, *83*, 108–114. [\[CrossRef\]](#) [\[PubMed\]](#)
52. Gordon, R.C.; Rose, M.C.; Skeaff, S.A.; Gray, A.R.; Morgan, K.; Ruffman, T. Iodine supplementation improves cognition in mildly iodine-deficient children. *Am. J. Clin. Nutr.* **2009**, *90*, 1264–1271. [\[CrossRef\]](#) [\[PubMed\]](#)
53. Lozoff, B. Early iron deficiency has brain and behavior effects consistent with dopaminergic dysfunction. *J. Nutr.* **2011**, *141*, 740–746. [\[CrossRef\]](#)
54. Carpenter, K.L.; Li, W.; Wei, H.; Wu, B.; Xiao, X.; Liu, C.; Worley, G.; Egger, H.L. Magnetic susceptibility of brain iron is associated with childhood spatial IQ. *NeuroImage* **2016**, *132*, 167–174. [\[CrossRef\]](#) [\[PubMed\]](#)
55. Jáuregui-Lobera, I. Iron deficiency and cognitive functions. *Neuropsychiatr. Dis. Treat.* **2014**, *10*, 2087–2095. [\[CrossRef\]](#)
56. Low, M.; Farrell, A.; Biggs, B.A.; Pasricha, S.R. Effects of daily iron supplementation in primary-school-aged children: Systematic review and meta-analysis of randomized controlled trials. *CMAJ* **2013**, *185*, 791–802. [\[CrossRef\]](#)
57. Scott, S.P.; Murray-Kolb, L.E.; Wenger, M.J.; Udipi, S.A.; Ghugre, P.S.; Boy, E.; Haas, J.D. Cognitive Performance in Indian School-Going Adolescents Is Positively Affected by Consumption of Iron-Biofortified Pearl Millet: A 6-Month Randomized Controlled Efficacy Trial. *J. Nutr.* **2018**, *148*, 1462–1471. [\[CrossRef\]](#)
58. Lomagno, K.A.; Hu, F.; Riddell, L.J.; Booth, A.O.; Szymlek-Gay, E.A.; Nowson, C.A.; Byrne, L.K. Increasing iron and zinc in pre-menopausal women and its effects on mood and cognition: A systematic review. *Nutrients* **2014**, *6*, 5117–5141. [\[CrossRef\]](#)
59. Ji, X.; Cui, N.; Liu, J. Neurocognitive Function Is Associated With Serum Iron Status in Early Adolescents. *Biol. Res. Nurs.* **2017**, *19*, 269–277. [\[CrossRef\]](#)
60. Spence, H.; McNeil, C.J.; Waiter, G.D. The impact of brain iron accumulation on cognition: A systematic review. *PLoS ONE* **2020**, *15*, e240697. [\[CrossRef\]](#) [\[PubMed\]](#)
61. Warthon-Medina, M.; Moran, V.H.; Stammers, A.L.; Dillon, S.; Qualter, P.; Nissensohn, M.; Serra-Majem, L.; Lowe, N.M. Zinc intake, status and indices of cognitive function in adults and children: A systematic review and meta-analysis. *Eur. J. Clin. Nutr.* **2015**, *69*, 649–661. [\[CrossRef\]](#) [\[PubMed\]](#)
62. Botturi, A.; Ciappolino, V.; Delvecchio, G.; Boscutti, A.; Viscardi, B.; Brambilla, P. The Role and the Effect of Magnesium in Mental Disorders: A Systematic Review. *Nutrients* **2020**, *12*, 1661. [\[CrossRef\]](#) [\[PubMed\]](#)
63. Andersen, G.W. Thyroid hormones and the brain. *Front. Neuroendocr.* **2001**, *22*, 1–17. [\[CrossRef\]](#) [\[PubMed\]](#)
64. Bono, G.; Fancelli, R.; Blandini, F.; Santoro, G.; Mauri, M. Cognitive and affective status in mild hypothyroidism and interactions with L-thyroxine treatment. *Acta Neurol. Scand.* **2004**, *110*, 59–66. [\[CrossRef\]](#)
65. Prinz, P.N.; Scanlan, J.M.; Vitaliano, P.P.; Moe, K.E.; Borson, S.; Toivola, B.; Merriam, G.R.; Larsen, L.H.; Reed, H.L. Thyroid hormones: Positive relationships with cognition in healthy, euthyroid older men. *J. Gerontol. Biol. Sci. Med. Sci.* **1999**, *54*, 111–116. [\[CrossRef\]](#)
66. Guidance on the Monitoring of Salt Iodization Programmes and Determination of Population Iodine Status: Russian language version. *Clin. Exp. Thyroidol.* **2018**, *14*, 100–112. [\[CrossRef\]](#)
67. Zimmermann, M.B.; Andersson, M. Assessment of iodine nutrition in populations: Past, present, and future. *Nutr. Rev.* **2012**, *70*, 553–570. [\[CrossRef\]](#) [\[PubMed\]](#)
68. Akram, M.; Munir, N.; Daniyal, M.; Egbuna, C.; Găman, M.-A. Vitamins and minerals: Types, sources and their functions. In *Functional Foods and Nutraceuticals*; Springer: Cham, Switzerland, 2020; pp. 149–172.
69. Gozzelino, R.; Arosio, P. The importance of iron in pathophysiologic conditions. *Front. Pharmacol.* **2015**, *6*, 26. [\[CrossRef\]](#) [\[PubMed\]](#)
70. Kaczorowska-Hań, B.; Łuszczek, M.; Antosiewicz, J.; Kaczor, J.J. Iron metabolism and hepcidin concentration in teenagers before and after exercise in relation to the HFE gene status. *Balt. J. Health Phys. Act.* **2019**, *1*, 26–35. [\[CrossRef\]](#)
71. Tamura, T.; Goldenberg, R.L.; Hou, J.; Johnston, K.E.; Cliver, S.P.; Ramey, S.L.; Nelson, K.G. Cord serum ferritin concentrations and mental and psychomotor development of children at five years of age. *J. Pediatr.* **2002**, *140*, 165–170. [\[CrossRef\]](#) [\[PubMed\]](#)



72. Sandstead, H.H.; Frederickson, C.J.; Penland, J.G. History of zinc as related to brain function. *J. Nutr.* **2000**, *130*, 496–502. [\[CrossRef\]](#) [\[PubMed\]](#)
73. Atamna, H.; Walter, P.B.; Ames, B.N. The role of heme and iron-sulfur clusters in mitochondrial biogenesis, maintenance, and decay with age. *Arch. Biochem. Biophys.* **2002**, *397*, 345–353. [\[CrossRef\]](#) [\[PubMed\]](#)
74. Youdim, M.B.; Yehuda, S. The neurochemical basis of cognitive deficits induced by brain iron deficiency: Involvement of dopamine-opiate system. *Cell. Mol. Biol.* **2000**, *46*, 491–500.
75. Chang, T.P.-Y.; Rangan, C. Iron poisoning: A literature-based review of epidemiology, diagnosis, and management. *Pediatr. Emerg. Care* **2011**, *27*, 978–985. [\[CrossRef\]](#)
76. Gower-Winter, S.D.; Levenson, C.W. Zinc in the central nervous system: From molecules to behavior. *Biofactors* **2012**, *38*, 186–193. [\[CrossRef\]](#)
77. Sensi, S.L.; Paoletti, P.; Bush, A.I.; Sekler, I. Zinc in the physiology and pathology of the CNS. *Nat. Rev. Neurosci.* **2009**, *10*, 780–791. [\[CrossRef\]](#) [\[PubMed\]](#)
78. Cowan, J.A. Structural and catalytic chemistry of magnesium-dependent enzymes. *BioMetals* **2002**, *15*, 225–235. [\[CrossRef\]](#) [\[PubMed\]](#)
79. Stangherlin, A.; O'Neill, J.S. Signal Transduction: Magnesium Manifests as a Second Messenger. *Curr. Biol.* **2018**, *28*, 1403–1405. [\[CrossRef\]](#) [\[PubMed\]](#)
80. Seyama, T.; Kamei, Y.; Iriyama, T.; Imada, S.; Ichinose, M.; Toshimitsu, M.; Fujii, T.; Asou, H. Pretreatment with magnesium sulfate attenuates white matter damage by preventing cell death of developing oligodendrocytes. *J. Obstet. Gynaecol. Res.* **2018**, *44*, 601–607. [\[CrossRef\]](#) [\[PubMed\]](#)
81. Sun, Q.; Weinger, J.G.; Mao, F.; Liu, G. Regulation of structural and functional synapse density by L-threonate through modulation of intraneuronal magnesium concentration. *Neuropharmacology* **2016**, *108*, 426–439. [\[CrossRef\]](#)
82. Spasov, A.A.; Iezhitsa, I.N.; Kravchenko, M.S.; Kharitonova, M.V. Features of central neurotransmission in animals in conditions of dietary magnesium deficiency and after its correction. *Neurosci. Behav. Physiol.* **2009**, *39*, 645–653. [\[CrossRef\]](#)
83. Kirkland, A.E.; Sarlo, G.L.; Holton, K.F. The Role of Magnesium in Neurological Disorders. *Nutrients* **2018**, *10*, 730. [\[CrossRef\]](#)
84. Volpe, S.L. Magnesium. In *Present Knowledge in Nutrition*, 10th ed.; Erdman, J.W., Macdonald, L.A., Zeisel, S.H., Eds.; International Life Sciences Institute: Washington, DC, USA; John Wiley & Sons, Inc.: Hoboken, NJ, USA, 2012; pp. 459–474.
85. Johnson, S. The multifaceted and widespread pathology of magnesium deficiency. *Med. Hypotheses* **2001**, *56*, 163–170. [\[CrossRef\]](#)
86. Kennedy, D.O. B Vitamins and the Brain: Mechanisms, Dose and Efficacy—A Review. *Nutrients* **2016**, *8*, 68. [\[CrossRef\]](#)
87. Raichle, M.E. Two views of brain function. *Trends Cogn. Sci.* **2010**, *14*, 180–190. [\[CrossRef\]](#) [\[PubMed\]](#)
88. Bâ, A. Metabolic and structural role of thiamine in nervous tissues. *Cell. Mol. Neurobiol.* **2008**, *28*, 923–931. [\[CrossRef\]](#) [\[PubMed\]](#)
89. Hirsch, J.A.; Parrott, J. New considerations on the neuromodulatory role of thiamine. *Pharmacology* **2012**, *89*, 111–116. [\[CrossRef\]](#) [\[PubMed\]](#)
90. Bottiglieri, T.; Laundry, M.; Crellin, R.; Toone, B.K.; Carney, M.W.; Reynolds, E.H. Homocysteine, folate, methylation, and monoamine metabolism in depression. *J. Neurol. Neurosurg. Psychiatry* **2000**, *69*, 228–232. [\[CrossRef\]](#)
91. Selhub, J.; Bagley, L.C.; Miller, J.; Rosenberg, I.H. B vitamins, homocysteine, and neurocognitive function in the elderly. *Am. J. Clin. Nutr.* **2000**, *71*, 614–620. [\[CrossRef\]](#)
92. Morris, M.S. The Role of B Vitamins in Preventing and Treating Cognitive Impairment and Decline. *Adv. Nutr.* **2012**, *3*, 801–812. [\[CrossRef\]](#)
93. Durga, J.; van Boxtel, M.P.; Schouten, E.G.; Kok, F.J.; Jolles, J.; Katan, M.B.; Verhoef, P. Effect of 3-year folic acid supplementation on cognitive function in older adults in the FACIT trial: A randomized, double blind, controlled trial. *Lancet* **2007**, *369*, 208–216. [\[CrossRef\]](#)
94. Ford, A.H.; Almeida, O.P. Effect of Vitamin B Supplementation on Cognitive Function in the Elderly: A Systematic Review and Meta-Analysis. *Drugs Aging* **2019**, *36*, 419–434. [\[CrossRef\]](#)
95. Qin, B.; Xun, P.; Jacobs, D.R., Jr.; Zhu, N.; Daviglus, M.L.; Reis, J.P.; Steen, L.M.; Van Horn, L.; Sidney, S.; He, K. Intake of niacin, folate, vitamin B-6, and vitamin B-12 through young adulthood and cognitive function in midlife: The Coronary Artery Risk Development in Young Adults (CARDIA) study. *Am. J. Clin. Nutr.* **2017**, *106*, 1032–1040. [\[CrossRef\]](#)
96. Kim, J.Y.; Kang, S.W. Relationships between Dietary Intake and Cognitive Function in Healthy Korean Children and Adolescents. *J. Lifestyle Med.* **2017**, *7*, 10–17. [\[CrossRef\]](#)
97. Louwman, M.W.; van Dusseldorp, M.; van de Vijver, F.J.; Thomas, C.M.; Schneede, J.; Ueland, P.M.; Refsum, H.; van Staveren, W.A. Signs of impaired cognitive function in adolescents with marginal cobalamin status. *Am. J. Clin. Nutr.* **2000**, *72*, 762–769. [\[CrossRef\]](#)
98. Venkatramanan, S.; Armata, I.E.; Strupp, B.J.; Finkelstein, J.L. Vitamin B-12 and Cognition in Children. *Adv. Nutr.* **2016**, *7*, 879–888. [\[CrossRef\]](#) [\[PubMed\]](#)
99. Markun, S.; Gravestock, I.; Jäger, L.; Rosemann, T.; Pichierri, G.; Burgstaller, J.M. Effects of Vitamin B12 Supplementation on Cognitive Function, Depressive Symptoms, and Fatigue: A Systematic Review, Meta-Analysis, and Meta-Regression. *Nutrients* **2021**, *13*, 923. [\[CrossRef\]](#) [\[PubMed\]](#)
100. Forbes, S.C.; Holroyd-Leduc, J.M.; Poulin, M.J.; Hogan, D.B. Effect of Nutrients, Dietary Supplements and Vitamins on Cognition: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Can. Geriatr. J.* **2015**, *18*, 231–245. [\[CrossRef\]](#) [\[PubMed\]](#)

101. McCleery, J.; Abraham, R.P.; Denton, D.A.; Rutjes, A.W.; Chong, L.Y.; Al-Assaf, A.S.; Griffith, D.J.; Rafeeq, S.; Yaman, H.; Malik, M.A.; et al. Vitamin and mineral supplementation for preventing dementia or delaying cognitive decline in people with mild cognitive impairment. *Cochrane Database Syst. Rev.* **2018**, *11*, CD011905. [CrossRef]
102. Maddock, J.; Zhou, A.; Cavadino, A.; Kuźma, E.; Bao, Y.; Smart, M.C.; Saun, K.U.; Schöttker, B.; Engmann, J.; Kjærgaard, M.; et al. Vitamin D and cognitive function: A Mendelian randomization study. *Sci. Rep.* **2017**, *7*, 1–8. [CrossRef]
103. Sommer, I.; Griebler, U.; Kien, C.; Auer, S.; Klerings, I.; Hammer, R.; Holzer, P.; Gartlehner, G. Vitamin D deficiency as a risk factor for dementia: A systematic review and meta-analysis. *BMC Geriatr.* **2017**, *17*, 16. [CrossRef]
104. Goodwill, A.M.; Szoek, C. A Systematic Review and Meta-Analysis of The Effect of Low Vitamin D on Cognition. *J. Am. Geriatr. Soc.* **2017**, *65*, 2161–2168. [CrossRef]
105. Dean, A.J.; Bellgrove, M.A.; Hall, T.; Phan, W.M.; Eyles, D.W.; Kvaskoff, D.; McGrath, J.J. Effects of vitamin D supplementation on cognitive and emotional functioning in young adults—A randomized controlled trial. *PLoS ONE* **2011**, *6*, e25966. [CrossRef]
106. Travica, N.; Ried, K.; Sali, A.; Scholey, A.; Hudson, I.; Pipingas, A. Vitamin C Status and Cognitive Function: A Systematic Review. *Nutrients* **2017**, *9*, 960. [CrossRef]
107. Sensi, S.; Paoletti, P.; Koh, J.; Aizenman, E.; Bush, A.; Hershfinkel, M. The Neurophysiology and Pathology of Brain Zinc. *J. Neurosci.* **2011**, *31*, 16076–16085. [CrossRef] [PubMed]
108. Skarupski, K.; Tangney, C.; Li, H.; Ouyang, B.; Evans, D.; Morris, M. Longitudinal association of vitamin B-6, folate, and vitamin B-12 with depressive symptoms among older adults over time. *Am. J. Clin. Nutr.* **2010**, *92*, 330–335. [CrossRef] [PubMed]
109. Traber, M.G.; Vitamin, E. *Present Knowledge in Nutrition*, 10th ed.; Erdman, J.W., Macdonald, I.A., Zeisel, S.H., Eds.; Wiley-Blackwell: Washington, DC, USA, 2012; pp. 214–229.
110. Perkins, A.J.; Hendrie, H.C.; Callahan, C.M.; Gao, S.; Unverzagt, F.W.; Xu, Y.; Hall, K.S.; Hui, S.L. Association of antioxidants with memory in a multiethnic elderly sample using the Third National Health and Nutrition Examination Survey. *Am. J. Epidemiol.* **1999**, *150*, 37–44. [CrossRef] [PubMed]
111. Lee, D.H.; Chon, J.; Kim, Y.; Seo, Y.K.; Park, E.J.; Won, C.W.; Soh, Y. Association between vitamin D deficiency and cognitive function in the elderly Korean population: A Korean frailty and aging cohort study. *Medicine* **2020**, *99*, e19293. [CrossRef] [PubMed]
112. Buell, J.S.; Dawson-Hughes, B. Vitamin D and neurocognitive dysfunction: Preventing Decline? *Mol. Asp. Med.* **2008**, *29*, 415–422. [CrossRef]
113. Dickens, A.P.; Lang, I.A.; Langa, K.M.; Kos, K.; Llewellyn, D.J. Vitamin D, cognitive dysfunction and dementia in older adults. *CNS Drugs* **2011**, *25*, 629–639. [CrossRef] [PubMed]
114. Whiteman, H. Vitamin D deficiency linked to poor brain function, death after cardiac arrest. *Med. News Today*. 2014. Available online: <https://www.medicalnewstoday.com/articles/283971> (accessed on 4 July 2018).
115. Ballaz, S.J.; Rebec, G.V. Neurobiology of vitamin C: Expanding the focus from antioxidant to endogenous neuromodulator. *Pharmacol. Res.* **2019**, *146*, 104321. [CrossRef]
116. Harrison, F.E.; May, J.M. Vitamin C function in the brain: Vital role of the ascorbate transporter SVCT2. *Free Radic. Biol. Med.* **2009**, *46*, 719–730. [CrossRef]
117. Cappelletti, S.; Piacentino, D.; Sani, G.; Aromatario, M. Caffeine: Cognitive and physical performance enhancer or psychoactive drug? *Curr. Neuropharmacol.* **2015**, *13*, 71–88. [CrossRef]
118. Maughan, R.J.; Burke, L.M.; Dvorak, J.; Larson-Meyer, D.E.; Peeling, P.; Phillips, S.M.; Rawson, E.S.; Walsh, N.P.; Garthe, I.; Geyer, H.; et al. IOC consensus statement: Dietary supplements and the high-performance athlete. *Br. J. Sports Med.* **2018**, *52*, 439–455. [CrossRef]
119. McLellan, T.M.; Caldwell, J.A.; Lieberman, H.R. A review of caffeine's effects on cognitive, physical and occupational performance. *Neurosci. Biobehav. Rev.* **2016**, *71*, 294–312. [CrossRef]
120. Zhang, B.; Liu, Y.; Wang, X.; Deng, Y.; Zheng, X. Cognition and Brain Activation in Response to Various Doses of Caffeine: A Near-Infrared Spectroscopy Study. *Front. Psychol.* **2020**, *11*, 1393. [CrossRef]
121. Lorenzo Calvo, J.; Fei, X.; Domínguez, R.; Pareja-Galeano, H. Caffeine and Cognitive Functions in Sports: A Systematic Review and Meta-Analysis. *Nutrients* **2021**, *13*, 868. [CrossRef]
122. Haskell, C.F.; Kennedy, D.O.; Milne, A.L.; Wesnes, K.A.; Scholey, A.B. The effects of L-theanine, caffeine and their combination on cognition and mood. *Biol. Psychol.* **2008**, *77*, 113–122. [CrossRef]
123. Camfield, D.A.; Stough, C.; Farrimond, J.; Scholey, A.B. Acute effects of tea constituents L-theanine, caffeine, and epigallocatechin gallate on cognitive function and mood: A systematic review and meta-analysis. *Nutr. Rev.* **2014**, *72*, 507–522. [CrossRef] [PubMed]
124. Dietz, C.; Dekker, M. Effect of Green Tea Phytochemicals on Mood and Cognition. *Curr. Pharm. Des.* **2017**, *23*, 2876–2905. [CrossRef]
125. Mancini, E.; Beglinger, C.; Drewe, J.; Zanchi, D.; Lang, U.E.; Borgwardt, S. Green tea effects on cognition, mood and human brain function: A systematic review. *Phytomedicine* **2017**, *34*, 26–37. [CrossRef] [PubMed]
126. Zaragoza, J.; Tinsley, G.; Urbina, S.; Villa, K.; Santos, E.; Juaneza, A.; Tinnin, M.; Davidson, C.; Mitmesser, S.; Zhang, Z.; et al. Effects of acute caffeine, theanine and tyrosine supplementation on mental and physical performance in athletes. *J. Int. Soc. Sports Nutr.* **2019**, *16*, 1–8. [CrossRef] [PubMed]



127. Decroix, L.; Tonoli, C.; Soares, D.; Tagougui, S.; Heyman, E.; Meeusen, R. Acute cocoa flavanol improves cerebral oxygenation without enhancing executive function at rest or after exercise. *J. Appl. Physiol. Nutr. Metab.* **2016**, *41*, 1225–1232. [\[CrossRef\]](#)
128. Lampert, D.; Pal, D.; Moutsiana, C.; Field, D.; Williams, C.; Spencer, J.; Butler, L.T. The effect of flavanol-rich cocoa on cerebral perfusion in healthy older adults during conscious resting state: A placebo controlled, crossover, acute trial. *Psychopharmacology* **2015**, *232*, 3227–3234. [\[CrossRef\]](#)
129. Hepsomali, P.; Greyling, A.; Scholey, A.; Vauzour, D. Acute Effects of Polyphenols on Human Attentional Processes: A Systematic Review and Meta-Analysis. *Front. Neurosci.* **2021**, *15*, 678769. [\[CrossRef\]](#)
130. Martin, M.A.; Goya, L.; de Pascual-Teresa, S. Effect of Cocoa and Cocoa Products on Cognitive Performance in Young Adults. *Nutrients* **2020**, *12*, 3691. [\[CrossRef\]](#)
131. Soggi, V.; Tempesta, D.; Desideri, G.; De Gennaro, L.; Ferrara, M. Enhancing Human Cognition with Cocoa Flavonoids. *Front. Nutr.* **2017**, *4*, 19. [\[CrossRef\]](#)
132. Tan, T.; Lim, X.Y.; Yeo, J.; Lee, S.; Lai, N.M. The Health Effects of Chocolate and Cocoa: A Systematic Review. *Nutrients* **2021**, *13*, 2909. [\[CrossRef\]](#)
133. Thompson, C.; Wylie, L.J.; Fulford, J.; Kelly, J.; Black, M.I.; McDonagh, S.T.; Jones, A.M. Dietary nitrate improves sprint performance and cognitive function during prolonged intermittent exercise. *Eur. J. Appl. Physiol.* **2015**, *115*, 1825–1834. [\[CrossRef\]](#) [\[PubMed\]](#)
134. Wightman, E.L.; Haskell-Ramsay, C.F.; Thompson, K.G.; Blackwell, J.R.; Winyard, P.G.; Forster, J.; Jones, A.M.; Kennedy, D.O. Dietary nitrate modulates cerebral blood flow parameters and cognitive performance in humans: A double-blind, placebo-controlled, crossover investigation. *Physiol. Behav.* **2015**, *149*, 149–158. [\[CrossRef\]](#)
135. Stanaway, L.; Rutherford-Markwick, K.; Page, R.; Wong, M.; Jirangrat, W.; Teh, K.H.; Ali, A. Acute Supplementation with Nitrate-Rich Beetroot Juice Causes a Greater Increase in Plasma Nitrite and Reduction in Blood Pressure of Older Compared to Younger Adults. *Nutrients* **2019**, *11*, 1683. [\[CrossRef\]](#) [\[PubMed\]](#)
136. Avgerinos, K.I.; Spyrou, N.; Bougioukas, K.I.; Kapogiannis, D. Effects of creatine supplementation on cognitive function of healthy individuals: A systematic review of randomized controlled trials. *Exp. Gerontol.* **2018**, *108*, 166–173. [\[CrossRef\]](#) [\[PubMed\]](#)
137. Watanabe, A.; Kato, N.; Kato, T. Effects of creatine on mental fatigue and cerebral hemoglobin oxygenation. *Neurosci. Res.* **2002**, *42*, 279–285. [\[CrossRef\]](#)
138. Rae, C.; Digney, A.L.; McEwan, S.R.; Bates, T.C. Oral creatine monohydrate supplementation improves brain performance: A double-blind, placebo-controlled, cross-over trial. *Proc. Biol. Sci.* **2003**, *270*, 2147–2150. [\[CrossRef\]](#)
139. McMorris, T.; Harris, R.C.; Swain, J.; Corbett, J.; Collard, K.; Dyson, R.J.; Dye, L.; Hodgson, C.; Draper, N. Effect of creatine supplementation and sleep deprivation, with mild exercise, on cognitive and psychomotor performance, mood state, and plasma concentrations of catecholamines and cortisol. *Psychopharmacology* **2006**, *185*, 93–103. [\[CrossRef\]](#)
140. Ling, J.; Kritikos, M.; Tiplady, B. Cognitive effects of creatine ethyl ester supplementation. *Behav. Pharmacol.* **2009**, *20*, 673–679. [\[CrossRef\]](#)
141. Benton, D.; Donohoe, R. The influence of creatine supplementation on the cognitive functioning of vegetarians and omnivores. *Br. J. Nutr.* **2011**, *105*, 1100–1105. [\[CrossRef\]](#)
142. Ostojic, S.M.; Ostojic, J.; Drid, P.; Vranes, M. Guanidinoacetic acid versus creatine for improved brain and muscle creatine levels: A superiority pilot trial in healthy men. *Appl. Physiol. Nutr. Metab.* **2016**, *41*, 1005–1007. [\[CrossRef\]](#) [\[PubMed\]](#)
143. Cook, C.J.; Crewther, B.T.; Kilduff, L.P.; Drawer, S.; Gaviglio, C.M. Skill execution and sleep deprivation: Effects of acute caffeine or creatine supplementation—a randomized placebo-controlled trial. *J. Int. Soc. Sports Nutr.* **2011**, *8*, 2. [\[CrossRef\]](#)
144. Dolan, E.; Gualano, B.; Rawson, E.S. Beyond muscle: The effects of creatine supplementation on brain creatine, cognitive processing, and traumatic brain injury. *Eur. J. Sport Sci.* **2019**, *19*, 1–14. [\[CrossRef\]](#) [\[PubMed\]](#)
145. Roschel, H.; Gualano, B.; Ostojic, S.M.; Rawson, E.S. Creatine Supplementation and Brain Health. *Nutrients* **2021**, *13*, 586. [\[CrossRef\]](#)
146. Bagga, D.; Aigner, C.S.; Reichert, J.L.; Cecchetto, C.; Fischmeister, F.P.S.; Holzer, P.; Moissl-Eichinger, C.; Schöpf, V. Influence of 4-week multi-strain probiotic administration on resting-state functional connectivity in healthy volunteers. *Eur. J. Nutr.* **2019**, *58*, 1821–1827. [\[CrossRef\]](#) [\[PubMed\]](#)
147. Desmedt, O.; Broers, V.; Zamariola, G.; Pachikian, B.; Delzenne, N.; Luminet, O. Effects of prebiotics on affect and cognition in human intervention studies. *Nutr. Rev.* **2020**, *77*, 81–95. [\[CrossRef\]](#) [\[PubMed\]](#)
148. Marx, W.; Scholey, A.; Firth, J.; D’Cunha, N.M.; Lane, M.; Hockey, M.; Ashton, M.M.; Cryan, J.F.; O’Neil, A.; Naumovski, N.; et al. Prebiotics, probiotics, fermented foods and cognitive outcomes: A meta-analysis of randomized controlled trials. *Neurosci. Biobehav. Rev.* **2020**, *118*, 472–484. [\[CrossRef\]](#)
149. Berding, K.; Long-Smith, C.M.; Carbia, C.; Bastiaanssen, T.; van de Wouw, M.; Wiley, N.; Strain, C.R.; Fouhy, F.; Stanton, C.; Cryan, J.F.; et al. A specific dietary fibre supplementation improves cognitive performance—an exploratory randomised, placebo-controlled, crossover study. *Psychopharmacology* **2021**, *238*, 149–163. [\[CrossRef\]](#) [\[PubMed\]](#)
150. Bloemendaal, M.; Szopinska-Tokov, J.; Belzer, C.; Boverhoff, D.; Papalini, S.; Michels, F.; van Hemert, S.; Arias Vasquez, A.; Aarts, E. Probiotics-induced changes in gut microbial composition and its effects on cognitive performance after stress: Exploratory analyses. *Transl. Psychiatry* **2021**, *11*, 300. [\[CrossRef\]](#)
151. Johnson, E.J. Role of lutein and zeaxanthin in visual and cognitive function throughout the lifespan. *Nutr. Rev.* **2014**, *72*, 605–612. [\[CrossRef\]](#)

152. Scott, T.M.; Rasmussen, H.M.; Chen, O.; Johnson, E.J. Avocado Consumption Increases Macular Pigment Density in Older Adults: A Randomized, Controlled Trial. *Nutrients* **2017**, *9*, 919. [\[CrossRef\]](#)
153. Sainz, I.; Collado-Mateo, D.; Coso, J.D. Effect of acute caffeine intake on hit accuracy and reaction time in professional e-sports players. *Physiol. Behav.* **2020**, *224*, 113031. [\[CrossRef\]](#)
154. Ma, L.; Lin, X.M.; Zou, Z.Y.; Xu, X.R.; Li, Y.; Xu, R. A 12-week lutein supplementation improves visual function in Chinese people with long-term computer display light exposure. *Br. J. Nutr.* **2009**, *102*, 186–190. [\[CrossRef\]](#)
155. Arab, L.; Biggs, M.L.; O'Meara, E.S.; Longstreth, W.T.; Crane, P.K.; Fitzpatrick, A.L. Gender differences in tea, coffee, and cognitive decline in the elderly: The cardiovascular health study. *J. Alzheimers Dis.* **2011**, *27*, 553–566. [\[CrossRef\]](#)
156. Rothenberg, D.O.; Zhang, L. Mechanisms Underlying the Anti-Depressive Effects of Regular Tea Consumption. *Nutrients* **2019**, *11*, 1361. [\[CrossRef\]](#)
157. Nathan, P.J.; Lu, K.; Gray, M.; Oliver, C. The neuropharmacology of L-theanine(N-ethyl-L-glutamine): A possible neuroprotective and cognitive enhancing agent. *J. Herb. Pharmacother.* **2006**, *6*, 21–30. [\[CrossRef\]](#) [\[PubMed\]](#)
158. Del Rio, D.; Rodriguez-Mateos, A.; Spencer, J.P.; Tognolini, M.; Borges, G.; Crozier, A. Dietary (poly)phenolics in human health: Structures, bioavailability, and evidence of protective effects against chronic diseases. *Antioxid. Redox Signal.* **2013**, *18*, 1818–1892. [\[CrossRef\]](#) [\[PubMed\]](#)
159. Shukitt-Hale, B.; Lau, F.C.; Joseph, J.A. Berry fruit supplementation and the aging brain. *J. Agric. Food Chem.* **2008**, *56*, 636–641. [\[CrossRef\]](#)
160. Williams, R.J.; Spencer, J.P.; Rice-Evans, C. Flavonoids: Antioxidants or signalling molecules? *Free Radic. Biol. Med.* **2004**, *36*, 838–849. [\[CrossRef\]](#) [\[PubMed\]](#)
161. Spencer, J.P. The impact of flavonoids on memory: Physiological and molecular considerations. *Chem. Soc. Rev.* **2009**, *38*, 1152–1161. [\[CrossRef\]](#) [\[PubMed\]](#)
162. Nagahama, Y.; Nabatame, H.; Okina, T.; Yamauchi, H.; Narita, M.; Fujimoto, N.; Murakami, M.; Fukuyama, H.; Matsuda, M. Cerebral correlates of the progression rate of the cognitive decline in probable Alzheimer's disease. *Eur. Neurol.* **2003**, *50*, 1–9. [\[CrossRef\]](#) [\[PubMed\]](#)
163. Wang, Q.; Ge, X.; Tian, X.; Zhang, Y.; Zhang, J.; Zhang, P. Soy isoflavone: The multipurpose phytochemical. (Review). *Biomed. Rep.* **2013**, *1*, 697–701. [\[CrossRef\]](#) [\[PubMed\]](#)
164. Ding, J.; Xi, Y.D.; Zhang, D.D.; Zhao, X.; Liu, J.M.; Li, C.Q.; Han, J.; Xiao, R. Soybean isoflavone ameliorates b-amyloid 1-42-induced learning and memory deficit in rats by protecting synaptic structure and function. *Synapse* **2013**, *67*, 856–864. [\[CrossRef\]](#)
165. Henderson, V.W.; St John, J.A.; Hodis, H.N.; Kono, N.; McCleary, C.A.; Franke, A.A.; Mack, W.J. Long-term soy isoflavone supplementation and cognition in women: A randomized, controlled trial. *Neurology* **2012**, *78*, 1841–1848. [\[CrossRef\]](#)
166. Spencer, J.P. Food for thought: The role of dietary flavonoids in enhancing human memory, learning and neuro-cognitive performance. *Proc. Nutr. Soc.* **2008**, *67*, 238–252. [\[CrossRef\]](#) [\[PubMed\]](#)
167. Harikumar, K.B.; Aggarwal, B.B. Resveratrol: A multitargeted agent for age-associated chronic diseases. *Cell Cycle* **2008**, *7*, 1020–1035. [\[CrossRef\]](#)
168. Vauzour, D. Dietary polyphenols as modulators of brain functions: Biological actions and molecular mechanisms underpinning their beneficial effects. *Oxid. Med. Cell. Longev.* **2012**, *2012*, 914273. [\[CrossRef\]](#)
169. Miller, M.G.; Thangthaeng, N.; Poulou, S.M.; Shukitt-Hale, B. Role of fruits, nuts, and vegetables in maintaining cognitive health. *Exp. Gerontol.* **2016**, *94*, 24–28. [\[CrossRef\]](#)
170. Andres-Lacueva, C.; Shukitt-Hale, B.; Galli, R.L.; Jauregui, O.; Lamuela-Raventos, R.M.; Joseph, J.A. Anthocyanins in aged blueberry-fed rats are found centrally and may enhance memory. *Nutr. Neurosci.* **2005**, *8*, 111–120. [\[CrossRef\]](#)
171. Martin, M.A.; Ramos, S. Cocoa polyphenols in oxidative stress: Potential health implications. *J. Funct. Foods.* **2016**, *27*, 570–588. [\[CrossRef\]](#)
172. Lamport, D.J.; Christodoulou, E.; Achilleos, C. Beneficial Effects of Dark Chocolate for Episodic Memory in Healthy Young Adults: A Parallel-Groups Acute Intervention with a White Chocolate Control. *Nutrients* **2020**, *12*, 483. [\[CrossRef\]](#)
173. Bailey, S.J.; Winyard, P.; Vanhatalo, A.; Blackwell, J.R.; DiMenna, F.J.; Wilkerson, D.P.; Tarr, J.; Benjamin, N.; Jones, A.M. Dietary nitrate supplementation reduces the O<sub>2</sub> cost of low-intensity exercise and enhances tolerance to high-intensity exercise in humans. *J. Appl. Physiol.* **2009**, *107*, 1144–1155. [\[CrossRef\]](#)
174. Wylie, L.J.; Bailey, S.J.; Kelly, J.; Blackwell, J.R.; Vanhatalo, A.; Jones, A.M. Influence of beetroot juice supplementation on intermittent exercise performance. *Eur. J. Appl. Physiol.* **2016**, *116*, 415–425. [\[CrossRef\]](#) [\[PubMed\]](#)
175. Jones, A.M. Dietary nitrate supplementation and exercise performance. *Sports Med.* **2014**, *44*, 35–45. [\[CrossRef\]](#) [\[PubMed\]](#)
176. Bailey, S.J.; Varnham, R.L.; DiMenna, F.J.; Breese, B.C.; Wylie, L.J.; Jones, A.M. Inorganic nitrate supplementation improves muscle oxygenation, O<sub>2</sub> uptake kinetics, and exercise tolerance at high but not low pedal rates. *J. Appl. Physiol.* **2015**, *118*, 1396–1405. [\[CrossRef\]](#) [\[PubMed\]](#)
177. Bailey, S.J.; Fulford, J.; Vanhatalo, A.; Winyard, P.G.; Blackwell, J.R.; DiMenna, F.J.; Wilkerson, D.P.; Benjamin, N.; Jones, A.M. Dietary nitrate supplementation enhances muscle contractile efficiency during knee-extensor exercise in humans. *J. Appl. Physiol.* **2010**, *109*, 135–148. [\[CrossRef\]](#) [\[PubMed\]](#)
178. Saks, V.A.; Kongas, O.; Vendelin, M.; Kay, L. Role of the creatine/phosphocreatine system in the regulation of mitochondrial respiration. *Acta Physiol. Scand.* **2000**, *168*, 635–641. [\[CrossRef\]](#)



179. Wallimann, T.; Wyss, M.; Brdiczka, D.; Nicolay, K.; Eppenberger, H.M. Intracellular compartmentation, structure and function of creatine kinase isoenzymes in tissues with high and fluctuating energy demands: The “phosphocreatine circuit” for cellular energy homeostasis. *Biochem. J.* **1992**, *281*, 21–40. [\[CrossRef\]](#) [\[PubMed\]](#)
180. Balestrino, M.; Adriano, E. Beyond sports: Efficacy and safety of creatine supplementation in pathological or parapsychological conditions of brain and muscle. *Med. Res. Rev.* **2019**, *39*, 2427–2459. [\[CrossRef\]](#) [\[PubMed\]](#)
181. Bermúdez-Humarán, L.G.; Salinas, E.; Ortiz, G.G.; Ramirez-Jirano, L.J.; Morales, J.A.; Bitzer-Quintero, O.K. From Probiotics to Psychobiotics: Live Beneficial Bacteria Which Act on the Brain-Gut Axis. *Nutrients* **2019**, *11*, 890. [\[CrossRef\]](#)
182. Cryan, J.; Dinan, T. Mind-altering microorganisms: The impact of the gut microbiota on brain and behaviour. *Nat. Rev. Neurosci.* **2012**, *13*, 701–712. [\[CrossRef\]](#) [\[PubMed\]](#)
183. Long-Smith, C.; O’Riordan, K.J.; Clarke, G.; Stanton, K.; Dinan, T.G.; Cryan, J.F. Microbiota-Gut-Brain Axis: New Therapeutic Opportunities. *Annu. Rev. Pharmacol. Toxicol.* **2020**, *60*, 477–502. [\[CrossRef\]](#) [\[PubMed\]](#)
184. Gareau, M.G. Cognitive Function and the Microbiome. *Int. Rev. Neurobiol.* **2016**, *131*, 227–246. [\[CrossRef\]](#) [\[PubMed\]](#)
185. Leung, K.; Thuret, S. Gut Microbiota: A Modulator of Brain Plasticity and Cognitive Function in Ageing. *Healthcare* **2015**, *3*, 898–916. [\[CrossRef\]](#)
186. Bercik, P.; Collins, S.M.; Verdu, E.F. Microbes and the gut-brain axis. *Neurogastroenterol. Motil.* **2012**, *24*, 405–413. [\[CrossRef\]](#)
187. Kamada, N.; Seo, S.U.; Chen, G.Y.; Nunez, G. Role of the gut microbiota in immunity and inflammatory disease. *Nat. Rev. Immunol.* **2013**, *13*, 321–335. [\[CrossRef\]](#)
188. Collins, S.M.; Bercik, P. The relationship between intestinal microbiota and the central nervous system in normal gastrointestinal function and disease. *Gastroenterology* **2009**, *136*, 2003–2014. [\[CrossRef\]](#)
189. Moustafa, A.; Li, W.; Anderson, E.L.; Wong, E.H.M.; Dulai, P.S.; Sandborn, W.J.; Biggs, W.; Yooseph, S.; Jones, M.B.; Venter, J.C.; et al. Genetic risk, dysbiosis, and treatment stratification using host genome and Gut microbiome in inflammatory bowel disease. *Clin. Transl. Gastroenterol.* **2018**, *9*, 132. [\[CrossRef\]](#)
190. Fung, T.C.; Olson, C.A.; Hsiao, E.Y. Interactions between the microbiota, immune and nervous systems in health and disease. *Nat. Neurosci.* **2017**, *20*, 145–155. [\[CrossRef\]](#)
191. Collins, S.M.; Surette, M.; Bercik, P. The interplay between the intestinal microbiota and the brain. *Nat. Rev. Microbiol.* **2012**, *10*, 735–742. [\[CrossRef\]](#)
192. Gibson, G.; Hutkins, R.; Sanders, M.E.; Prescott, S.L.; Reimer, R.A.; Salminen, S.J.; Scott, K.; Stanton, C.; Swanson, K.S.; Cani, P.D.; et al. Expert consensus document: The International Scientific Association for Probiotics and Prebiotics (ISAPP) consensus statement on the definition and scope of prebiotics. *Nat. Rev. Gastroenterol. Hepatol.* **2017**, *14*, 491–502. [\[CrossRef\]](#)
193. Sanders, M.E.; Merenstein, D.J.; Reid, G.; Gibson, G.R.; Rastall, R.A. Probiotics and prebiotics in intestinal health and disease: From biology to the clinic. *Nat. Rev. Gastroenterol. Hepatol.* **2019**, *16*, 605–616. [\[CrossRef\]](#)
194. Aslam, H.; Green, J.; Jacka, F.N.; Collier, F.; Berk, M.; Pasco, J.; Dawson, S.L. Fermented foods, the gut and mental health: A mechanistic overview with implications for depression and anxiety. *Nutr. Neurosci.* **2020**, *23*, 659–671. [\[CrossRef\]](#) [\[PubMed\]](#)
195. Bailey, M.T.; Dowd, S.E.; Galley, J.D.; Hufnagle, A.R.; Allen, R.G.; Lyte, M. Exposure to a social stressor alters the structure of the intestinal microbiota: Implications for stressor-induced immunomodulation. *Brain Behav. Immun.* **2011**, *25*, 397–407. [\[CrossRef\]](#) [\[PubMed\]](#)
196. Abdel-Aal, E.-S.M.; Akhtar, H.; Zaheer, K.; Ali, R. Dietary Sources of Lutein and Zeaxanthin Carotenoids and Their Role in Eye Health. *Nutrients* **2013**, *5*, 1169–1185. [\[CrossRef\]](#)
197. Suliman, N.A.; Mat Taib, C.N.; Mohd Moklas, M.A.; Adenan, M.I.; Hidayat Baharudin, M.T.; Basir, R. Establishing Natural Nootropics: Recent Molecular Enhancement Influenced by Natural Nootropic. *Evid. Based Complement. Altern. Med.* **2016**, *11*, 2326. [\[CrossRef\]](#) [\[PubMed\]](#)
198. Joshi Pranav, C. A review on natural memory enhancers (Nootropics). *Unique J. Eng. Adv. Sci.* **2013**, *1*, 8–18.
199. DiFrancisco-Donoghue, J.; Balentine, J.; Schmidt, G.; Zwiab, H. Managing the health of the eSport athlete: An integrated health management model. *BMJ Open Sport Exerc. Med.* **2019**, *5*, e000467. [\[CrossRef\]](#) [\[PubMed\]](#)
200. Pérez-Rubio, C.; González, J.; de los Fayos, E.G. Personalidad y burnout en jugadores profesionales de e-sports. *Cuad. Psicol. Deporte* **2017**, *17*, 41–50.
201. Reeves, S.; Brown, B.; Laurier, E. Experts at Play: Understanding Skilled Expertise. *Games Cult. Games Cult.* **2009**, *4*, 205–227. [\[CrossRef\]](#)
202. Huang, J.; Yan, E.; Cheung, G.; Nagappan, N.; Zimmermann, T. Master Maker: Understanding Gaming Skill Through Practice and Habit From Gameplay Behavior. *Top. Cogn. Sci.* **2017**, *9*, 437–466. [\[CrossRef\]](#) [\[PubMed\]](#)
203. Kokkinakis, A.V.; Cowling, P.I.; Drachen, A.; Wade, A.R. Exploring the relationship between video game expertise and fluid intelligence. *PLoS ONE* **2017**, *12*, e0186621. [\[CrossRef\]](#)
204. Cottrell, C.; McMillen, N.; Harris, B.S. Sport psychology in a virtual world: Considerations for practitioners working in eSports. *J. Sport Psychol. Action* **2019**, *10*, 73–81. [\[CrossRef\]](#)
205. Han, D.H.; Lyoo, I.K.; Renshaw, P.F. Differential regional gray matter volumes in patients with on-line game addiction and professional gamers. *J. Psychiatr. Res.* **2012**, *46*, 507–515. [\[CrossRef\]](#)
206. Rosell Llorens, M. Sport Gaming: The Rise of a New Sports Practice. *Sport Ethics Philos.* **2017**, *11*, 464–476. [\[CrossRef\]](#)
207. Brock, T.; Fraser, E. Is computer gaming a craft? Prehension, practice, and puzzle-solving in gaming labour. *Inf. Commun. Soc.* **2018**, *21*, 1219–1233. [\[CrossRef\]](#)



208. Witkowski, E. On the Digital Playing Field: How We “Do Sport” With Networked Computer Games. *Games Cult.* **2012**, *7*, 349–374. [\[CrossRef\]](#)
209. Kou, Y.; Gui, X. Emotion Regulation in eSports Gaming: A Qualitative Study of League of Legends. *ACM Hum. Comput. Interact.* **2020**, *4*, 1–25. [\[CrossRef\]](#)
210. Jiang, Q. Natural forms of vitamin E: Metabolism, antioxidant, and anti-inflammatory activities and their role in disease prevention and therapy. *Free Radic. Biol. Med.* **2014**, *72*, 76–90. [\[CrossRef\]](#)
211. Lloret, A.; Esteve, D.; Monllor, P.; Cervera-Ferri, A.; Lloret, A. The Effectiveness of Vitamin E Treatment in Alzheimer’s Disease. *J. Mol. Sci.* **2019**, *20*, 879. [\[CrossRef\]](#)
212. Pludowski, P.; Holick, M.F.; Grant, W.B.; Konstantynowicz, J.; Mascarenhas, M.R.; Haq, A.; Povoroznyuk, V.; Balatska, N.; Koronova, T.; Rudenka, E.; et al. Vitamin D supplementation guidelines. *J. Steroid Biochem. Mol. Biol.* **2018**, *175*, 125–135. [\[CrossRef\]](#)
213. Vellekkatt, F.; Menon, V. Efficacy of vitamin D supplementation in major depression: A meta-analysis of randomized controlled trials. *J. Postgrad. Med.* **2019**, *65*, 74–80. [\[CrossRef\]](#)
214. Shaffer, J.A.; Edmondson, D.; Taggart Wasson, L.; Falzon, L.; Homma, K.; Ezeokoli, N.; Li, P.; Davidson, K.W. Vitamin D supplementation for depressive symptoms: A systematic review and meta-analysis of randomized controlled trials. *Psychosom. Med.* **2014**, *76*, 190–196. [\[CrossRef\]](#) [\[PubMed\]](#)
215. Spedding, S. Vitamin D and depression: A systematic review and meta-analysis comparing studies with and without biological flaws. *Nutrients* **2014**, *6*, 1501–1518. [\[CrossRef\]](#) [\[PubMed\]](#)
216. Cheng, Y.C.; Huang, Y.C.; Huang, W.L. The effect of vitamin D supplement on negative emotions: A systematic review and meta-analysis. *Depress. Anxiety* **2020**, *37*, 549–564. [\[CrossRef\]](#) [\[PubMed\]](#)
217. Tosini, G.; Ferguson, I.; Tsubota, K. Effects of blue light on the circadian system and eye physiology. *Mol. Vis.* **2016**, *22*, 61–72. [\[PubMed\]](#)
218. Pereira, A.M.; Brito, J.; Figueiredo, P.; Verhagen, E. Virtual sports deserve real sports medical attention. *BMJ Open Sport Exerc. Med.* **2019**, *5*, 1–4. [\[CrossRef\]](#)
219. Smith, M.J.; Birch, P.D.; Bright, D. Identifying stressors and coping strategies of elite esports competitors. *Int. J. Gaming Comput. Mediat. Simul.* **2019**, *11*, 22–39. [\[CrossRef\]](#)
220. Marker, C.; Gnambs, T.; Appel, M. Exploring the Myth of the Chubby Gamer: A Meta-Analysis on Sedentary Video Gaming and Body Mass. *Soc. Sci. Med.* **2019**, 112325. [\[CrossRef\]](#)
221. Arnaez, J.M.; Frey, G.; Cothran, D.; Lion, M.; Chomistek, A.K.; Hwang, J.; Bervoets, J.; Carrion, C.; Kretschmann, R. Physical Wellness Among Gaming Adults: Cross-Sectional Study. *JMIR Serious Games* **2018**, *6*, e12. [\[CrossRef\]](#) [\[PubMed\]](#)
222. Turel, O.; Romashkin, A.; Morrison, K.M. Health Outcomes of Information System Use Lifestyles among Adolescents: Videogame Addiction, Sleep Curtailment and Cardio-Metabolic Deficiencies. *PLoS ONE* **2016**, *11*, e0154764. [\[CrossRef\]](#) [\[PubMed\]](#)
223. Bastien, M.; Poirier, P.; Lemieux, I.; Després, J.P. Overview of Epidemiology and Contribution of Obesity to Cardiovascular Disease. *Prog. Cardiovasc. Dis.* **2014**, *56*, 369–381. [\[CrossRef\]](#)
224. Cameron, A.J.; Magliano, D.J.; Shaw, J.E.; Zimmet, P.Z.; Carstensen, B.; Alberti, K.G.M.; Tuomilehto, J.; Barr, E.L.M.; Pauvaday, V.K.; Kowlessur, S.; et al. The Influence of Hip Circumference on the Relationship Between Abdominal Obesity and Mortality. *Int. J. Epidemiol.* **2012**, *41*, 484–494. [\[CrossRef\]](#) [\[PubMed\]](#)
225. Grzywacz, E.; Jaron, A. Well-being and mental health—diet, supplements, exercise or sleep? A review of reports from the last five years. *Balt. J. Health Phys. Act.* **2020**, *12*, 73–82. [\[CrossRef\]](#)
226. Ari, Y.; Cakir, E. Correlation between participation in physical activity and healthy nutrition: An example of a sports science faculty. *Balt. J. Health Phys. Act.* **2021**, *13*, 37–45. [\[CrossRef\]](#)
227. Leher, P.; Villaseca, P.; Hogervorst, E.; Maki, P.M.; Henderson, V.W. Individually modifiable risk factors to ameliorate cognitive aging: A systematic review and meta-analysis. *Climacteric.* **2015**, *18*, 678–689. [\[CrossRef\]](#) [\[PubMed\]](#)
228. Singh, B.; Parsaik, A.K.; Mielke, M.M.; Ewring, P.J.; Knopman, D.S.; Petersen, R.C.; Roberts, R.O. Association of mediterranean diet with mild cognitive impairment and Alzheimer’s disease: A systematic review and meta-analysis. *J. Alzheimers Dis.* **2014**, *39*, 271–282. [\[CrossRef\]](#)
229. Van den Brink, A.C.; Brouwer-Brolsma, E.M.; Berendsen, A.A.M.; van de Rest, O. The Mediterranean, Dietary Approaches to Stop Hypertension (DASH), and Mediterranean-DASH Intervention for Neurodegenerative Delay (MIND) Diets Are Associated with Less Cognitive Decline and a Lower Risk of Alzheimer’s Disease—A Review. *Adv. Nutr.* **2019**, *10*, 1040–1065. [\[CrossRef\]](#)
230. Carrillo, J.A.; Zafrilla, M.P.; Marhuenda, J. Cognitive Function and Consumption of Fruit and Vegetable Polyphenols in a Young Population: Is There a Relationship? *Foods* **2019**, *8*, 507. [\[CrossRef\]](#)
231. Dye, L.; Lluch, A.; Blundell, J.E. Macronutrients and mental performance. *Nutrition* **2000**, *16*, 1021–1034. [\[CrossRef\]](#)
232. Hoyland, A.; Dye, L.; Lawton, C.L. A systematic review of the effect of breakfast on the cognitive performance of children and adolescents. *Nutr. Res. Rev.* **2009**, *22*, 220–243. [\[CrossRef\]](#)
233. Nilsson, A.; Radeborg, K.; Björck, I. Effects of differences in postprandial glycaemia on cognitive functions in healthy middle-aged subjects. *Eur. J. Clin. Nutr.* **2009**, *63*, 113–120. [\[CrossRef\]](#)
234. Wittbrodt, M.T.; Millard-Stafford, M. Dehydration Impairs Cognitive Performance: A Meta-analysis. *Med. Sci. Sports Exerc.* **2018**, *50*, 2360–2368. [\[CrossRef\]](#) [\[PubMed\]](#)

- 
- 235. Erevik, E.K.; Torsheim, T.; Andreassen, C.S.; Krossbakken, E.; Veda, Ø.; Pallesen, S. The associations between low-level gaming, high-level gaming and problematic alcohol use. *Addict. Behav. Rep.* **2019**, *10*, 100186. [[CrossRef](#)] [[PubMed](#)]
  - 236. Lee, S.; Bonnar, D.; Kim, Y.; Lee, Y.; Lee, S.; Gradisar, M.; Suh, S. Sleep Characteristics and Risk Factors of Korean Esports Athletes: An Exploratory Study. *Sleep Med. Res.* **2020**, *11*, 77–87. [[CrossRef](#)]
  - 237. Bonnar, D.; Castine, B.; Kakoschke, N.; Sharp, G. Sleep and performance in Eathletes: For the win! *Sleep Health* **2019**, *5*, 647–650. [[CrossRef](#)] [[PubMed](#)]
  - 238. Gomes de Assis, G.; Ciężczyk, P. Exercise—A unique endogenous regulator of irisin, BDNF, leptin and cortisol against depression. *Balt. J. Health Phys. Act.* **2020**, *12*, 1–8. [[CrossRef](#)]

## Article

# Nutrition Patterns of Polish Esports Players

Monika Szot \*, Barbara Frączek  and Florentyna Tyrła

Department of Sports Dietetics, Gdansk University of Physical Education and Sport, 80-336 Gdansk, Poland  
\* Correspondence: monika.szot@awf.gda.pl

**Abstract:** The aim of this study was to quantify the dietary patterns (DPs) of Polish esports players aged 18–26 years. Data were obtained via questionnaires that assessed dietary habits and frequency of food consumption. Dietary patterns were derived using Principal Component Analysis (PCA) and Factor Analysis (FA). In total, nine distinct DPs were identified. Eight DPs were considered unhealthy; ‘fast food’, ‘High-processed food, meat and confectionery’, ‘Sweet’, ‘Fat-dairy products’, ‘Vegetable-fruit’, ‘Spices and additives’, ‘Fats’ and ‘Cereal’; and only one was deemed healthy. E-athletes presented mostly poor dietary habits, which included: irregular eating of meals, frequent snacking, at least three meals a day and composition of snacks, frying of meat dishes and sweetening of hot drinks. Healthy dietary habits included proper hydration during the day and consumption of mainly non-sparkling water. The unbalanced and largely unhealthy dietary habits of esports players raise health concerns for these e-athletes, particularly when combined with a sedentary lifestyle. Future research could assess the nutritional knowledge of this group as it relates to national guidelines, investigate interventions designed to introduce healthier eating options into their lifestyle and examine the relationship between DPs and health or cognitive performance.

**Keywords:** esports; cognitive performance; video gaming; dietary patterns; eating habits; cognitive performance; western diet



Citation: Szot, M.; Frączek, B.; Tyrła, F. Nutrition Patterns of Polish Esports Players. *Nutrients* **2023**, *15*, 149. <https://doi.org/10.3390/nu15010149>

Academic Editor: Antoni Sureda

Received: 16 November 2022

Revised: 22 December 2022

Accepted: 24 December 2022

Published: 28 December 2022



Copyright: © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

Electronic sports (esports) have gained high popularity and success in the global entertainment industry [1,2]. Esports represents organized and competitive video gaming, where individuals or teams of players compete against each other through human-computer interactions [3,4]. Esports requires a combination of motor, cognitive, strategic, and mimetic skills [5]. Several factors, such as proper diet, sleep pattern and fitness level, seem to be crucial for cognitive performance [6]. However, few studies have examined the health-related behaviors of esports players [7,8]. These players paid less attention to a healthy diet and were characterized by lower consumption of vegetables and fruits compared to daily recommendations for the general population [7]. It is clear that prolonged gaming is linked to poor dietary habits [9]. In general, DPs focus on the impact of the whole diet rather than examining individual nutrients and products within that diet, which could provide a stronger format to understand the complex relationship between diet and health [10,11]. Despite many studies of DPs among different populations, the food intake and diet quality of esports players have not been studied. Therefore, the purpose of this study was to describe the DPs of esports players in terms of the frequency of consumption of products that potentially affect brain function.

## 2. Materials and Methods

### 2.1. Participants and Survey Tools

This study was conducted in a group of 233 male esports players, 18–26 years (mean age was  $20.5 \pm 2.0$ ), from 2019 to 2021. The cohort was considered well-trained, which we defined as receiving gratification and training under the supervision of a trainer ( $n = 47$ ;



20.2%), and some were semi-professional players ( $n = 186$ ; 79.8%). The participants' average body mass was  $76.3 \pm 15.8$  kg, and their height was  $180.3 \pm 6.3$  cm. The inclusion criteria were: men, age  $\geq 17$  years, training and playing in esports for at least 3 years. The players represented diverse genres of games, such as Counter Strike: Global Offensive (CS:GO) (69.1%) and League of Legends (LOL) (30.9%). The average playing time was 4–6 h per day. Study data were obtained via self-administered, anonymous dietary questionnaires assessing dietary habits and frequency of food consumption. Additional socio-demographic information was collected by surveys, such as gender, age, weight, height, sport status, training experience and esports games. The study focus was on the assessment of dietary habits, i.e., the number and regularity of meals consumed, the frequency of eating meals, the composition of snacks eaten, the type of milk and milk products consumed, the type of culinary techniques used to prepare meat dishes, the type of fat used to spread and fry meals, sweetening of hot drinks and salting of food, the type of water consumed during the day, last meal practices and daily fluid consumption used the KomPAN questionnaire (part A) [12].

To assess the food consumption frequency of participants, we implemented a modified questionnaire based on the International Food Frequency Questionnaires (FFQ), Harvard Food Frequency [13] and National Health and Nutrition Examination Survey (NHANES) [14]. The FFQ was translated from English into Polish and adapted to reflect the Polish diet by adding the usual foods consumed in Poland to each section. In order to retain international comparability, part of the food items was kept. The adaptations were related to products, which potentially impact positively or negatively on brain function. Each food item in FFQ had assigned a portion size as grams or home measures (using a detailed table of home measures and grams of foods and selected food). The frequency of consumption scale was increased from 1 to 7, and portion sizes (e.g., average portion) were specified in each product. The FFQ consisted of 145 food items consumed during meals and between meals, at home and outside. It was used to assess the dietary intake of participants over the previous year. Briefly, the questionnaire contained 15 categories of foods and beverages: unsweetened drinks and soups (7 items); vegetables and vegetable preserves including vegetable juices (25 items); fruit and fruit preserves including fruit juices (17 items); legumes and legumes preserves (7 items); cereal products, potatoes, flour and potato dishes (14 items); milk and dairy products (13 items); meat and meat products (10); fishes and seafood (11 items); eggs (1 item); vegetable fats, nuts and seeds (21 items); animal fats (2); sugar and confectionery (2); other drinks—sweetened, energizing, alcohol (8 items); spices (5 items) and fast food (2 items). The food items in the FFQ were categorized into 37 food groups. The FFQ uses a seven-point scale of frequency of consumption, as follows: never/less than once a month (1), 1–3 times a month (2), once/twice a week (3), a few times a week (4), once a day (5), 2–3 times a day (6) and 4–5 times a day (7). For each food and beverage item, participants were asked to quantify their frequency of consumption in an open-ended format (using one of the seven options). To interpret the average values of the frequency of consumption, the following rankings were used: never/less than once a month (1–1.49), 1–3 times a month (1.5–2.49), once/twice a week (2.5–3.49), a few times a week (3.5–4.49), once a day (4.5–5.49), 2–3 times a day (5.5–6.49) and 4–5 times a day (6.5–7.00).

## 2.2. Derivation of Dietary Patterns

DPs were empirically extracted using factor analysis (FA) of principal components (PCA), which is a multivariate statistical procedure. The 145 items from the FFQ were aggregated into 37 mutually exclusive food groups and individual food items. The frequency of consumption of the 37 food groups constituted the output factors of the variable base. Where appropriate, the Kaiser–Meyer–Olkin (KMO) test (to verify method applicability) and Bartlett's test of sphericity (to test the null hypothesis of no relationship between variables) were carried out [15,16]. The KMO value was 0.82, and the significance of Bartlett's Sphericity was below 0.001, indicating that FA was appropriate to use. Varimax orthogonal

rotation was performed to maintain independent factors while improving interpretability. We identified the main factors (i.e., DPs) according to the eigenvalue ( $>1$ ), a scree plot (Figure A1), factor interpretability and the proportion of variance explained by each factor [17]. The first 11 factors were identified, each accounting for at least 61.27% of the model variance. Food items with absolute factor loadings  $\geq 0.40$  were considered representative of each DP. Indeed, a 0.40 cut-off implied a minimum contribution of any factor to any food group's total variance. Ultimately, 9 predominant factors constituting the DPs were subject to further analysis. Interpretation of the remaining factors was abandoned because they were made up of individual products. The total contribution of the dietary profiles in explaining model variance was 54.97%. The higher the values of the factor loadings, the stronger the association between a participant's diet and the DP. The DPs were named according to the magnitude of the factor scores, published studies, cultural aspects and interpretability of the overall diet.

### 2.3. Statistical and Data Analyses

The statistical analyses were carried out using IBM SPSS 21<sup>®</sup> software (IBM Corp., Armonk, NY, USA). Descriptive statistics were computed for all questions. Data are presented as numbers (n) and percentages (%) for qualitative data (categorical, nominal), whereas quantitative data are presented as means (M) and standard deviations (SD).

## 3. Results

### 3.1. Dietary Habits of the Study Subjects

A majority of the esports players had at least 3 meals per day (40.87%), followed by 45.21% who had greater than 3 meals per day. At the same time, 39.13% of respondents ate between meals at least once a day. The survey results demonstrated that only 10.43% of the sample ingested regular meals. A minority of esports players (31.30%) consumed their last meal 2–3 h before going to bed, but nearly 68.66% did not follow this recommendation. In terms of the type of snacks consumed, nearly 41.74% of respondents used fruit, but only every tenth esports player ate vegetables, and 12.17% of the sample consumed different types of nuts and oil seeds. On average, every third participant reached for sweets (39.13%) and salted snacks (28.70%). One in three participants reported using quick-cooking products five or more times a month, but almost 25% do not consume them at all. Consumption of milk and dairy products with standard fat content was declared by a higher percentage of esports players (66.09%) than those using products with a reduced fat content (27.83%). Regarding the less healthy culinary techniques, most of the respondents reported preparing meat dishes by frying (80.87%), followed by baking (53.04%) and boiling (45.22%). Only every third of the participants chose to grill to prepare meat dishes. Usually, the e-athletes used mainly vegetable fats (47.83%) for frying meals. The majority of respondents (56.90%) declared using butter to prepare sandwiches. Every second contestant claimed to sweeten hot drinks such as coffee, tea and cocoa with at least two teaspoons of sugar. A similar percentage of esports players indicated occasional salting of dishes and sandwiches (47.83%), but some did not follow this custom (40.00%). It was found that the majority of e-athletes (62.61%) drank at least 1.5–2 L of fluids a day, with a preference for non-sparkling water (69.57%) than sparkling water or fluids with additives. More detailed data are included in Table A1 of Appendix A.

### 3.2. Food Frequency Questionnaires

Table 1 presents the results of the frequency of food consumption that arguably, have a positive influence on brain function. The highest frequency of consumption was indicated for mineral water ( $5.56 \pm 1.65$ ), which was usually taken at least 2–3 times a day by nearly 2/3 of the respondents (Table A2). This food item was followed by hot beverages, spices, table and spring water, fruits, vegetables, milk, white meat dishes and eggs, usually consumed several times a week or more frequently by most of the esports players (55.36–71.67%). At the same time, vegetables were consumed at least 2–3 times a day by



only 9.87% of e-athlete and milk (including flavored milks, cocoa, and coffee with milk) was consumed by 12.45%. Potatoes, olive oil and rapeseed oils, fruit juices, fermented milk drinks, buckwheats, other whole grains, cereals, whole grain pasta and whole grain bread were ingested once or twice a week. Less than a third of the respondents used olive oil or rapeseed oil as a cooking additive several times a week ( $3.33 \pm 1.43$ ). Only every tenth respondent chose yogurts and kefir at least once a day, while 1/4 of the sample consumed these products exactly 1–2 times a week or several times a week. An equally low percentage of people observed the consumption of wholegrain bread—only 10% of respondents chose this product at least once a day ( $2.59 \pm 1.53$ ). Most, as many as 1/3 of the sample, did not include it in their diet or used it less frequently than once a month. Meanwhile, only 1/3 of the group consumed buckwheats, other whole grains, cereals and whole grain pasta at least several times a week ( $2.87 \pm 1.24$ ).

**Table 1.** The average consumption frequency (frequency/day) of food items positively influencing brain function.

| Food Items                                                    | M    | SD   |
|---------------------------------------------------------------|------|------|
| Mineral water                                                 | 5.56 | 1.65 |
| Hot beverages (tea, coffee, herb or fruit infusions)          | 4.39 | 1.63 |
| Spices                                                        | 4.06 | 1.63 |
| Table water, spring water                                     | 4.03 | 2.39 |
| Fruits                                                        | 4.00 | 1.30 |
| Vegetables                                                    | 4.00 | 1.26 |
| Milk (flavored milks, cocoa, coffee with milk)                | 3.96 | 1.40 |
| White meat dishes (chicken, turkey, rabbit)                   | 3.68 | 1.07 |
| Eggs                                                          | 3.53 | 1.17 |
| Potatoes (excluding fries and chips)                          | 3.34 | 1.10 |
| Olive oil and rapeseed oils                                   | 3.33 | 1.43 |
| Fruit juices                                                  | 3.27 | 1.41 |
| Fermented milk drinks (yoghurt, kefir)                        | 2.95 | 1.39 |
| Buckwheats, other whole grains, cereals, whole grain pasta    | 2.87 | 1.24 |
| Whole grain bread                                             | 2.59 | 1.53 |
| Cottage cheese (homogenized cheese, cheese deserts)           | 2.41 | 1.28 |
| Fishes                                                        | 2.40 | 1.10 |
| Nuts, pumpkin seeds, sunflower seeds and other oil seeds      | 2.38 | 1.25 |
| Legumes or dishes from legume seeds (beans, peas, lens, soya) | 2.12 | 1.13 |
| Vegetable or vegetable-fruit juices                           | 1.99 | 1.25 |
| Vegetable canned, marinated or pickled vegetable              | 1.75 | 1.08 |

M—arithmetic mean; SD—standard deviation.

The least frequently consumed products (1–3 times a month) were cottage cheese, fish, nuts, pumpkin seeds, sunflower seeds and other oil seeds, legumes or dishes from legumes, vegetable or vegetable-fruit juices and vegetable canned, marinated or pickled vegetables (Table 1). Only 7.30% of respondents used nuts and oilseeds at least once a day, and the vast majority of esports players (59.23%) consumed them less than 1–3 times a month (Table A2). The participants rarely, on average 1–3 times a month, chose fish to eat ( $2.83 \pm 0.93$ ), and less than half of the sample (43.78%) consumed them 1–2 times a week or several times a week. Legumes ( $2.12 \pm 1.13$ ) were included in the diets of most competitors (67.81%), never or rarely, i.e., 1–3 times a month or less (Tables 1 and A2).

Table 2 presents the results concerning the frequency of consumption of products with an adverse effect on brain function. The participants most often consumed light bread, wheat, rye, mixed wheat and rye bread, toast, rolls and rogals ( $4.85 \pm 1.29$ ), with a lower frequency of consumption for margarine or mixes ( $2.27 \pm 1.54$ ), lard/coconut oil ( $2.17 \pm 1.42$ ), alcohol drinks ( $1.99 \pm 1.03$ ), powder soups or ready soups ( $1.88 \pm 1.10$ ) and meat canners ( $1.52 \pm 0.95$ ). The survey revealed that as many as 66.52% of respondents ate processed cereal products once a day or more. Other food products, such as fried food, meats and pork sausages, cheese, white rice, standard pasta and fine groats and sweets, were taken on average several times a week by most competitors (54.94–75.54%) (Table A3).

**Table 2.** The average consumption frequency (frequency/day) of food items negatively influencing brain function.

| Food Items                                                                               | M    | SD   |
|------------------------------------------------------------------------------------------|------|------|
| Light bread (wheat, rye, mixed wheat and rye bread, toast, rolls, rogals)                | 4.85 | 1.29 |
| Fried food (meat or flour)                                                               | 3.93 | 1.05 |
| Meats, pork sausages                                                                     | 3.86 | 1.33 |
| Cheese (molded cheese, blue cheese)                                                      | 3.67 | 1.35 |
| White rice, standard pasta, fine groats (manna, cuscus)                                  | 3.61 | 1.04 |
| Sweets (cookies, cakes, chocolate bars, 'muesli' types and other confectionery products) | 3.52 | 1.25 |
| Sweet carbonated or non-carbonated beverages (coca-cola, pepsi, sprite, fanta, lemonade) | 3.39 | 1.56 |
| Meat, sausage, poultry and veal                                                          | 3.21 | 1.32 |
| Fast food (fries, hamburgers, pizza, chips)                                              | 2.88 | 1.07 |
| Red meat dishes (pork, beef, veal, lamb, venison)                                        | 2.73 | 1.24 |
| Energy drinks (red bull, shot, black horse and others)                                   | 2.69 | 1.44 |
| Margarine or mixes with butter and margarine                                             | 2.27 | 1.54 |
| Lard/coconut oil                                                                         | 2.17 | 1.42 |
| Alcohol drinks                                                                           | 1.99 | 1.03 |
| Powder soups or ready soups (can, jar, concentrated) not including frozen soups          | 1.88 | 1.10 |
| Canned meat                                                                              | 1.52 | 0.95 |

M—arithmetic mean; SD—standard deviation.

Less frequently (i.e., 1–2 times a week), the respondents drank sweet carbonated or non-carbonated beverages ( $3.39 \pm 1.56$ ). Moreover, every fourth e-athletes used these products several times a week. Also, a similar frequency of consumption was noted for fast foods ( $2.88 \pm 1.07$ ), red meat dishes ( $2.73 \pm 1.24$ ) and energy drinks ( $2.69 \pm 1.44$ ), which were consumed at least 1–2 times a week by less than 50% of respondents. Interestingly, every fourth e-gamer never or very rarely consumed energizing drinks (Tables 2 and A3).

### 3.3. Dietary Pattern Characterization

Nine DPs were identified and labeled: pattern one—'Almost healthy', pattern two—'Western fast food', pattern three—'High-processed food, meat and confectionery', pattern four—'Sweet', pattern five—'Fat-dairy products', pattern six—'Vegetable-fruit', pattern seven—'Spices and additives', pattern eight—'Fats' and pattern nine—'Cereal'. These patterns explained the total variance of 9.47%, 9.22%, 7.14%, 5.81%, 5.56%, 5.34%, 4.61%, 4.08% and 3.73% respectively (Table 3). Pattern one: 'Almost healthy' was characterized by white rice, standard pasta, fine groats (manna, cuscus), whole grain bread, white meat dishes (chicken, turkey, rabbit), vegetables, and eggs which were eaten several times a week

on average, fishes, nuts, pumpkin seeds, sunflower seeds and other oil seeds, legumes or dishes from legume seeds (beans, peas, lens, soya) and cottage cheese (homogenized cheese, cheese deserts) which were eaten 1–3 times a month. Pattern two: ‘Western fast food/Unhealthy’ included fast food (fries, hamburgers, pizza, chips) consumed on average 1–2 times a week, legumes or dishes from legume seeds (beans, peas, lens, soya), canned meat, vegetable canned, marinated or pickled vegetable, vegetable or vegetable-fruit juices, powder soups or ready soups (can, jar, concentrated) and alcohol drinks eaten less frequently, i.e., 1–3 times a month on average. Pattern three: ‘High-processed food, meat and confectionery’ was characterized by intake of light bread (wheat, rye, mixed wheat and rye bread, toast, rolls, rogals) consumed at least once a day, meats, pork sausages, fried food (meat or flour) and sweets (cookies, cakes, chocolate bars, ‘muesli’ types and other confectionery products, consumed on average several times a week and meat, sausage, poultry and veal eaten on average 1–2 times a week. Pattern four: ‘Sweet’ included sweets (cookies, cakes, chocolate bars, ‘muesli’ types and other confectionery products) consumed on average several times a week and sweet carbonated or non-carbonated beverages (Coca-cola, Pepsi, Sprite, Fanta, lemonade), energy drinks (red bull, shot, black horse and others) which were eaten less frequently, i.e., 1–2 times a week. Pattern five: ‘Fatty-diary products’ was characterized by intake of cheese (molded cheese, blue cheese) on average several times a week, fermented milk drinks (yogurt, kefir) consumed 1–2 times a week, and cottage cheese (homogenized cheese, cheese deserts) which were consumed less often, i.e., 1–3 times a month. Pattern six: ‘Vegetable-fruit’ included vegetables, fruits and hot beverages (tea, coffee, herb or fruit infusions), which were eaten on average several times a week, and fruit juices, consumed 1–2 times a week. Pattern 7: ‘Spices and food additives/oils’ was characterized by intake of spices, which were consumed on average several times a week, and olive oil and rapeseed oils eaten less often, i.e., 1–2 times a week. Pattern eight: ‘Fats’ included margarine or mixes with butter and margarine and lard/coconut oil, rarely consumed 1–3 times a month on average. Pattern nine: ‘Cereal’ was characterized by a higher consumption of buckwheats, other whole grains, cereals, whole grain pasta and a lower consumption of lard and coconut oil.

**Table 3.** Factor loading matrix for the nine major dietary patterns identified from the Food Frequency Questionnaire (FFQ).

|                                                                                 | Dietary Patterns (n = 233) |                   |                                             |        |                    |                 |                      |        |        |
|---------------------------------------------------------------------------------|----------------------------|-------------------|---------------------------------------------|--------|--------------------|-----------------|----------------------|--------|--------|
|                                                                                 | Almost Healthy             | Western Fast Food | High-Processed Food, Meat and Confectionery | Sweet  | Fat-diary Products | Vegetable-Fruit | Spices and Additives | Fats   | Cereal |
| <b>Variance explained (%)</b>                                                   | 9.47                       | 9.22              | 7.14                                        | 5.81   | 5.56               | 5.34            | 4.61                 | 4.08   | 3.73   |
| <b>Food and food products</b>                                                   | <b>Factor loadings</b>     |                   |                                             |        |                    |                 |                      |        |        |
| White rice, standard pasta, fine groats (manna, cuscus)                         | <b>0.663</b>               | −0.001            | −0.097                                      | 0.040  | 0.048              | 0.027           | 0.056                | −0.035 | 0.107  |
| Whole grain bread                                                               | <b>0.645</b>               | 0.133             | 0.027                                       | −0.062 | 0.156              | −0.035          | −0.147               | 0.066  | 0.265  |
| White meat dishes (chicken, turkey, rabbit)                                     | <b>0.644</b>               | 0.065             | 0.293                                       | 0.172  | −0.049             | 0.051           | 0.174                | −0.019 | −0.187 |
| Fishes                                                                          | <b>0.531</b>               | 0.344             | 0.204                                       | −0.073 | −0.078             | 0.049           | 0.081                | 0.034  | 0.127  |
| Nuts, pumpkin seeds, sunflower seeds and other oil seeds                        | <b>0.487</b>               | 0.213             | −0.028                                      | −0.094 | −0.092             | 0.142           | 0.123                | 0.313  | 0.145  |
| Legumes or dishes from legume seeds (beans, peas, lens, soya)                   | <b>0.476</b>               | <b>0.414</b>      | 0.136                                       | −0.153 | 0.150              | 0.145           | 0.051                | 0.092  | 0.179  |
| Vegetables                                                                      | <b>0.435</b>               | 0.112             | 0.130                                       | −0.105 | 0.017              | <b>0.426</b>    | 0.351                | −0.069 | 0.119  |
| Eggs                                                                            | <b>0.403</b>               | 0.082             | 0.149                                       | 0.002  | 0.286              | −0.007          | 0.196                | 0.263  | −0.080 |
| Canned meat                                                                     | 0.258                      | <b>0.680</b>      | 0.103                                       | 0.142  | 0.132              | 0.006           | −0.015               | 0.101  | 0.111  |
| Vegetable canned, marinated or pickled vegetable                                | 0.261                      | <b>0.679</b>      | 0.172                                       | −0.094 | 0.154              | 0.028           | 0.101                | 0.124  | 0.071  |
| Vegetable or vegetable-fruit juices                                             | −0.091                     | <b>0.662</b>      | 0.153                                       | 0.012  | −0.004             | 0.316           | 0.004                | 0.011  | 0.190  |
| Powder soups or ready soups (can, jar, concentrated) not including frozen soups | 0.106                      | <b>0.598</b>      | 0.083                                       | 0.273  | 0.137              | 0.014           | −0.099               | 0.194  | −0.011 |
| Fast food (fries, hamburgers, pizza, chips)                                     | 0.058                      | <b>0.522</b>      | 0.099                                       | 0.388  | −0.156             | −0.152          | −0.079               | −0.048 | −0.098 |
| Alcohol drinks                                                                  | 0.097                      | <b>0.402</b>      | −0.136                                      | 0.152  | −0.002             | 0.007           | 0.164                | 0.091  | −0.071 |

Table 3. Cont.

|                                                                                          | Dietary Patterns (n = 233) |                   |                                             |              |                    |                 |                      |        |        |
|------------------------------------------------------------------------------------------|----------------------------|-------------------|---------------------------------------------|--------------|--------------------|-----------------|----------------------|--------|--------|
|                                                                                          | Almost Healthy             | Western Fast Food | High-Processed Food, Meat and Confectionery | Sweet        | Fat-diary Products | Vegetable-Fruit | Spices and Additives | Fats   | Cereal |
| Red meat dishes (pork, beef, veal, lamb, venison)                                        | 0.355                      | 0.368             | 0.338                                       | 0.122        | 0.003              | 0.139           | −0.104               | −0.108 | −0.205 |
| Meats, pork sausages                                                                     | 0.070                      | 0.137             | <b>0.739</b>                                | 0.060        | 0.207              | 0.067           | 0.072                | 0.172  | −0.038 |
| Meat, sausage, poultry and veal                                                          | 0.224                      | 0.193             | <b>0.636</b>                                | 0.043        | 0.135              | 0.076           | 0.141                | −0.045 | 0.073  |
| Light bread (wheat, rye, mixed wheat and rye bread, toast, rolls, rogals)                | −0.098                     | −0.038            | <b>0.621</b>                                | −0.067       | 0.155              | 0.300           | −0.187               | 0.169  | 0.073  |
| Fried food (meat tor flour)                                                              | 0.145                      | 0.182             | <b>0.480</b>                                | 0.276        | −0.004             | −0.076          | 0.152                | 0.106  | 0.001  |
| Sweet carbonated or non-carbonated beverages (coca-cola, pepsi, sprite, fanta, lemonade) | −0.163                     | 0.147             | 0.165                                       | <b>0.812</b> | −0.095             | 0.075           | 0.074                | 0.128  | −0.070 |
| Energy drinks (red bull, shot, black horse and others)                                   | −0.034                     | 0.250             | −0.088                                      | <b>0.774</b> | 0.179              | 0.012           | −0.090               | 0.021  | 0.110  |
| Sweets (cookies, cakes, chocolate bars, ‘muesli’ types and other confectionery products) | 0.150                      | −0.041            | <b>0.409</b>                                | <b>0.503</b> | 0.053              | 0.066           | 0.035                | −0.024 | 0.030  |
| Milk (flavored milks, cocoa, coffee with milk)                                           | −0.016                     | −0.068            | 0.130                                       | 0.036        | <b>0.751</b>       | 0.054           | −0.009               | 0.097  | 0.056  |
| Fermented milk drinks (yoghurt, kefir)                                                   | 0.182                      | 0.260             | 0.099                                       | 0.003        | <b>0.661</b>       | 0.208           | 0.069                | −0.228 | 0.045  |
| Cheese (molded cheese, blue cheese)                                                      | −0.081                     | 0.185             | 0.335                                       | 0.074        | <b>0.515</b>       | 0.077           | 0.216                | 0.183  | 0.098  |
| Cottage cheese (homogenized cheese, cheese deserts)                                      | <b>0.461</b>               | 0.316             | 0.159                                       | −0.007       | <b>0.468</b>       | 0.010           | 0.068                | 0.105  | −0.013 |
| Hot beverages (tea, coffee, herb or fruit infusions)                                     | 0.184                      | −0.274            | −0.141                                      | 0.174        | 0.374              | <b>0.660</b>    | 0.100                | 0.256  | −0.167 |
| Fruit juices                                                                             | −0.143                     | 0.367             | 0.200                                       | 0.214        | 0.055              | <b>0.626</b>    | 0.145                | 0.042  | 0.043  |



Table 3. Cont.

|                                                            | Dietary Patterns (n = 233) |                   |                                             |        |                    |                 |                      |              |              |
|------------------------------------------------------------|----------------------------|-------------------|---------------------------------------------|--------|--------------------|-----------------|----------------------|--------------|--------------|
|                                                            | Almost Healthy             | Western Fast Food | High-Processed Food, Meat and Confectionery | Sweet  | Fat-dairy Products | Vegetable-Fruit | Spices and Additives | Fats         | Cereal       |
| Fruits                                                     | 0.374                      | 0.103             | 0.225                                       | −0.187 | 0.051              | <b>0.608</b>    | 0.089                | −0.095       | 0.208        |
| Potatoes (excluding fries and chips)                       | 0.063                      | 0.094             | 0.211                                       | 0.057  | 0.186              | 0.348           | 0.075                | 0.295        | 0.219        |
| Spices                                                     | 0.002                      | 0.010             | −0.026                                      | 0.001  | 0.121              | 0.226           | <b>0.864</b>         | −0.067       | −0.097       |
| Olive oil and rapeseed oils                                | 0.345                      | −0.005            | 0.219                                       | −0.004 | 0.045              | −0.005          | <b>0.615</b>         | 0.121        | 0.086        |
| Margarine or mixes with butter and margarine               | 0.017                      | 0.289             | 0.271                                       | 0.063  | 0.048              | 0.142           | −0.126               | <b>0.758</b> | −0.132       |
| Lard /coconut oil                                          | 0.249                      | 0.168             | 0.057                                       | 0.207  | 0.064              | −0.122          | 0.219                | <b>0.534</b> | <b>0.429</b> |
| Buckwheats, other whole grains, cereals, whole grain pasta | 0.268                      | 0.096             | 0.028                                       | 0.019  | 0.083              | 0.172           | −0.067               | −0.029       | <b>0.822</b> |
| Mineral water                                              | 0.053                      | −0.029            | 0.068                                       | −0.073 | 0.019              | 0.016           | −0.021               | 0.018        | 0.035        |
| Table water, spring water                                  | −0.011                     | 0.116             | 0.123                                       | −0.059 | −0.015             | 0.011           | 0.088                | 0.002        | 0.057        |

Factor loadings with absolute values > 0.40 are in bold; Method of extracting factors—main components; Rotation method—*Varimax* with Kaiser normalization.

#### 4. Discussion

To our knowledge, this study is the first attempt to identify and characterize DPs among Polish professional and semi-professional esports players, taking into account potential beneficial and detrimental products for brain health. There is sufficient evidence that has investigated the relationship between specific nutrients and brain function [18–20]. Based on the obtained data from previous studies, we have divided products with beneficial and adverse effects on brain function (Tables 1 and 2). Using factors analysis, the main nine DPs were identified. Among them, eight were unhealthy, and one was considered as healthy.

High cognitive abilities (intelligence, perception, spatial orientation, attention, and dual-tasking) are required for many esports games, such as League of Legends and Counter-Strike: Global Offensive [21,22]. So far, a limited number of studies have focused on describing the cognition abilities of esports players [23–25].

Defining a healthy DP is important for creating dietary guidelines and defining practices to monitor and improve diet quality, both at the individual level and for the general population [26]. Adherence to the Mediterranean diet (MeDi) pattern in middle-aged and elderly populations correlates with better cognitive abilities [27–29]. Our list (Table 1) is consistent with the main characteristics of MeDi, including consumption of fruits, vegetables, olive oils, whole grains products, fish, low-fat milk products, poultry, tea, coffee and reduced consumption of red meat, sausages and refined cereals, which negatively impact on brain function (Table 2) [30].

An ‘Almost healthy’ DP is characterized by high-frequency consumption of white meat and vegetables, which are potentially associated with better brain function (Table 1). Other foods in this pattern, such as white rice, standard pasta and fine groats, were consumed less frequently, and their possible impact on brain function was identified as being negative (Table 2).

‘Western food’ mainly consists of fast-food products such as fried chips, hamburgers, pizzas and potato chips, which are part of the Western diet (WD). Western DPs consist of a high intake of fats, carbohydrates, processed foods and red meats (as a source of protein) with a reduced intake of fruits and vegetables [31,32]. In previous studies among young adults, western patterns have also been identified [33–37]. Long-term adherence to habitual consumption of WD contributes to the development of metabolic diseases and psychological problems [38,39]. A growing body of evidence has demonstrated associations between Western DP and cognitive function [40–42]. Altering the composition of gut microbiota and interactions among the brain-axis can negatively affect brain function [38]. Experimental studies conducted on animals, and a few on humans, have shown that the excessive intake of WD can lead to hippocampal dysfunction and, consequently, to cognitive impairments [42,43].

The next two identified DPs also represent the westernized diet. ‘High-processed food, meat and confectionery’ DP is characterized by frequent high consumption of light bread and less frequently consumed fried food, meats, pork and sweets. This pattern resembles traditional Polish cuisine, with white flour products, fried foods, fatty meats and sweets [44,45]. Frequent ingestion of the above-mentioned products is detrimental to health and brain functions (Table 2). ‘Sweet’ DP is based on a high-frequency intake of sweets and less frequent consumption of sweet carbonated, non-carbonated beverages and energy drinks. ‘Fatty-dairy products’ DP included a high intake of different types of cheese and other dairy products, which were consumed less often. Some findings suggest that there are associations between frequent dairy foods intakes with better cognition [46]. One recent report of a study involving esports players aged 16–36 years found no link between dairy intake and cognitive performance [47].

‘Vegetable-fruit’ DP represents a healthy DP, consisting of a high frequency of vegetables, fruits and hot beverages (tea, coffee, herb) or fruit infusions, although fruit juices are consumed with lower frequency. Fruits and beverages such as tea and coffee are the main sources of dietary polyphenols, which have a positive effect on cognition and memory [19,48,49]. However, one study found that habitual coffee and tea drinking had mixed effects on cognitive improvement [50]. Scientific evidence confirmed that adequate vegetable and fruit consumption has a beneficial influence on health and can prevent cognitive impairment due to the presence of antioxidants and anti-inflammatory factors [51,52].

The positive cognitive effects of bioactive compounds also depend, in part, on portion sizes and frequency of consumption [53]. Essaw et al. concluded that young undergraduate students do not consume fruits and vegetables every day due to a higher cost compared to other foods [54]. ‘Spices and food additives’ DP are characterized by the intake of spices on average several times a week and less consumption of olive oil and rapeseed oils. There are findings that the effects of herbs and plant ingredients may positively affect cognitive performance and memory, but there is a need for further research [19,55].

Some evidence supports the idea that the consumption of extra-virgin olive oils can promote brain health and prevent cognitive decline [56]. ‘Fats’ DP consisted of frequent intake of margarine or mixes with butter and margarine and lard with rarely consumed coconut oil. A diet rich in trans isomers (TFAs) and saturated fatty acids (SFAs) may carry a risk of cognitive disorders [57]. In contrast, the consumption of omega-3 fatty acids, which are components of cell membranes, can promote normal cerebral functions and cognitive abilities [17,58]. Omega-3 fatty acids could prevent cognitive decline, but confirmatory evidence is scarce [59]. Sánchez-Villegas et al. indicated the relationship between TFAs consumption and depression risk among Spanish university graduates, while a weak inverse was noted for monounsaturated fatty acids (MUFAs), polyunsaturated fatty acids (PUFAs) and olive oil [60]. ‘Cereal’ DP is characterized by a higher consumption of buckwheat, other whole grains, cereals, and whole grain pasta and a lower consumption of lard and coconut oil. The consumption of whole grains is a part of healthy DPs. Whole grains are a source of dietary fiber, antioxidants, minerals and vitamins, as well as other components such as phytates and phytoestrogens [61]. Currently, no studies have evaluated the impact of whole grain consumption on the cognitive function of young adults. So far, exposure to refined carbohydrates (early in life) has been associated with neurocognitive deficits in later life [62].

Our results showed that the majority of Polish esports players consumed at least three meals a day. Similar results were obtained by Baumann et al. for Norwegian esports students aged 17–21 years, who consumed three to four meals per day [6]. A large group of esports players declared regularity of some meals (47.83%), while irregularity of all eating meals claimed 41.74%. According to Polish nutritional dietary guidelines, 2–3 h intervals between meal consumptions are appropriate [63]. A minority of the esports players (31.30%) consumed their last meal 2–3 h before going to bed, but nearly 68.66% did not follow this dietary guideline. Snacking between meals was also a common feature. Most participants declared that they reached for fruits and sweets when snacking. According to Newzoo’s report, 64% of e-athletes aged 10–65 years in Latin America, North America and Western Europe were regularly consuming salty snacks while playing games, while sweet snacks were followed by soft drinks [64]. Snacking may be caused by irregular eating or low-energy values of meals. In terms of culinary techniques, over 80% of participants declared preparing dishes using frying, and over half chose baking. The participants were asked about the addition of salt to dishes, with around half (47.83%) reporting occasional salting of dishes and sandwiches. The high content of salt in dishes can have a negative impact on blood pressure, which is linked to the risk of cardiovascular diseases [65,66] and, according to actual dietary guidelines, should be limited to 5 g per day [66]. Every second esports player confirmed adding at least two teaspoons of sugar to hot beverages such as tea, coffee or cocoa. Eating excessive amounts of added sugars in a diet, coupled with a sedentary lifestyle, may lead to increased body mass (e.g., body fat) that, in turn, has other health implications. The positive fact is that minimal consumption (1.5–2 L per day) of mineral water was declared by over half participants.

#### Limitations

Dietary assessment methods can represent measurement error due to the unreliability of survey participants’ responses. Consequently, we acknowledge that the food and frequency data reported in the present study may be lower or higher than that actually consumed. In addition, our sample was restricted to male esports athletes. Another potential limitation was the lack of information between the reported DPs and tangible health outcomes, such as daily physical activity or more direct measures of cognitive performance reflecting brain function.



In subsequent studies, we suggest calculating a coefficient of variation for each participant, based on their specific eating patterns, to more closely examine the relationship between eating patterns and health or cognitive performance. The current results could provide reference data for establishing norms for this population and planning future dietary interventions in this population.

## 5. Conclusions

Nine major DPs were identified among professional and semi-professional Polish esports players. This study found that e-athletes had mostly adherence to unhealthy dietary behaviors and common DPs related to poor dietary quality and high consumption of a high-calorie diet. One identified DP (Vegetable-Fruit) was considered as healthy, but eight DPs were deemed unhealthy and related to a traditional Western diet. Esports players were characterized by a low frequency of consumption of products with potential beneficial effects on brain function, such as fish, nuts, pumpkin seeds, sunflower seeds and other oil seeds. E-athletes were mostly characterized by unhealthy dietary habits that were associated with irregular eating of meals, frequent snacking, at least three meals a day and composition of snacks, the use of frying meat dishes and sweetening hot drinks. More healthy dietary habits included proper hydration during the day and consumption of mainly non-sparkling water. The unhealthy DPs in a group of e-athletes indicate the need to undertake future research assessing knowledge of healthy eating principles and the selection of products that show beneficial effects on brain function, taking into account other factors such as sociodemographics at the time.

**Author Contributions:** Conceptualization, M.S. and B.F.; methodology, M.S.; software, M.S.; validation, M.S.; formal analysis, M.S.; investigation, M.S.; resources, M.S.; data curation, F.T.; writing—original draft preparation, M.S. and B.F.; writing—review and editing, B.F. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest in the study.

## Appendix A

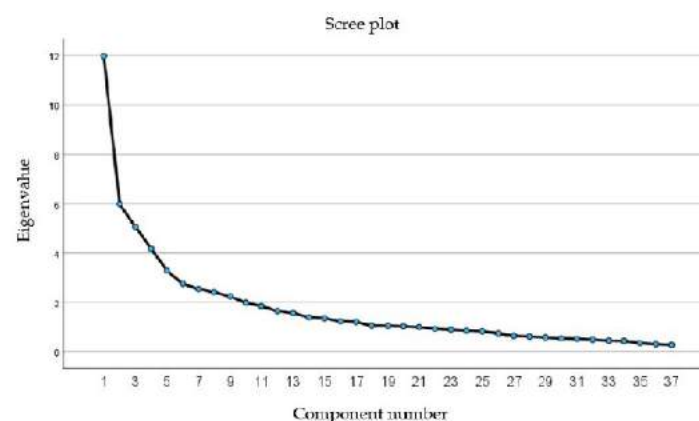


Figure A1. PCA scree plot.

Table A1. Esports players dietary habits—percentage response distribution.

| Dietary Habits                           |  | Responses                                                                                     | Percent |
|------------------------------------------|--|-----------------------------------------------------------------------------------------------|---------|
| Number of meals                          |  | 1 meal                                                                                        | 0.00    |
|                                          |  | 2 meals                                                                                       | 13.91   |
|                                          |  | 3 meals                                                                                       | 40.87   |
|                                          |  | 4 meals                                                                                       | 33.91   |
|                                          |  | 5 meals and more                                                                              | 11.30   |
| The frequency of eating between meals    |  | Never                                                                                         | 5.22    |
|                                          |  | 1–3 times a month                                                                             | 6.09    |
|                                          |  | Once a week                                                                                   | 13.04   |
|                                          |  | Several times a week                                                                          | 36.52   |
|                                          |  | Once a day                                                                                    | 22.61   |
|                                          |  | Several times a day                                                                           | 16.52   |
| The regularity of eating meals           |  | No                                                                                            | 41.74   |
|                                          |  | Yes, but only some                                                                            | 47.83   |
|                                          |  | Yes, all                                                                                      | 10.43   |
| Eating the last meal before going to bed |  | 2–3 h before bedtime                                                                          | 31.30   |
|                                          |  | Less than 2 h                                                                                 | 11.30   |
|                                          |  | There is no rule                                                                              | 57.39   |
| The composition of the snacks consumed   |  | Fruits                                                                                        | 41.74   |
|                                          |  | Vegetables                                                                                    | 9.57    |
|                                          |  | Unsweetened milk drinks and desserts, e.g., yoghurts, cottage cheese, milk                    | 18.26   |
|                                          |  | Sweetened milk drinks and desserts (homogenized cheese, sweetened milk drinks, flavored milk) | 21.74   |
|                                          |  | Sweet snacks, e.g., candies, cookies, cakes, chocolate bars, muesli bars, wafers              | 39.13   |
|                                          |  | Salty snacks, e.g., crackers, sticks, chips, chips                                            | 28.70   |



Table A1. Cont.

| Dietary Habits                                                                  | Responses                                        | Percent |
|---------------------------------------------------------------------------------|--------------------------------------------------|---------|
| Use of fast-food products (instant soups, ready-made sauces, ready meals, etc.) | <i>Nuts, almonds, seeds, pips</i>                | 12.17   |
|                                                                                 | <i>Other products</i>                            | 9.57    |
|                                                                                 | <i>Never</i>                                     | 26.09   |
|                                                                                 | <i>Almost every day</i>                          | 5.22    |
|                                                                                 | <i>Often, i.e., several times a week</i>         | 8.70    |
|                                                                                 | <i>Sometimes, i.e., 5 or more times a month</i>  | 33.91   |
|                                                                                 | <i>Rarely, i.e., 3–4 times a month</i>           | 26.09   |
| The type of milk and milk drinks consumed                                       | <i>Standard fat (full fat)</i>                   | 66.09   |
|                                                                                 | <i>Low fat</i>                                   | 27.83   |
|                                                                                 | <i>Fat free</i>                                  | 0.87    |
|                                                                                 | <i>I don't eat dairy products</i>                | 5.22    |
| Culinary techniques used to prepare meat dishes                                 | <i>Boiled</i>                                    | 45.22   |
|                                                                                 | <i>Braised</i>                                   | 15.65   |
|                                                                                 | <i>Grilled</i>                                   | 30.43   |
|                                                                                 | <i>Baked</i>                                     | 53.04   |
|                                                                                 | <i>Fried</i>                                     | 80.87   |
|                                                                                 | <i>I don't eat meat</i>                          | 0.87    |
| The type of fat used to fry food                                                | <i>I do not use any frying fat</i>               | 6.96    |
|                                                                                 | <i>I use various fats</i>                        | 19.13   |
|                                                                                 | <i>I use vegetable oil (including olive oil)</i> | 47.83   |
|                                                                                 | <i>I use a margarine</i>                         | 3.48    |
|                                                                                 | <i>I use a butter</i>                            | 20.00   |
|                                                                                 | <i>I use lard</i>                                | 2.61    |

Table A1. Cont.

| Dietary Habits                                        | Responses                                                               | Percent |
|-------------------------------------------------------|-------------------------------------------------------------------------|---------|
| The use of fat as a spread                            | <i>I do not use any fat to spread my bread</i>                          | 21.55   |
|                                                       | <i>I use various fats</i>                                               | 9.48    |
|                                                       | <i>I use a mayonnaise</i>                                               | 1.72    |
|                                                       | <i>I use a margarine</i>                                                | 5.17    |
|                                                       | <i>I use a butter</i>                                                   | 56.90   |
|                                                       | <i>I use a mix butter with margarine</i>                                | 2.59    |
|                                                       | <i>I use lard</i>                                                       | 2.59    |
| Sweetening hot drinks (e.g., tea, coffee, cocoa)      | <i>No</i>                                                               | 20.87   |
|                                                       | <i>Yes, I sweeten it with one teaspoon of sugar (or honey)</i>          | 22.61   |
|                                                       | <i>Yes, I sweeten it with two or more teaspoons of sugar (or honey)</i> | 52.17   |
|                                                       | <i>Yes, I use sweeteners (low-energy sweeteners)</i>                    | 4.35    |
| The use of salt in dishes and sandwiches at the table | <i>No</i>                                                               | 47.83   |
|                                                       | <i>Yes, but only sometimes</i>                                          | 40.00   |
|                                                       | <i>Yes, I add salt in most of the dishes</i>                            | 12.17   |
|                                                       | <i>Less than 1 L (less than 4 glasses)</i>                              | 0.00    |
| Daily fluid intake                                    | <i>About 1.5 L (about 6 glasses)</i>                                    | 26.96   |
|                                                       | <i>About 2 L (about 8 glasses)</i>                                      | 35.65   |
|                                                       | <i>More than 2 L (more than 8 glasses)</i>                              | 37.39   |
| The type of water drunk                               | <i>I don't drink water</i>                                              | 0.87    |
|                                                       | <i>I drink non-sparkling water</i>                                      | 69.57   |
|                                                       | <i>I drink sparkling water</i>                                          | 24.35   |
|                                                       | <i>I drink flavored water</i>                                           | 5.22    |

**Table A2.** The frequency of food items consumption positively influences brain function—The distribution of responses.

| Food Items                                                    | The Frequency of Consumption of Food Products—the Percentage Distribution of the Response |       |       |       |       |       |       |
|---------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|
|                                                               | 1                                                                                         | 2     | 3     | 4     | 5     | 6     | 7     |
| Mineral water                                                 | 4.29                                                                                      | 2.15  | 5.58  | 10.73 | 15.88 | 21.46 | 39.91 |
| Hot beverages (tea, coffee, herb or fruit infusions)          | 6.87                                                                                      | 9.44  | 12.02 | 17.17 | 22.32 | 28.76 | 3.43  |
| Spices                                                        | 12.88                                                                                     | 3.86  | 14.16 | 26.18 | 23.61 | 15.45 | 3.86  |
| Table water, spring water                                     | 30.04                                                                                     | 4.29  | 5.58  | 13.73 | 10.30 | 11.59 | 24.46 |
| Fruits                                                        | 3.86                                                                                      | 8.15  | 20.60 | 34.33 | 19.31 | 12.45 | 1.29  |
| Vegetables                                                    | 4.72                                                                                      | 6.87  | 16.74 | 39.48 | 21.03 | 9.87  | 1.29  |
| Milk (flavored milks, cocoa, coffee with milk)                | 6.87                                                                                      | 9.01  | 15.88 | 31.76 | 24.03 | 11.16 | 1.29  |
| White meat dishes (chicken, turkey, rabbit)                   | 4.72                                                                                      | 7.73  | 21.46 | 50.64 | 13.73 | 0.00  | 1.72  |
| Eggs                                                          | 6.44                                                                                      | 10.73 | 27.47 | 37.77 | 14.16 | 3.00  | 0.43  |
| Potatoes (excluding fries and chips)                          | 7.73                                                                                      | 14.59 | 23.18 | 45.92 | 7.73  | 0.43  | 0.43  |
| Olive oil and rapeseed oils                                   | 43.35                                                                                     | 17.17 | 17.17 | 18.03 | 3.43  | 0.43  | 0.43  |
| Fruit juices                                                  | 11.59                                                                                     | 18.45 | 25.75 | 29.18 | 6.44  | 7.30  | 1.29  |
| Fermented milk drinks (yoghurt, kefir)                        | 18.88                                                                                     | 20.17 | 24.46 | 24.46 | 8.58  | 2.58  | 0.86  |
| Buckwheats, other whole grains, cereals, whole grain pasta    | 14.16                                                                                     | 26.18 | 29.61 | 21.89 | 5.15  | 2.58  | 0.43  |
| Whole grain bread                                             | 34.33                                                                                     | 20.60 | 12.88 | 21.89 | 5.15  | 4.72  | 0.43  |
| Cottage cheese (homogenized cheese, cheese deserts)           | 29.18                                                                                     | 30.04 | 19.74 | 14.16 | 5.58  | 0.86  | 0.43  |
| Fishes                                                        | 24.89                                                                                     | 28.76 | 31.33 | 12.45 | 2.15  | 0.00  | 0.43  |
| Nuts, pumpkin seeds, sunflower seeds and other oil seeds      | 27.47                                                                                     | 34.76 | 18.45 | 12.02 | 6.44  | 0.43  | 0.43  |
| Legumes or dishes from legume seeds (beans, peas, lens, soya) | 37.77                                                                                     | 30.04 | 17.60 | 12.02 | 2.15  | 0.43  | 0.00  |
| Vegetable or vegetable-fruit juices                           | 48.50                                                                                     | 24.89 | 12.45 | 9.44  | 2.58  | 2.15  | 0.00  |
| Vegetable canned, marinated or pickled vegetable              | 57.08                                                                                     | 21.89 | 13.30 | 5.58  | 1.29  | 0.43  | 0.43  |

Never less than once a month (1), 1–3 times a month (2), once /twice a week (3), a few times a week (4), once a day (5), 2–3 times a day (6), 4–5 times a day (7).

**Table A3.** The frequency of food items consumption negatively influences the brain function—the distribution of responses.

| Food Items                                                                               | The Frequency of Consumption of Food Products—The Percentage Distribution of the Response |       |       |       |       |       |      |
|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|------|
|                                                                                          | 1                                                                                         | 2     | 3     | 4     | 5     | 6     | 7    |
| Light bread (wheat, rye, mixed wheat and rye bread, toast, rolls, rogals)                | 1.72                                                                                      | 3.86  | 10.30 | 17.60 | 27.47 | 36.05 | 3.00 |
| Fried food (meat tor flour)                                                              | 3.00                                                                                      | 5.58  | 15.88 | 52.79 | 17.60 | 3.86  | 1.29 |
| Meats, pork sausages                                                                     | 6.44                                                                                      | 8.58  | 17.60 | 39.48 | 16.31 | 10.73 | 0.86 |
| Cheese (molded cheese, blue cheese)                                                      | 7.73                                                                                      | 11.59 | 22.32 | 31.76 | 18.45 | 7.73  | 0.43 |
| White rice, standard pasta, fine groats (manna, cuscus)                                  | 2.15                                                                                      | 10.30 | 30.90 | 42.49 | 9.44  | 4.29  | 0.43 |
| Sweets (cookies, cakes, chocolate bars, ‘muesli’ types and other confectionery products) | 6.01                                                                                      | 15.45 | 23.61 | 37.34 | 11.16 | 6.01  | 0.43 |
| Sweet carbonated or non-carbonated beverages (coca-cola, pepsi, sprite, fanta, lemonade) | 11.59                                                                                     | 19.74 | 22.32 | 26.61 | 8.15  | 7.73  | 3.86 |
| Meat, sausage, poultry and veal                                                          | 12.45                                                                                     | 18.45 | 23.18 | 32.62 | 9.01  | 3.86  | 0.43 |
| Fast food (fries, hamburgers, pizza, chips)                                              | 6.87                                                                                      | 33.48 | 31.33 | 23.18 | 3.43  | 1.29  | 0.43 |
| Red meat dishes (pork, beef, veal, lamb, venison)                                        | 16.31                                                                                     | 31.33 | 24.03 | 22.75 | 3.86  | 0.43  | 1.29 |
| Energy drinks (red bull, shot, black horse and others)                                   | 25.32                                                                                     | 24.03 | 24.03 | 15.88 | 6.01  | 3.43  | 1.29 |
| Margarine or mixes with butter and margarine                                             | 46.35                                                                                     | 19.74 | 10.30 | 13.30 | 5.15  | 4.72  | 0.43 |
| Lard/coconut oil                                                                         | 47.64                                                                                     | 20.17 | 9.44  | 16.31 | 4.29  | 1.29  | 0.86 |
| Alcohol drinks                                                                           | 37.34                                                                                     | 37.77 | 16.31 | 6.44  | 1.29  | 0.86  | 0.00 |
| Powder soups or ready soups (can, jar, concentrated) not including frozen soups          | 48.93                                                                                     | 28.33 | 11.59 | 7.73  | 3.43  | 0.00  | 0.00 |
| Canned meat                                                                              | 68.24                                                                                     | 20.60 | 4.72  | 4.29  | 1.72  | 0.43  | 0.00 |

Never/less than once a month (1), 1–3 times a month (2), once / twice a week (3), a few times a week (4), once a day (5), 2–3 times a day (6), 4–5 times a day (7).

## References

- Nagorsky, E.; Wiemeyer, J. The structure of performance and training in esports. *PLoS ONE* **2020**, *15*, e0237584. [CrossRef] [PubMed]
- Mangelaja, E. Economics of Esports. *Electron. J. Bus. Ethics Organ. Stud.* **2019**, *24*, 34–42.
- Giakoni-Ramírez, F.; Merellano-Navarro, E.; Duclos-Bastías, D. Professional Esports Players: Motivation and Physical Activity Levels. *Int. J. Environ. Res. Public Health* **2022**, *19*, 2256. [CrossRef]
- Pluss, M.A.; Bennett, K.J.M.; Novak, A.R.; Panchuk, D.; Coutts, A.J.; Fransen, J. Esports: The Chess of the 21st Century. *Front. Psychol.* **2019**, *10*, 156. [CrossRef]
- Hilvoorde, I.V.; Pot, N. Embodiment and fundamental motor skills in eSports. *Sport Ethics Philos.* **2016**, *10*, 14–27. [CrossRef]
- Baumann, A.; Mentzoni, R.A.; Erevik, E.; Pallesen, S. A qualitative study on Norwegian esports students' sleep, nutritional and physical activity habits and the link to health and performance. *Int. J. Esports* **2022**, *1*.
- Huth, C. Nutritional behaviour of (Non-) eSports players—A comparative study. *Qual. Sport* **2021**, *7*, 38–44. [CrossRef]
- Rudolf, K.; Bickmann, P.; Froböse, I.; Tholl, C.; Wechsler, K.; Grieben, C. Demographics and Health Behavior of Video Game and eSports Players in Germany: The eSports Study 2019. *Int. J. Environ. Res. Public Health* **2020**, *17*, 1870. [CrossRef] [PubMed]
- Chan, G.; Huo, Y.; Kelly, S.; Leung, J.; Tisdale, C.; Gullo, M. The impact of eSports and online video gaming on lifestyle behaviours in youth: A systematic review. *Comput. Hum. Behav.* **2022**, *126*, 106974. [CrossRef]
- Hu, F.B. Dietary pattern analysis: A new direction in nutritional epidemiology. *Curr. Opin. Lipidol.* **2002**, *13*, 3–9. [CrossRef]
- Herbeth, B.; Samara, A.; Stathopoulou, M.; Siest, G.; Visvikis-Siest, S. Alcohol Consumption, Beverage Preference, and Diet in Middle-Aged Men from the STANISLAS Study. *J. Nutr. Metab.* **2012**, *2012*, 987243. [CrossRef] [PubMed]
- Jeżewska-Zychowicz, M.; Gawęcki, J.; Wądołowska, L.; Czarnocińska, J.; Galiński, G.; Kollajtis-Dołowy, A.; Roszkowski, W.; Wawrzyniak, A.; Przybyłowicz, K.; Krusińska, B.; et al. *Kwestionariusz Do Badania Poglądów i Zwyczajów Żywnościowych Oraz Procedura Opracowania Danych*; Wydawnictwo Komitetu Nauki o Żywieniu Człowieka Polskiej Akademii Nauk: Warszawa, Poland, 2014; pp. 21–33. [CrossRef]
- Stark, A. An historical review of the Harvard and the National Cancer Institute Food Frequency Questionnaires: Their similarities, differences, and their limitations in assessment of food intake. *Ecol. Food Nutr.* **2002**, *41*, 35–74. [CrossRef]
- Centers for Disease Control and Prevention; National Center for Health Statistics (NHANES). Questionnaires, Datasets, and Related Documentation. Available online: <https://www.cdc.gov/nchs/nhanes/continuousnhanes/default.aspx> (accessed on 15 October 2022).
- Alvin, R.C. Factor analysis. In *Methods of Multivariate Analysis*; John Wiley and Sons, Inc.: New York, NY, USA, 2002; pp. 408–450.
- Hair, J.F.; Black, W.C.; Babin, B.J. Factor analysis. In *Multivariate Data Analysis: A Global Perspective*; Pearson Education: London, UK, 2010; Chapter 3.
- Newby, P.K.; Tucker, K.L. Empirically derived eating patterns using factor or cluster analysis: A review. *Nutr. Rev.* **2004**, *62*, 177–203. [CrossRef] [PubMed]
- Gómez-Pinilla, F. Brain foods: The effects of nutrients on brain function. *Nat. Rev. Neurosci.* **2008**, *9*, 568–578. [CrossRef] [PubMed]
- Szot, M.; Karpecka-Galka, E.; Drózd, R.; Frączek, B. Can Nutrients and Dietary Supplements Potentially Improve Cognitive Performance Also in Esports? *Healthcare* **2022**, *10*, 186. [CrossRef] [PubMed]
- Ekstrand, B.; Scheers, N.; Rasmussen, M.K.; Young, J.F.; Ross, A.B.; Landberg, R. Brain foods—the role of diet in brain performance and health. *Nutr. Rev.* **2021**, *79*, 693–708. [CrossRef]
- Himmelstein, D.; Liu, Y.; Shapiro, J.L. An exploration of mental skills among competitive league of legend players. *Int. J. Gaming Comput.-Mediat. Simul. (IJGCMs)* **2017**, *9*, 1–21. [CrossRef]
- Pederaza-Ramirez, I.; Musculus, L.; Raab, M.; Laborde, S. Setting the scientific stage for esports psychology: A systematic review. *Int. Rev. Sport Exerc. Psychol.* **2020**, *13*, 319–352. [CrossRef]
- Ding, Y.; Hu, X.; Li, J.; Ye, J.; Wang, F.; Zhang, D. What Makes a Champion: The Behavioral and Neural Correlates of Expertise in Multiplayer Online Battle Arena Games. *Int. J. Hum. Comput. Interact.* **2018**, *34*, 682–694. [CrossRef]
- Toth, A.J.; Kowal, M.; Campbell, M.J. The Color-Word Stroop Task Does Not Differentiate Cognitive Inhibition Ability among Esports Gamers of Varying Expertise. *Front. Psychol.* **2019**, *10*, 2852. [CrossRef]
- Li, X.; Huang, L.; Li, B.; Wang, H.; Han, C. Time for a true display of skill: Top players in League of Legends have better executive control. *Acta Psychol.* **2020**, *204*, 103007. [CrossRef] [PubMed]
- Dominguez, L.J.; Barbagallo, M.; Muñoz-García, M.; Godos, J.; Martínez-González, M.A. Dietary Patterns and Cognitive Decline: Key features for prevention. *Curr. Pharm. Des.* **2019**, *25*, 2428–2442. [CrossRef] [PubMed]
- Féart, C.; Samieri, C.; Barberger-Gateau, P. Mediterranean diet and cognitive function in older adults. *Curr. Opin. Clin. Nutr. Metab. Care* **2010**, *13*, 14–18. [CrossRef]
- Moustafa, B.; Trifan, G.; Isasi, C.R.; Lipton, R.B.; Sotres-Alvarez, D.; Cai, J.; Tarraf, W.; Stickel, A.; Mattei, J.; Talavera, G.A.; et al. Association of Mediterranean Diet With Cognitive Decline Among Diverse Hispanic or Latino Adults From the Hispanic Community Health Study/Study of Latinos. *JAMA Netw. Open* **2022**, *5*, e2221982. [CrossRef] [PubMed]
- Mamalaki, E.; Charisis, S.; Anastasiou, C.A.; Ntanas, E.; Georgiadi, K.; Balomenos, V.; Kosmidis, M.H.; Dardiotis, E.; Hadjigeorgiou, G.; Sakka, P.; et al. The Longitudinal Association of Lifestyle with Cognitive Health and Dementia Risk: Findings from the HELIAD Study. *Nutrients* **2022**, *14*, 2818. [CrossRef] [PubMed]



30. Vinciguerra, F.; Graziano, M.; Hagnäs, M.; Frittitta, L.; Tumminia, A. Influence of the Mediterranean and Ketogenic Diets on Cognitive Status and Decline: A Narrative Review. *Nutrients* **2020**, *12*, 1019. [\[CrossRef\]](#) [\[PubMed\]](#)
31. Statovci, D.; Aguilera, M.; MacSharry, J.; Melgar, S. The impact of Western Diet and Nutrients on the Microbiota and Immune Response at Mucosal Interfaces. *Front. Immunol.* **2017**, *8*, 838. [\[CrossRef\]](#)
32. Cordain, L.; Eaton, S.B.; Sebastian, A.; Mann, N.; Lindeberg, S.; Watkins, B.A.; O'Keefe, J.H.; Brand-Miller, J. Origins and evolution of the Western diet: Health implications for the 21st century. *Am. J. Clin. Nutr.* **2005**, *81*, 341–354. [\[CrossRef\]](#)
33. Ushula, T.W.; Mamun, A.; Darssan, D.; Wang, W.Y.S.; Williams, G.M.; Whiting, S.J.; Najman, J.M. Dietary patterns and the risks of metabolic syndrome and insulin resistance among young adults: Evidence from a longitudinal study. *Clin. Nutr.* **2022**, *41*, 1523–1531. [\[CrossRef\]](#)
34. Deshmukh-Taskar, P.R.; O'Neil, C.E.; Nicklas, T.A.; Yang, S.J.; Liu, Y.; Gustat, J.; Berenson, G.S. Dietary patterns associated with metabolic syndrome, sociodemographic and lifestyle factors in young adults: The Bogalusa Heart Study. *Public Health Nutr.* **2009**, *12*, 2493–2503. [\[CrossRef\]](#)
35. Hare-Bruun, H.; Togo, P.; Andersen, L.B.; Heitmann, B.L. Adult food intake patterns are related to adult and childhood socioeconomic status. *J. Nutr.* **2011**, *141*, 928–934. [\[CrossRef\]](#) [\[PubMed\]](#)
36. Olinto, M.T.A.; Willett, W.C.; Gigante, D.P.; Victora, C.G. Sociodemographic and lifestyle characteristics in relation to dietary patterns among young Brazilian adults. *Public Health Nutr.* **2011**, *14*, 150–159. [\[CrossRef\]](#) [\[PubMed\]](#)
37. Morinaka, T.; Wozniiewicz, M.; Jeszka, J.; Bajerska, J.; Nowaczyk, P.; Sone, Y. Westernization of dietary patterns among young Japanese and Polish females—A comparison study. *Ann. Agric. Environ. Med.* **2013**, *20*, 122–130. [\[PubMed\]](#)
38. Hasegawa, Y.; Chen, S.Y.; Sheng, L.; Jena, P.K.; Kalanetra, K.M.; Mills, D.A.; Wan, Y.Y.; Slupsky, C.M. Long-term effects of western diet consumption in male and female mice. *Sci. Rep.* **2020**, *10*, 14686. [\[CrossRef\]](#) [\[PubMed\]](#)
39. López-Taboada, I.; González-Pardo, H.; Conejo, N.M. Western Diet: Implications for Brain Function and Behavior. *Front. Psychol.* **2020**, *11*, 564413. [\[CrossRef\]](#)
40. Parrott, M.; Shatenstein, B.; Ferland, G.; Morais, J.A.; Belleville, S.; Kergoat, M.J.; Payette, H.; Greenwood, C.E. The influence of empirically derived dietary patterns on cognitive function in independent older adults depends on income and education: The NuAge Study. *FASEB J.* **2011**, *25*, 97.1. [\[CrossRef\]](#)
41. Parrott, M.D.; Shatenstein, B.; Ferland, G.; Payette, H.; Morais, J.A.; Belleville, S.; Kergoat, M.J.; Gaudreau, P.; Greenwood, C.E. Relationship between diet quality and cognition depends on socioeconomic position in healthy older adults. *J. Nutr.* **2013**, *143*, 1767–1773. [\[CrossRef\]](#)
42. Kanoski, S.E.; Davidson, T.L. Western diet consumption and cognitive impairment: Links to hippocampal dysfunction and obesity. *Physiol. Behav.* **2011**, *103*, 59–68. [\[CrossRef\]](#)
43. Attuquayefio, T.; Stevenson, R.J.; Boakes, R.A.; Oaten, M.J.; Yeomans, M.R.; Mahmut, M.; Francis, H.M. A high-fat high-sugar diet predicts poorer hippocampal-related memory and a reduced ability to suppress wanting under satiety. *J. Exp. Psychol. Anim. Learn. Cogn.* **2016**, *42*, 415–428. [\[CrossRef\]](#)
44. Krusińska, B.; Hawrysz, I.; Słowińska, M.A.; Wądołowska, L.; Biernacki, M.; Czerwińska, A.; Gołota, J.J. Dietary patterns and breast or lung cancer risk: A pooled analysis of 2 case-control studies in north-eastern Poland. *Adv. Clin. Exp. Med.* **2017**, *26*, 1367–1375. [\[CrossRef\]](#)
45. Gajda, R.; Jeżewska-Zychowicz, M.; Raczkowska, E. Differences in Dietary Patterns among the Polish Elderly: A Challenge for Public Health. *Nutrients* **2021**, *13*, 3966. [\[CrossRef\]](#) [\[PubMed\]](#)
46. Crichton, G.E.; Elias, M.F.; Dore, G.A.; Robbins, M.A. Relation between dairy food intake and cognitive function: The Maine-Syracuse Longitudinal Study. *Int. Dairy J.* **2012**, *22*, 15–23. [\[CrossRef\]](#) [\[PubMed\]](#)
47. Goulart, J.; Aitken, L.; Siddiqui, S.; Cardenas, J.; Cuevas, M.; Riechman, S.; Beathard, K. Nutrition, Vision, and Cognition in Sport: E-Sport Gaming Athletes. *Curr. Dev. Nutr.* **2022**, *6*, 789. [\[CrossRef\]](#)
48. Mancini, E.; Beglinger, C.; Drewe, J.; Zanchi, D.; Lang, U.E.; Borgwardt, S. Green tea effects on cognition, mood and human brain function: A systematic review. *Phytomedicine* **2017**, *34*, 26–37. [\[CrossRef\]](#)
49. Shukitt-Hale, B.; Miller, M.; Chu, Y.F.; Lyle, B.J.; Joseph, J.A. Coffee, but not caffeine, has positive effects on cognition and psychomotor behavior in aging. *Age* **2013**, *35*, 2183–2192. [\[CrossRef\]](#)
50. Panza, F.; Solfrizzi, V.; Barulli, M.R.; Bonfiglio, C.; Guerra, V.; Osella, A.; Seripa, D.; Sabbà, C.; Pilotto, A.; Logroscino, G. Coffee, tea, and caffeine consumption and prevention of late-life cognitive decline and dementia: A systematic review. *J. Nutr. Health Aging* **2015**, *19*, 313–328. [\[CrossRef\]](#)
51. Gardener, S.L.; Rainey-Smith, S.R. The Role of Nutrition in Cognitive Function and Brain Ageing in the Elderly. *Curr. Nutr. Rep.* **2018**, *7*, 139–149. [\[CrossRef\]](#)
52. Carrillo, J.A.; Zafrilla, M.P.; Marhuenda, J. Cognitive Function and Consumption of Fruit and Vegetable Polyphenols in a Young Population: Is There a Relationship? *Foods* **2019**, *8*, 507. [\[CrossRef\]](#)
53. Lampert, D.J.; Lawton, C.L.; Merat, N.; Jamson, H.; Myrissa, K.; Hofman, D.; Chadwick, H.K.; Quadt, F.; Wightman, J.D.; Dye, L. Concord grape juice, cognitive function, and driving performance: A 12-wk, placebo-controlled, randomized crossover trial in mothers of preteen children. *Am. J. Clin. Nutr.* **2016**, *103*, 775–783. [\[CrossRef\]](#)
54. Essaw, E.; Moses, M.O.; Afrifa, D.; Acheampong, I.K.; Mensah, W.; Owusu, L. Physical activity patterns and dietary habits of undergraduate students. *Bali. J. Health Phys. Act.* **2019**, *11*, 115–123. [\[CrossRef\]](#)

55. Halder, S.; Anand, U.; Nandy, S.; Oleksak, P.; Qusti, S.; Alshammari, E.M.; El-Saber Batiha, G.; Koshy, E.P.; Dey, A. Herbal drugs and natural bioactive products as potential therapeutics: A review on pro-cognitives and brain boosters perspectives. *Saudi Pharm J.* **2021**, *29*, 879–907. [CrossRef] [PubMed]
56. Lauretti, E.; Iuliano, L.; Praticò, D. Extra-virgin olive oil ameliorates cognition and neuropathology of the 3xTg mice: Role of autophagy. *Ann. Clin. Transl. Neurol.* **2017**, *4*, 564–574. [CrossRef] [PubMed]
57. Barnard, N.D.; Bunner, A.E.; Agarwal, U. Saturated and trans fats and dementia: A systematic review. *Neurobiol. Aging* **2014**, *35*, 65–73. [CrossRef] [PubMed]
58. Dylla, S.C. Long-chain omega-3 fatty acids and the brain: A review of the independent and shared effects of EPA, DPA and DHA. *Front. Aging Neurosci.* **2015**, *7*, 52. [CrossRef] [PubMed]
59. Karpecka, E.; Frączek, B. Macronutrients and water—Do they matter in the context of cognitive performance in athletes? *Balt. J. Health Phys. Act.* **2020**, *12*, 114–124. [CrossRef]
60. Sánchez-Villegas, A.; Verberne, L.; De Irala, J.; Ruiz-Canela, M.; Toledo, E.; Serra-Majem, L.; Martínez-González, M.A. Dietary fat intake and the risk of depression: The SUN Project. *PLoS ONE* **2011**, *6*, e16268. [CrossRef]
61. Slavin, J. Whole grains and human health. *Nutr. Res. Rev.* **2004**, *17*, 99–110. [CrossRef]
62. Hawkins, M.A.W.; Keirns, N.G.; Helms, Z. Carbohydrates and cognitive function. *Curr. Opin. Clin. Nutr. Metab. Care* **2018**, *21*, 302–307. [CrossRef]
63. Jarosz, M. *Human Nutrition Recommendations for Polish Population*; IZZ: Warsaw, Poland, 2017. (In Polish)
64. Deep-Dive: The Eating and Drinking Habits of Consumers While Playing and Viewing Games. Available online: <https://newzoo.com/insights/articles/the-eating-and-drinking-habits-of-consumers-while-playing-and-viewing-games> (accessed on 13 November 2022).
65. Mente, A.; O'Donnell, M.J.; Rangarajan, S.; McQueen, M.J.; Poirier, P.; Wielgosz, A.; Morrison, H.; Li, W.; Wang, X.; Di, C.; et al. PURE Investigators. Association of urinary sodium and potassium excretion with blood pressure. *N. Engl. J. Med.* **2014**, *371*, 601–611. [CrossRef]
66. World Health Organization. *WHO Guideline: Sodium Intake for Adults and Children*; World Health Organization: Geneva, Switzerland, 2012.

**Disclaimer/Publisher's Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

(0.0) DOI: 10.5604/01.3001.0054.5121

## EVALUATION OF THE EATING HABITS OF POLISH ESPORTS PLAYERS USING THE QUICK DIET SURVEY (QDS)

Monika Szot<sup>1</sup> \* ABCDEF, Barbara Frączek<sup>1</sup> ABCDEF

### Authors' contribution:

A. Study design/planning  
B. Data collection/entry  
C. Data analysis/statistics  
D. Data interpretation  
E. Preparation of manuscript  
F. Literature analysis/search  
G. Funds collection

Revised: 09.04.2024  
Accepted: 0  
Ahead of Print: 08.05.2024

<sup>1</sup>Department of Sports Dietetics, Gdansk University of Physical Education and Sport, Poland

**Keywords:** esports, athletes, nutrition

\*Author for correspondence: monika.szot@awf.gda.pl

### Abstract:

**Background:** A healthy diet is crucial for the health and physical fitness of both traditional sports and esports athletes. The present study aimed to assess the eating behaviors of elite Polish esports players using the QDS questionnaire.

**Methods:** The survey was conducted on a group of 188 men aged 18-29 years, and a proprietary standardized questionnaire for rapid dietary assessment (QDS) was used. A chi-square test was used for the statistical analysis, assuming a significance level of  $p < 0.05$ .

**Results:** The results indicate that the largest percentage of esports players surveyed adhered to the dietary recommendations related to fluid intake (75%), fluid replacement during exercise (72.3%), consuming cereal products (67.6%), the recommended number of meals (62.2%), and adequate hydration after exercise (60.1%). The study found that the most common dietary mistakes were usage of dietary supplements without consulting a doctor or nutritionist (75.9%), low consumption of meat substitutes (66.5%), and inadequate intake of recommended products such as pulses (64.4%), fish (62.8%), vegetables (53.3%), and whole grain cereal products (51.1%). Most study participants were players characterized by low (44.7%) and average (40.4%) levels of following dietary recommendations, as indicated by the nutrition score used. A higher level of rational dietary choices was observed in 14.9% of the group. Statistical analysis revealed no significant differentiation of the analyzed dietary behaviors between professional and semi-professional players ( $p > 0.05$ ).

**Conclusion:** The Quick Diet Survey (QDS) questionnaire used in the study is a valuable and reliable tool for rapid diet assessment. Therefore, the high prevalence of unhealthy eating behaviors among esports players highlights the need for nutrition education.

### Introduction

Electronic sports (or esports) is a rapidly growing organized video game practice where individuals or teams compete for monetary rewards and prestige. It has become a noteworthy economic and social phenomenon worldwide, attracting audiences comparable to those of traditional sports. The professionalization of esports has increased in recent years, leading to its recognition as a profession. Esports games are complex and can vary widely within and between genres. There are various types of esports games such as multiplayer online battle arena (MOBA), first-person shooter (FPS), real-time strategy, and sports simulation, which are played in virtual environments [1–4].

Professional players spend an average of 5.5 to 10 hours per day playing video games to improve skills such as gamepad and keyboard operation, game knowledge, strategy, and tactics. Prolonged periods of sedentary behavior can have negative health consequences including injuries (e.g., eye fatigue, musculoskeletal pain including wrist and hand pain) [5,6].



Similar to traditional athletes, esports players require extensive training to achieve and maintain high levels of physical, mental, and cognitive abilities necessary for athletic success. Compared to traditional sports, esports players rely more heavily on cognitive skills to achieve victory. Esports players' capabilities are supported by a rational and balanced diet with adequate hydration based on qualitative and quantitative nutritional recommendations and tailored to the individual needs of the body [7].

The literature on the diets of professional athletes of various sports is dominated by papers that confirm the limited scale of rational dietary choices among athletes [8–11]. Reports on the diets of esports players are limited but the available research suggests that inappropriate dietary behavior is prevalent among esports players from various countries [12–16]. This implies that further research is necessary to monitor the diets of this specific group.

A study was conducted to evaluate the dietary behavior of Polish professional and semi-professional esports players using the (QDS) questionnaire. The study aimed to determine the role of a rational diet in promoting health and improving psychophysical and cognitive abilities. The results can be utilized in the future to develop health promotion and nutrition education programs for esports players.

## Material and Methods

### Participants

The study was conducted on a group of 188 male esports players aged between 18 and 29 years, at professional ( $n = 37$ ) and semi-professional ( $n = 151$ ) levels across different game genres (CS: GO, LOL, StarCraft). The target group size was estimated using the G\*Power program. The margin of error for the difference between the results obtained in the sample and those in the population was assumed to be 5% ( $\alpha = 0.05$ ), which corresponds to a confidence interval of 95% ( $z = 1.96$ ). With an estimated fraction in the population of 50%, the minimum sample size was formed at 127 people. The main inclusion criteria for the study group were age  $\geq 17$  years and a minimum of 3 years of training experience. The study was conducted in 2020–2022, approved by the Bioethics Committee of the Regional Medical Society in Gdansk (KB-63/22), and conducted in accordance with the Declaration of Helsinki.

### Research tool

The study employed a proprietary and validated quick dietary assessment (QDS) questionnaire consisting of 37 closed-ended single-choice questions. Respondents were given the option to answer 'Yes', 'No', or 'Difficult to say' (in the absence of a clear indication). The questionnaire addresses various dietary behaviors, such as meal frequency and frequency of snacks by types, frequency of consuming selected food and beverage groups, avoiding unhealthy foods, and adherence to adequate fluid intake.

The QDS questionnaire results were interpreted using the author's point scale. Each consecutive affirmative answer was awarded 1 point, resulting in a maximum of 37 points. The raw QDS results were used to assess the diet based on the following criteria: 0–19 points indicated an inadequate diet (low level of following dietary recommendations), 20–26 points indicated a not fully adequate diet (average level of following dietary recommendations) and 27–37 points indicated an adequate diet (high level of dietary recommendations).

### Statistical analyses

The validation procedure using IBM SPSS statistics software v26 (IBM Corp., Armonk, NY, USA) demonstrated a high degree of reproducibility of the QDS results. McNemar's Chi2 test values indicated no statistical differences between test and retest results for any of the 37 statements of the QDS questionnaire ( $p > 0.05$ ). The psychometric evaluation also confirmed good internal consistency of the tool (Cronbach's  $\alpha$  coefficient was 0.79).

## Results

The study found that esports players were the most likely to follow the recommendations for adequate fluid intake throughout the day (75%) and proper hydration during exercise (72.3%). Furthermore, the majority of players reported consuming cereal products in each main meal (67.6%), having at least three meals a day (62.2%), hydrating properly after exercise (60.1%), and preferring mineral water for rehydration (54.8%). Nearly half of the group (50.5%) consumed vegetable fats almost daily. Less than half of the esports players reported consuming 1 or 2 portions of fruit daily (47.3%), avoiding fizzy and sweetened drinks (47.3%), and limiting the consumption of energy drinks (45.2%). The study group of esports players made rational dietary choices on average 42.9% of

the time (Table 1). Statistical analysis revealed no significant differences in dietary behaviors between professional and semi-professional esports players ( $p > 0.05$ ). Therefore, the results are presented for the total number of esports players surveyed.

**Table 1.** Dietary habits of esports players in light of quality recommendations

| Nutritional behaviors                                                                                              | Total (%)       |                 |                  |
|--------------------------------------------------------------------------------------------------------------------|-----------------|-----------------|------------------|
|                                                                                                                    | Yes             | No              | Difficult to say |
| Providing sufficient energy with the diet to maintain a healthy body weight                                        | 44.7            | 30.9            | 24.5             |
| Eating 3-5 meals a day                                                                                             | 62.2            | 36.2            | 1.6              |
| Eating meals regularly, with 3-5 hour intervals                                                                    | 36.2            | 52.7            | 11.2             |
| Eating breakfast up to one hour after waking up                                                                    | 45.2            | 47.3            | 7.4              |
| The last meal no later than 1.5-2 hours before bedtime                                                             | 33              | 56.9            | 10.1             |
| The most calorific meal should be consumed at times of increased physical activity                                 | 45.2            | 44.7            | 10.1             |
| Vegetables (approximately 250g) should be included in at least two meals                                           | 28.7            | 55.3            | 16               |
| Raw vegetables should be consumed at least once                                                                    | 40.4            | 53.2            | 6.4              |
| Consumption of 2-3 portions of vegetables                                                                          | 44.7            | 48.9            | 6.4              |
| Consumption of 1-2 portions of fruit                                                                               | 47.3            | 46.3            | 6.4              |
| Cereal products at each main meal                                                                                  | 67.6            | 27.1            | 5.3              |
| Whole grain cereal products at least twice a day                                                                   | 34.6            | 51.1            | 14.4             |
| Consuming milk or dairy products twice a day                                                                       | 50              | 42.6            | 7.4              |
| Providing sources of complete protein in the diet                                                                  | 44.1            | 35.6            | 20.2             |
| Eating lean meats                                                                                                  | 42.6            | 47.9            | 9.6              |
| Provision of wholesome protein (eggs, meat) at a rate of 150 g per day                                             | 35.1            | 49.5            | 15.4             |
| Limiting the consumption of processed meat products                                                                | 31.9            | 59.6            | 8.5              |
| Replacing meat with substitutes                                                                                    | 28.7            | 66.5            | 4.8              |
| Eating pulses at least twice a week                                                                                | 23.4            | 64.4            | 12.2             |
| Eating fish 1 or 2 times a week                                                                                    | 30.9            | 62.8            | 6.4              |
| Limiting consumption of animal fats                                                                                | 34              | 55.9            | 10.1             |
| Eating vegetable fats almost every day                                                                             | 50.5            | 38.3            | 11.2             |
| Daily consumption of foods which are sources of probiotics                                                         | 47.3            | 40.4            | 12.2             |
| Adequate hydration during the day (30 ml/kg body weight)                                                           | 75.0            | 9.0             | 16.0             |
| Adequate hydration during exercise (approx. one liter of isotonic drink/medium or high mineralized water per hour) | 72.3            | 16              | 11.7             |
| Adequate post-exercise hydration (approx. 400-700 ml / 0.5 kg body weight lost)                                    | 60.1            | 27.7            | 12.2             |
| Preference for consumption of mineral water                                                                        | 54.8            | 39.4            | 5.9              |
| Avoiding the consumption of sweetened and carbonated drinks                                                        | 47.3            | 47.3            | 5.3              |
| Avoiding the consumption of energy drinks                                                                          | 45.2            | 49.5            | 5.3              |
| Avoiding the consumption of fast-food products                                                                     | 40.4            | 55.9            | 3.7              |
| Moderate consumption of confectionery and salty snacks                                                             | 50.5            | 40.4            | 9                |
| Avoidance of sugar and sweets                                                                                      | 36.2            | 47.3            | 16.5             |
| Appropriate cooking techniques                                                                                     | 42              | 47.3            | 10.6             |
| Balanced diet                                                                                                      | 25              | 55.3            | 19.7             |
| Varied diet                                                                                                        | 36.7            | 49.5            | 13.8             |
| Choosing the least processed foods possible based on information on labels and principles of good nutrition        | 34.8            | 56.3            | 8.9              |
| Use of dietary supplementation after consultation with a doctor/nutritionist                                       | 17.9            | 75.9            | 6.3              |
| Average (M $\pm$ SD)                                                                                               | 42.9 $\pm$ 12.8 | 46.8 $\pm$ 13.2 | 10.3 $\pm$ 4.9   |



The assessment of the diet of esports players showed that the gamers surveyed achieved low (44.7%) and average (40.4%) levels of fulfillment of dietary recommendations. Only 14.9% of the total players exhibited a high level of correct eating behavior (Table 2). Statistical analysis indicated no significant variation in diet quality (degree of following dietary recommendations) among esports players surveyed, regardless of their sports skill level ( $p > 0.05$ ).

**Table 2.** Scale and interpretation of the QDS questionnaire results

| Score (points) | Number of responses (n) | Percentage (%) | Results                 |
|----------------|-------------------------|----------------|-------------------------|
| 0-19           | 84                      | 44.7           | Inadequate diet         |
| 20-26          | 76                      | 40.4           | Not fully adequate diet |
| 27-37          | 28                      | 14.9           | Adequate diet           |

## Discussion

The literature indicates that esports nutrition is still an area of research that has not yet been fully explored. This is supported by the limited number of publications in this field to date [12–16]. The study revealed a prevalence of unhealthy qualitative dietary choices among Polish esports players, which is consistent with the findings of previous studies conducted on different groups of esports players including groups from Poland, Germany, Portugal, and Brazil [12,15,16].

As the literature on the qualitative assessment of nutrition in esports is limited, this discussion will address the results obtained in different groups of athletes, focusing on the quality of dietary choices in the context of current dietary recommendations.

The results of the self-reported study indicate that approximately 66% of Polish e-gamers consume at least three meals a day, which is a positive trend compared to previous studies (approximately 41%) [15]. Similarly, Norwegian esports players also tend to follow a 3-4 meal dietary pattern [17]. Studies of other groups of Polish athletes of various sports, such as long-distance runners, volleyball players, and team game players, have also documented a similar level of following the recommendation to consume at least three meals per day [8–10,18–20]. Long intervals between meals can negatively impact the efficiency of training sessions and cognitive function, not only for traditional athletes [21] but also for professional esports players. In the aforementioned study, only about one-third of the participants reported regularly consuming meals at sufficiently frequent intervals, indicating a negative trend compared to the previous study where approximately 48% reported doing so [15].

The proportion of fruits and vegetables in a daily diet is crucial due to their high content of dietary fiber, minerals, vitamins, and antioxidant substances that have numerous health-promoting properties [22,23]. It is important to maintain a balanced diet that includes a variety of fruits and vegetables to ensure optimal health benefits. A diet high in antioxidants is essential for the nutrition of both professional athletes [24] and esports players. The consumption of these products has been linked to enhanced cognitive performance [25,26]. It is recommended that a balanced diet should consist of at least 2-3 servings of vegetables and 2-3 servings of fruit per day [27,28]. The studies indicate that less than half of the surveyed esports players consumed the recommended number of servings of vegetables and fruits per day (about 45% and 47%, respectively), and only about 40% of the group consumed raw vegetables. In contrast, a study involving German, Portuguese, and Brazilian gamers found that the majority of them did not consume the recommended 5 servings of fruits and vegetables [16,29]. The inadequate consumption of fruits and vegetables, including raw produce, was also noted among a group of Polish athletes from various sports [8–10,18–20].

Carbohydrates, including complex carbohydrates found in grain products, legumes, and potatoes, should be the primary source of energy in the human diet [28]. It is recommended to include these products in every main meal, with two servings of whole grain cereal products. About 67% of surveyed esports players declared daily consumption of cereal products in each main meal, with only about 35% including two servings of whole grains in their daily diet. Other groups of Polish athletes representing various sports also confirmed the limited levels of daily consumption of wholemeal cereal products [8–10,20]. This low consumption of whole grain cereals limits the supply of dietary fiber, which has numerous health-promoting properties, including those related to the regulation of intestinal peristalsis and detoxification of the body [30].

Milk and dairy products are recommended in a daily diet due to their complete protein and mineral content, including easily absorbable calcium and vitamin B<sub>2</sub> [28]. It is also recommended to include fermented dairy products in the diet as they are probiotic foods that promote the maintenance of eubiosis in the gut [31]. The study indicates that

approximately half of the participants reported consuming dairy products with the recommended frequency, which is a higher percentage compared to traditional athletes such as volleyball players (36%) [18], long-distance runners (45%) [19], and team game players (45%) [20]. In a previous study, only 10% of respondents reported consuming yogurt and kefir daily, while 25% reported consuming them 1-2 times a week or several times a week [15].

Fish is a nutrient-rich food that contains complete protein, polyunsaturated fatty acids (omega-3), and essential vitamins and minerals (such as vitamins A and D) that are necessary for proper body function [32]. According to the study, approximately 31% of participants reported consuming fish within the recommended range of 1-2 servings per week. Various groups of professional athletes, including team sports players, have been found to consume insufficient amounts of marine fish [9–11].

Dietary fats play a crucial role in the body, and their correct structure is of utmost importance. To maintain a healthy blood lipid profile and reduce the risk of atherosclerotic lesions, it is recommended to prioritize oils and other vegetable fats while limiting those of animal origin due to the high content of saturated fatty acids and cholesterol in the latter, which can have negative effects when consumed in excess [33–35]. Our study found that only 34% of respondents reported limiting their intake of animal fats, while approximately half reported regularly consuming vegetable fats rich in unsaturated fatty acids. Soccer players were found to follow the recommendations to limit consumption of animal fats in favor of plant-based fats more often [36].

Proper hydration and fluid replacement during and after exercise are crucial components of a healthy diet [37]. Our analysis indicates that approximately three-quarters of esports players employ effective hydration strategies, with over half of them opting for mineral water. In a previous study, it was found that 62.61% of e-gamers drank at least 1.5-2 liters of non-alcoholic fluids per day [15]. Similar trends toward proper nutritional behavior in terms of fluid replacement have also been observed among traditional athletes in various sports [9,10,20,36].

In contrast, a smaller percentage of esports players reported avoiding certain dietary products, such as sugary and carbonated drinks (approximately 47%) and energy drinks (approximately 45%). Similarly, the esports players surveyed limited consumption of other contraindicated products, including confectionery (approximately 40%) and candy (approximately 36%). Consuming these products can increase dietary intake of simple sugars and trans isomers, which can increase health risks [28]. Processed foods, which are rich in saturated fatty acids, sugar, and protein, are associated with an increased risk of developing obesity, type 2 diabetes, and cognitive decline [38].

A balanced and diverse diet based on the supply of foods from all food groups and maintaining correct amounts and proportions enables individuals to meet their energy and nutrient requirements. In the surveyed group of esports players, only 25% rated their diets as balanced, and approximately 37% rated them as varied.

The discussion of dietary abnormalities was reflected in the diet score, confirming the dominance of those with low and average levels of following qualitative dietary recommendations. In this study, only about 15% of the group of esports players showed a satisfactory level of diet quality. The statistical analysis did not confirm the differentiation of diet quality according to sports skill level (professional vs. semi-professional players).

The findings from this self-study suggest that esports players and their training staff require education on diet rationalization and healthy nutrition. Alongside proper nutrition, recent studies have highlighted the importance of physical activity [39]. Future research should explore the various determinants of eating behaviors in esports players.

#### **Limitations of the study**

The limitations of this study include the use of self-reported data, which may be subject to reporting bias. Furthermore, the data only relates to a qualitative assessment of diet, and there may be imprecision in the interpretation of portion sizes by esports players. This can increase the risk of over- or undersupplying certain products. Greater emphasis should be placed on the development of skills and awareness in the calculation of portion sizes for specific food products.

#### **Conclusions:**

1. The dietary habits of the esports players surveyed were found to be lacking in recommended food groups such as vegetables, legumes, whole grain cereal products, and fish. This may have reduced the overall nutritional value of their diets. It was observed that correct dietary behavior for esports players included consuming the recommended number of meals, proper fluid supplementation, and including grain products in meals.
2. The study group was dominated by players with low and average levels of following dietary recommendations, confirming the prevalence of dietary irregularities among esports players.



3. Statistical analysis revealed no significant variation in the analyzed dietary behaviors between professional and semi-professional esports players.
4. The results indicate a need for education on diet rationalization and healthy nutrition among esports players.

#### **Practical Implication**

The Quick Diet Survey (QDS) is a valuable tool for the efficient and accurate collection of data on dietary habits, which is crucial for dietary research and health interventions. Its use is recommended in future diet-related studies to increase the speed and accuracy of assessing food consumption and identifying dietary patterns.

**Conflict of interest:** The author(s) declare no conflict of interest.

**Funding:** This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

**Institutional Review Board Statement:** The research was approved by the Bioethics Committee of the Regional Medical Society in Gdansk (KB-63/22), and conducted in accordance with the Declaration of Helsinki.

**Informed consent statement:** Informed consent was obtained from all subjects involved in the study.

**Data availability statement:** Data available on request due to restrictions eg privacy or ethical.

#### **References:**

- [1] Saiz-Alvarez JM, Palma-Ruiz JM, Valles-Baca HG, Fierro-Ramírez LA. Knowledge Management in the Esports Industry: Sustainability, Continuity, and Achievement of Competitive Results. *Sustainability*. 2021 Sep 30;13(19):10890.
- [2] Abbott C, Watson M, Birch P. Perceptions of Effective Training Practices in League of Legends: A Qualitative Exploration. *Journal of Electronic Gaming and Esports*. 2023 Jan 1;1(1).
- [3] Giakoni-Ramírez F, Merellano-Navarro E, Duclos-Bastías D. Professional Esports Players: Motivation and Physical Activity Levels. *Int J Environ Res Public Health*. 2022 Feb 16;19(4):2256.
- [4] Brevers D, King DL, Billieux J. Delineating adaptive esports involvement from maladaptive gaming: a self-regulation perspective. *Curr Opin Psychol*. 2020 Dec;36:141–6.
- [5] DiFrancisco-Donoghue J, Balentine J, Schmidt G, Zwibel H. Managing the health of the eSport athlete: an integrated health management model. *BMJ Open Sport Exerc Med*. 2019 Jan 10;5(1):e000467.
- [6] Martin-Niedecken AL, Schättin A. Let the Body'n'Brain Games Begin: Toward Innovative Training Approaches in eSports Athletes. *Front Psychol*. 2020 Feb 19;11.
- [7] Szot M, Karpecka-Galka E, Drózd R, Frączek B. Can Nutrients and Dietary Supplements Potentially Improve Cognitive Performance Also in Esports? *Healthcare (Switzerland)*. 2022 Jan 28;10(2):186.
- [8] Frączek B, Gacek M. Frequency of consumption of food products by a group of Polish athletes in relationship to the qualitative recommendations included in the Swiss Food Pyramid. *Medicina Sportiva*. 2013 Mar 31;17(1):12–6.
- [9] Frączek B, Gacek M, Pięta A, Tyrła F, Mazur-Kurach P, Karpecka E. Dietary mistakes of Polish athletes in relation to the frequency of consuming foods recommended in the Swiss food pyramid for active people. *Rocz Panstw Zakł Hig*. 2020;71(1):97–104.
- [10] Gacek M, Wojtowicz A. Personal Resources and Nutritional Behaviour of Polish Basketball Players. *Journal of Physical Education and Sport*. 2021 Jan 30;21(01):130–9.
- [11] Gacek M. Selected personal resources and nutritional behaviours of Polish handball players. *Rocz Panstw Zakł Hig*. 2023 Jun 12;74(2):151–8.
- [12] Soffner M, Bickmann P, Tholl C, Froböse I. Dietary behavior of video game players and esports players in Germany: a cross-sectional study. *J Health Popul Nutr*. 2023 Apr 6;42(1):29.
- [13] Huth C. Nutritional behaviour of (Non-)eSports players – a comparative study. *Quality in Sport*. 2021 Jun 8;7(2):38–44.
- [14] Goulart JB, Aitken LS, Siddiqui S, Cuevas M, Cardenas J, Beathard KM, et al. Nutrition, lifestyle, and cognitive performance in esports athletes. *Front Nutr*. 2023 May 18;10.
- [15] Szot M, Frączek B, Tyrła F. Nutrition Patterns of Polish Esports Players. *Nutrients*. 2023 Dec 28;15(1):149.
- [16] Ribeiro FJ, Teixeira R, Poinhos R. Dietary Habits and Gaming Behaviors of Portuguese and Brazilian Esports Players. *Nutrients*. 2023 Sep 28;15(19):4200.
- [17] Baumann A, Mentzoni RA, Erevik E, Pallesen S. A qualitative study on Norwegian esports students' sleep, nutritional and physical activity habits and the link to health and performance. *International Journal of Esports*. 2022 Oct 25;1(1).
- [18] Gacek M, Popek A. Analysis of nutritional behaviors of males – competitive and recreational volleyball players. *Sport i Turystyka Środkowoeuropejskie Czasopismo Naukowe*. 2018;1(2):93–102.
- [19] Gacek M. Eating habits of young male long-distance runners. *Medycyna Ogólna i Nauki o Zdrowiu*. 2017 Apr 13;23(1):57–61.

- [20] Frączek B, Brzozowska E, Morawska Małgorzata. Ocena zachowań żywieniowych zawodników trenujących gry zespołowe w świetle rekomendacji piramidy żywieniowej dla sportowców. *Probl Hig Epidemiol*. 2013;94(2):280–5.
- [21] Kałużny K, Śpiąca D, Drobik P, Michalska A, Kałużna A, Kochański B, et al. Ocena oraz porównanie zachowań żywieniowych u osób uprawiających sport zawodowo i amatorsko = Evaluation and comparison of nutritional behavior of people practicing professional and amateur sport. *Journal of Education, Health and Sport*. 2016 Feb 28;6(2):301–10.
- [22] Slavin JL, Lloyd B. Health Benefits of Fruits and Vegetables. *Advances in Nutrition*. 2012 Jul;3(4):506–16.
- [23] Boeing H, Bechthold A, Bub A, Ellinger S, Haller D, Kroke A, et al. Critical review: vegetables and fruit in the prevention of chronic diseases. *Eur J Nutr*. 2012 Sep 9;51(6):637–63.
- [24] Frączek B, Morawska M, Gacek M, Pogoń K. Antioxidant activity as well as vitamin C and polyphenol content in the diet for athletes. 2019 Nov 29;31:617–30.
- [25] Gardener SL, Rainey-Smith SR. The Role of Nutrition in Cognitive Function and Brain Ageing in the Elderly. *Curr Nutr Rep*. 2018 Sep 5;7(3):139–49.
- [26] Zhou Y, Wang J, Cao L, Shi M, Liu H, Zhao Y, et al. Fruit and Vegetable Consumption and Cognitive Disorders in Older Adults: A Meta-Analysis of Observational Studies. *Front Nutr*. 2022 Jun 20;9.
- [27] Walter P, Infanger E, Mühlemann P. Food Pyramid of the Swiss Society for Nutrition. *Ann Nutr Metab*. 2007;51(Suppl. 2):15–20.
- [28] Samuel M. A food pyramid for Swiss athletes. Interview by Louise M. Burke. *Int J Sport Nutr Exerc Metab*. 2008 Aug;18(4):430–7.
- [29] Rudolf K, Bickmann P, Froböse I, Tholl C, Wechsler K, Grieben C. Demographics and Health Behavior of Video Game and eSports Players in Germany: The eSports Study 2019. *Int J Environ Res Public Health*. 2020 Mar 13;17(6):1870.
- [30] Barber TM, Kabisch S, Pfeiffer AFH, Weickert MO. The Health Benefits of Dietary Fibre. *Nutrients*. 2020 Oct 21;12(10):3209.
- [31] Marttinen M, Ala-Jaakkola R, Laitila A, Lehtinen MJ. Gut Microbiota, Probiotics and Physical Performance in Athletes and Physically Active Individuals. *Nutrients*. 2020 Sep 25;12(10):2936.
- [32] Usydus Z, Szlinder-Richert J. Functional Properties of Fish and Fish Products: A Review. *Int J Food Prop*. 2012 Jul;15(4):823–46.
- [33] Barnard N, Goldman D, Loomis J, Kahleova H, Levin S, Neabore S, et al. Plant-Based Diets for Cardiovascular Safety and Performance in Endurance Sports. *Nutrients*. 2019 Jan 10;11(1):130.
- [34] de Oliveira Otto MC, Wu JHY, Baylin A, Vaidya D, Rich SS, Tsai MY, et al. Circulating and Dietary Omega-3 and Omega-6 Polyunsaturated Fatty Acids and Incidence of CVD in the Multi-Ethnic Study of Atherosclerosis. *J Am Heart Assoc*. 2013 Nov 18;2(6).
- [35] Liu AG, Ford NA, Hu FB, Zelman KM, Mozaffarian D, Kris-Etherton PM. A healthy approach to dietary fats: understanding the science and taking action to reduce consumer confusion. *Nutr J*. 2017 Dec 30;16(1):53.
- [36] Gacek M. Wybrane zasoby osobiste a zachowania żywieniowe grupy piłkarzy nożnych. *Polish Journal of Sports Medicine*. 2019 Nov 19;35(3):149–55.
- [37] Kerkick CM, Wilborn CD, Roberts MD, Smith-Ryan A, Kleiner SM, Jäger R, et al. ISSN exercise & sports nutrition review update: research & recommendations. *J Int Soc Sports Nutr*. 2018 Jan 5;15(1).
- [38] Karpecka E, Frączek B. Macronutrients and water – do they matter in the context of cognitive performance in athletes? *Balt J Health Phys Act*. 2020 Sep 30;12(3):114–24.
- [39] Frączek B, Szot M, Sagalara A, Krzepota S, Skorko M, Blachnio D, et al. Assessment of physical activity, exercise capacity and fitness level of the Polish esports players. *Physical Activity Review*. 2024;12(1):32–46.

**Citation:**

Szot M, Frączek B: Evaluation of the eating habits of Polish esports players using the Quick Diet Survey (QDS). *Journal of Kinesiology and Exercise Sciences*, 2024; 34:107: 1-14.



## OPEN ACCESS

EDITED BY  
Joanne DiFrancisco-Donoghue,  
New York Institute of Technology, United States

REVIEWED BY  
Agnieszka Biatek-Dratwa,  
Medical University of Silesia, Poland  
Ulrike Löber,  
Max Delbrück Center for Molecular Medicine  
(HZI), Germany

\*CORRESPONDENCE  
Jerzy Ostrowski  
✉ jostrow@warman.com.pl

<sup>†</sup>These authors have contributed equally to this work and share first authorship

## SPECIALTY SECTION

This article was submitted to  
Sport and Exercise Nutrition,  
a section of the journal  
Frontiers in Nutrition

RECEIVED 08 November 2022  
ACCEPTED 30 December 2022  
PUBLISHED 16 January 2023

CITATION  
Kulecka M, Fraczek B, Balabas A, Czarnowski P,  
Zeber-Lubecka N, Zapala B, Baginska K,  
Glowienka M, Szot M, Skorko M, Kluska A,  
Piatkowska M, Mikula M and Ostrowski J (2023)  
Characteristics of the gut microbiome in  
esports players compared with those in  
physical education students and professional  
athletes. *Front. Nutr.* 9:1092846.  
doi: 10.3389/fnut.2022.1092846

COPYRIGHT  
© 2023 Kulecka, Fraczek, Balabas, Czarnowski,  
Zeber-Lubecka, Zapala, Baginska, Glowienka,  
Szot, Skorko, Kluska, Piatkowska, Mikula and  
Ostrowski. This is an open-access article  
distributed under the terms of the [Creative  
Commons Attribution License \(CC BY\)](#). The use,  
distribution or reproduction in other forums is  
permitted, provided the original author(s) and  
the copyright owner(s) are credited and that  
the original publication in this journal is cited, in  
accordance with accepted academic practice.  
No use, distribution or reproduction is  
permitted which does not comply with these  
terms.

# Characteristics of the gut microbiome in esports players compared with those in physical education students and professional athletes

Maria Kulecka<sup>1,2†</sup>, Barbara Fraczek<sup>3†</sup>, Aneta Balabas<sup>2</sup>,  
Paweł Czarnowski<sup>2,4</sup>, Natalia Zeber-Lubecka<sup>1,2</sup>, Barbara Zapala<sup>5</sup>,  
Katarzyna Baginska<sup>2</sup>, Maria Glowienka<sup>2</sup>, Monika Szot<sup>6</sup>,  
Maciek Skorko<sup>7</sup>, Anna Kluska<sup>2</sup>, Magdalena Piatkowska<sup>2</sup>,  
Michał Mikula<sup>2</sup> and Jerzy Ostrowski<sup>1,2\*</sup>

<sup>1</sup>Department of Gastroenterology, Hepatology and Clinical Oncology, Centre of Postgraduate Medical Education, Warsaw, Poland, <sup>2</sup>Department of Genetics, Maria Skłodowska-Curie National Research Institute of Oncology, Warsaw, Poland, <sup>3</sup>Department of Sports Medicine and Human Nutrition, Institute of Biomedical Sciences, University of Physical Education, Krakow, Poland, <sup>4</sup>Department of Biochemistry, Radioimmunology and Experimental Medicine, The Children's Memorial Health Institute, Warsaw, Poland, <sup>5</sup>Department of Clinical Biochemistry, Faculty of Medicine, Jagiellonian University Medical College, Krakow, Poland, <sup>6</sup>Department of Sports Dietetics, Gdansk University of Physical Education and Sport, Gdansk, Poland, <sup>7</sup>Institute of Psychology, Polish Academy of Sciences, Warsaw, Poland

**Introduction:** Esports is a category of competitive video games that, in many aspects, may be similar to traditional sports; however, the gut microbiota composition of players has not been yet studied.

**Materials and methods:** Here, we investigated the composition and function of the gut microbiota, as well as short chain fatty acids (SCFAs), and amino acids, in a group of 109 well-characterized Polish male esports players. The results were compared with two reference groups: 25 endurance athletes and 36 healthy students of physical education. DNA and metabolites isolated from fecal samples were analyzed using shotgun metagenomic sequencing and mass spectrometry, respectively. Physical activity and nutritional measures were evaluated by questionnaire.

**Results:** Although anthropometric, physical activity and nutritional measures differentiated esports players from students, there were no differences in bacterial diversity, the Bacteroidetes/Firmicutes ratio, the composition of enterotype clusters, metagenome functional content, or SCFA concentrations. However, there were significant differences between esports players and students with respect to nine bacterial species and nine amino acids. By contrast, all of the above-mentioned measures differentiated professional athletes from esports players and students, with 45 bacteria differentiating professional athletes from the former and 31 from the latter. The only species differentiating all three experimental groups was *Parabacteroides distasonis*, showing the lowest and highest abundance in esports players and athletes, respectively.

**Conclusion:** Our study confirms the marked impact of intense exercise training on gut microbial structure and function. Differences in lifestyle and dietary habits between esports players and physical education students appear to not have a major effect on the gut microbiota.

## KEYWORDS

shotgun metagenomics, metabolomics, esports players, professional athletes, diet, physical activity



## 1. Introduction

The colonic microbiota in healthy adults is dominated by the phyla Firmicutes and Bacteroidetes (which comprise over 90% of the bacteria), and to a lesser extent by Actinobacteria, Proteobacteria, Verrucomicrobia, and Fusobacteria. The gut phyla comprises at least 1,800 different genera, and 15,000–36,000 bacterial species, which contain ~10 million non-redundant microbial genes (1, 2). This complex ecosystem trains the immune system, protects against opportunistic pathogens, harvests nutrients and energy from the diet, and degrades dietary carbohydrates, lipids, and proteins, thereby producing metabolites with both local and systemic actions (3). The relative abundance of gut bacterial strains is impacted by host genotype and ethnicity, age, and sex, and is highly associated with changes in environmental factors such as diet, physical activity, sanitation, illness, and therapies (4–7). It is not surprising, therefore, that changes in the functional composition of the gut microbiota and its metabolites are associated with several disorders, including obesity-related disorders (3, 6–8). The microbiome of obese individuals is less rich than that of normal body weight individuals, the latter being characterized by changes in the relative abundance of the two dominant phyla: Bacteroidetes and Firmicutes (4, 9). In turn, physical exercise correlates with increased richness and diversity of the gut microbiota, a higher abundance of health-promoting bacteria such as *Faecalibacterium prausnitzii*, *Roseburia hominis*, *Akkermansia muciniphila*, and *Prevotella* species, and an increase in beneficial microbial-associated metabolites, mostly short chain fatty acids (SCFAs) (10–13).

According to the Central Statistical Office, a Polish system of official statistics (<http://www.stat.gov.pl/>), the estimated number of video games players in Poland in 2021 reached 16 million, and about 2.6 million are esports enthusiasts; the number of sports clubs that have esports sections in their structures or create programs to support esports is growing. It is difficult to estimate the exact number of gamers worldwide, as the gaming industry is constantly evolving. However, according to a report by Newzoo, the global gaming market is expected to generate \$184.4 billion in 2022 with a forecast of growth to \$211.2 billion by 2025 (14). Esports, like traditional sports, require a combination of physical and mental skills. However, esports players seem to rely more on cognitive abilities to achieve success (15, 16). Searching for excellence, esports players from universities in the United States practice between 5.5 and 10 h a day before competitions; however, 40% do not participate in any kind of physical activity (17). Moreover, prolonged gaming and associated physical inactivity can lead to malnutrition or overeating, and inappropriate eating habits (18, 19). Male collegiate esports players are significantly less active, and have a higher body-fat percentage, with lower lean body mass and bone mineral content, than non-esports players (20). Other negative consequences of esports gaming include upper limb dysfunction, neck, back, or wrists pain, vision problems, metabolic dysregulation, and sympathetic overstimulation (21–23). However, evidence on whether esports players are more or less physically active than the general population is controversial, as esports players may include physical training as a part of their training regimen and to manage stress (24); indeed, 92.7% of 260 male professional esports players with the normal body mass index (BMI) reported high or moderate levels of physical activity (21). The top 10% of

higher-ranked esports players were more physically active than the bottom 90% of players (25); however, 80.3% of 1,772 esports players representing five esports across all skill levels were not meeting the WHO physical activity guidelines at the same rates as others in the general population.

To identify objective measures of factors related to the lifestyle, physical activity, and dietary habits of esports players, we used shotgun metagenomic sequencing and small molecule mass spectrometry (MS) to investigate the gut microbiota and bacterial metabolites, as well as SCFAs and amino acids, in a group of well-characterized Polish male esports players. The results were compared with those obtained from two reference groups: endurance athletes and healthy students of physical education. This is the first metagenomic study exploring esports players' gut microbiome.

## 2. Materials and methods

### 2.1. Participants

This study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by Maria Skłodowska-Curie National Research Institute of Oncology Local Bioethics Board (decision 54/2017). All participants provided informed consent to participate. Between July 2020 and July 2021, 109 male esports players were recruited at the peak of their gaming season. In addition, 36 male education physical education students were recruited as a control group (University of Physical Education, Cracow) and 25 professional athletes (eight marathon runners, three cross-country skiers, and 14 football players) were assigned to an independent endurance sports player group. Of these, 59 and 36 esports players and students, respectively, completed dietary questionnaires.

The inclusion criteria were the professional level of esportsmanship (for esports players), self-declaration of a good health condition and remaining on a Western-type diet without specific dietary restrictions (for esports players and students). Due to the dominance of men in esports, women were excluded from the study. None of the participants received antibiotic treatment in the last 6 months before entering the study.

### 2.2. Collection of data regarding physical activity and nutritional habits

#### 2.2.1. Evaluation of physical activity

By definition, the physical activity of professional athletes was extremely high. The Polish version of the International Physical Activity Questionnaire was used to measure the physical activity of esports players and students of physical education (26). The questions in the questionnaire referred to the time the subjects spent sitting, walking, or performing moderate to vigorous physical activity for at least 10 min (without interruption) over the last 7 days. Activities that lasted <10 min at a time were not considered. Energy expenditure (expressed as MET-min/week) was calculated by multiplying the number of days of activity per week by the corresponding MET value and the average duration of that activity (in minutes). The results for all activities undertaken during the week were then summed to obtain the weekly energy expenditure. Based

on the results, participants were assigned to one of three physical activity levels: (1) insufficient (low), physical activity that did not meet the conditions for sufficient or high levels; (2) sufficient, when individuals met one of the following criteria: three or more days of intense physical exertion of not <20 min per day, or five or more days of moderate exertion or walking for not <30 min per day, or five or more days of any combination of physical activity (walking, moderate or intense exertion) exceeding 600 MET-min/week; and (3) high, when individuals met one of the following criteria: three or more days of intense exercise, totaling at least 1,500 MET-min/week, or seven days of any combination of exertion (walking, moderate, or intense exertion) exceeding 3,000 MET-min/week.

### 2.2.2. Evaluation of the energy and nutritional value of the diet

A quantitative dietary assessment was performed via a three day running diary method and a weighing method. Participants recorded a food diary listing all foods and beverages consumed for 3 consecutive days, or on 3 days selected at random, specifying their size in grams or home measures (using a detailed table of home measures and grams of foods and selected foods). Before monitoring, all subjects were trained to ensure correct dietary recording, which consisted of specifying precisely the type of meal consumed (breakfast, second breakfast, lunch, afternoon tea, dinner), the time of consumption, and the food products and dishes (including the method of preparation).

The Remote Food Photography Method was used if there were difficulties estimating the portion size consumed. This involved taking digital photographs of food before and after consumption and then sending them to the study author to estimate the amount of a portion consumed (compared with a standard serving size) (27). The completed food diaries were analyzed for accuracy and correctness, and participants were asked to fill in any gaps. All dietary data were then entered into the 'Aliant. Dietary Calculator' (version 2.0) assesses the energy value and nutrient content of foods. The average intake of macronutrients (protein, fat, total carbohydrates), fatty acids, fiber, and cholesterol in both groups was related to normal values for the Polish population (28), and recommendations for athletes (29–32), as well as the average supply of selected micronutrients, were related to normal values for the level of safe (Estimated Average Requirement, EAR), recommended daily amounts, and adequate intake (AI) (28).

## 2.3. Metagenomics and metabolomics procedures

Fecal samples were collected from all participants. The stool was self-collected using a stool specimen collection kit consisting of a Styrofoam box containing a sterile tube with a spatula and an ice pack. Following collection, the samples were transported at  $-20^{\circ}\text{C}$  to the laboratory and stored at  $-80^{\circ}\text{C}$  until use.

### 2.3.1. Metagenomics

DNA was isolated using the QIAamp Fast DNA Stool Mini Kit protocol (Qiagen, Hilden, Germany), as described previously (33). The quality and quantity of the extracted DNA was assessed

by detecting the optical density using a NanoDrop 2000/2000c Spectrophotometer (Thermo Fisher Scientific, Carlsbad, CA, USA) and a fluorometric-based method using the Qubit dsDNA HS Assay Kit (Thermo Fisher Scientific, Carlsbad, CA, USA), respectively. DNA libraries were prepared and sequenced at the CeGaT GmbH genomic service (Tübingen, Germany) on the Illumina NovaSeq 6,000 Platform using 100 bps paired-end reads.

### 2.3.2. Short-chain fatty acid and amino acid profiling

Metabolites were extracted and derivatized as described (34). Briefly, 100 mg of each frozen stool sample was placed in a 2 ml tube containing ceramic beads and 1 ml of 10% iso-butanol. The sample was mechanically homogenized and centrifuged, and 675  $\mu\text{l}$  of supernatant was transferred to a new Eppendorf tube. After adding 125  $\mu\text{l}$  of 20 mM NaOH and 400  $\mu\text{l}$  chloroform to the sample, it was vortexed and centrifuged. A 400  $\mu\text{l}$  aliquot of the upper aqueous phase was transferred to a new tube, followed by the addition of 100  $\mu\text{l}$  of pyridine and 80  $\mu\text{l}$  of isobutanol. The volume of each sample was adjusted to 650  $\mu\text{l}$  with ultra-pure water. Calibration standards of SCFAa (formate, acetate, propionate, butyrate, isobutyrate, and valerate) and amino acids (alanine, L-arginine, L-cystine, L-glutamic acid, L-leucine, L-lysine, L-serine, L-threonine, L-tyrosine, L-valine, and L-histidine) were obtained from Sigma-Aldrich (St. Louis, MO). Samples and standards were derivatized with chloroformate isobutyl (50  $\mu\text{l}$  per 650  $\mu\text{l}$  sample or standard). The samples were vortexed and after adding 170  $\mu\text{l}$  hexane were vortexed again and centrifuged. An aliquot of the upper isobutyl-hexane phase was transferred to an autosampler vial. Gas chromatographic analysis of the fecal extracts was performed on an Agilent 7000D Triple Quadrupole mass spectrometer coupled to a 7,890 GC System with a G4513A autosampler (Agilent Technologies, Santa Clara, CA, USA). A VF-5ms column (30 m, 0.25 mm, 0.50  $\mu\text{m}$ ) was used for analysis. The temperatures of the injector, ion source, quadrupole, and transfer line were set to 260, 250, 150, and  $275^{\circ}\text{C}$ , respectively. The carrier gas was helium and the flow rate was 1 mL/min. The derivatized sample was injected into the VF-5ms column with a split ratio of 50:1, and the solvent delay was set to 3 min. The oven temperature program started at  $40^{\circ}\text{C}$ , where it was kept for 5 min before increasing to  $275^{\circ}\text{C}$  at a rate of  $10^{\circ}\text{C}/\text{min}$ , where it was held for 10 min. The total run time was 38.5 min. MS data were gathered in full scan mode from  $m/z$  15–650 at a frequency of 4.9 scans per second. MassHunter software (Agilent Technologies, Santa Clara, CA, USA) was used for analysis.

## 2.4. Statistical analysis

Shannon diversity indices were calculated using the diversity function in the vegan package (version 2.5-7) (35). Values were compared using the Kruskal-Wallis or Mann-Whitney U-test (for two groups only). Bacterial taxa were assigned with Metaphlan3 (36), version 3.0.13, with default parameters. Enterotypes were assigned according to the methods described by Arumugam et al. (37), using the R code present at <https://enterotype.embl.de/enterotypes.html>. Enterotype drivers were assigned based on NetConfer (38) analysis of correlation coefficient weighted networks. Fisher's exact test verified the relationship between the experimental group and enterotype. *Post-hoc* analysis was performed according to the



methods described by Shan and Gerstenberger (39). Differences in taxa abundance between groups were assessed using the LINDA [Linear (Lin) Model for Differential Abundance (DA)] (40) method for compositional data, with  $p$ -values corrected using the Benjamini–Hochberg (41) procedure to minimize the false discovery rate (FDR) and using relative abundance values, computed by Metaphlan3. The Bacteroidetes/Firmicutes ratios were compared using the Kruskal–Wallis or Mann–Whitney U-tests (for two groups only). Differences in metabolite concentrations between study groups and enterotypes were assessed using the Kruskal–Wallis test (with an FDR-corrected Mann–Whitney U-test as a *post-hoc* test).

Functional assignments were conducted by human version 3.0 (part of BioBakery Workflows) (36), using MetaCyc (42) pathways as a reference database. Quality filtering and decontamination were performed with KneadData as a part of the functional analysis. The LINDA method was used to assess compositional data, with  $p$ -values corrected by the Benjamini–Hochberg procedure to minimize the FDR.

### 3. Results

Altogether, the study included three groups of participants: 109 esports players and two reference groups (36 physical education students and 25 professional athletes).

Sixty-three esports players answered the questionnaire regarding gaming experience. They trained and participated in League of Legends (LOL) (46%), Counter Strike: Global Offensive (CS:GO) (52.4%), and Starcraft (1.6%); 13 and 87% reported having professional (receiving financial gratification and training under the supervision of a trainer) and semi-professional experience, respectively. Professionals spent more time playing than semi-professionals ( $6 \pm 1.95$  h/day vs.  $4 \pm 1.15$  h/day, respectively); the gaming experience of professional players averaged  $6.4 \pm 2.6$  years. Mechanics, tactics, communication, and movement precision were the main contents of the training sessions, which took place daily or several times a week. The weekly training session of CS:GO players consisted of watching two video replays (demos) and participating in 20 practice matches (approximately 3–4 h in total), while official games were played in BO3 mode (about 1–1.5 h). League of Legends players participated in three-team training sessions (scrims) per day (lasting approximately 4–6 h) and took part in Solo Q, a 1 vs. 1 ranking game against randomly assigned non-team players. Esports games are played on various platforms, i.e., consoles, computers, and mobile phones, and using different control devices (computer mouses, keyboards, and gamepads), either live in front of an audience or via an online broadcast. Among esports players, 60.3 and 17.3% were university students and secondary school students, respectively (Supplementary Table 1).

As summarized in Supplementary Table 2, the average age of esports players was significantly lower than that of students (21 vs. 23 years,  $p < 0.001$ ). The body mass, height, and BMI did not differ between esports players and students. However, esports players demonstrated significantly lower muscle mass ( $p < 0.001$ ) and higher fat mass ( $p < 0.001$ ) than students. While the self-reported physical activity of esports players, estimated as energy expenditure, was significantly lower ( $p < 0.01$ ), their self-reported physical activity level was higher ( $p < 0.05$ ) than that of students.

### 3.1. Dietary variables

Dietary variables of esports players and students were converted to nutrient intake values (Supplementary Table 3). The energy value of the esports players' diet was significantly lower ( $p < 0.01$ ) than that of the students' diet (2,063 kcal vs. 2,418 kcal, respectively). Evaluation of energy balance showed poor balance (in terms of energy intake) in the majority of esports players (70.49%) and students (66.67%). The total protein content and the amount of plant and animal protein in the regular diet of esports players was significantly lower than in the student group. This is a mean (from 3 consecutive days) daily intake (as mentioned in the methodology section) (gg). Total carbohydrate intake was also significantly lower ( $p < 0.001$ ) for esports players than for students. There was no statistically significant difference in the intake of fat and trans-fatty acids in both groups, although the diet of esports players had a lower fat content than that of students. Evaluation of the average intake of macronutrients, expressed in grams per kilogram of body weight (g/kg bw), showed that the average protein intake of esports players was significantly lower ( $p < 0.05$ ) than that of students. Intake of total carbohydrates, fructose, and sugars was also significantly lower in esports players than in students; 8.1 vs. 10.4%, respectively), although there was no difference in dietary fat content). Nutrient standards of sugars consumption are expressed as a percentage of energy intake. The supply of saturated fatty acids was higher in esports players (12.01 vs. 9.97%) than in students, and polyunsaturated fatty acids (PUFAs) and cholesterol levels were lower (2.97 vs. 3.92%). As above, nutrient standards are expressed as a percentage of energy intake. Esports players consumed a significantly lower amount of fiber than the student group. It was noted that both esports players and students showed a tendency to avoid alcohol (consumption was expressed in grams and grams per kilogram bw).

### 3.2. Evaluation of the gut microbiome, SCFAs, and amino acids in esports players, students, and professional athletes

On average, 43 million reads were generated per sample (median = 43 million). On average, five out of 13 detected phyla (Actinobacteria, Bacteroidetes, Firmicutes, Proteobacteria, and Verrucomicrobia) comprised more than 1% of the microbiome. The dominant phylum was Bacteroidetes, with a mean abundance of 75.45%. Of the 136 genera detected, 13 had a mean abundance higher than 1%; of these, the five most prevalent were *Bacteroides*, *Alistipes*, *Prevotella*, *Faecalibacterium*, and *Bifidobacterium* (Figure 1). On the species level, 382 species were detected.

### 3.3. Enterotype-related changes

SparCC correlation analysis using NetConfer identified three enterotypes, of which enterotype 1 was *Bacteroides*-driven and enterotype 3 was *Prevotella*-driven. While both of those taxa had the most significant degrees and betweenness levels in their respective enterotype networks, enterotype 2 shared similar degrees of *Alistipes*, *Bacteroides*, and *Bifidobacterium* in the network.

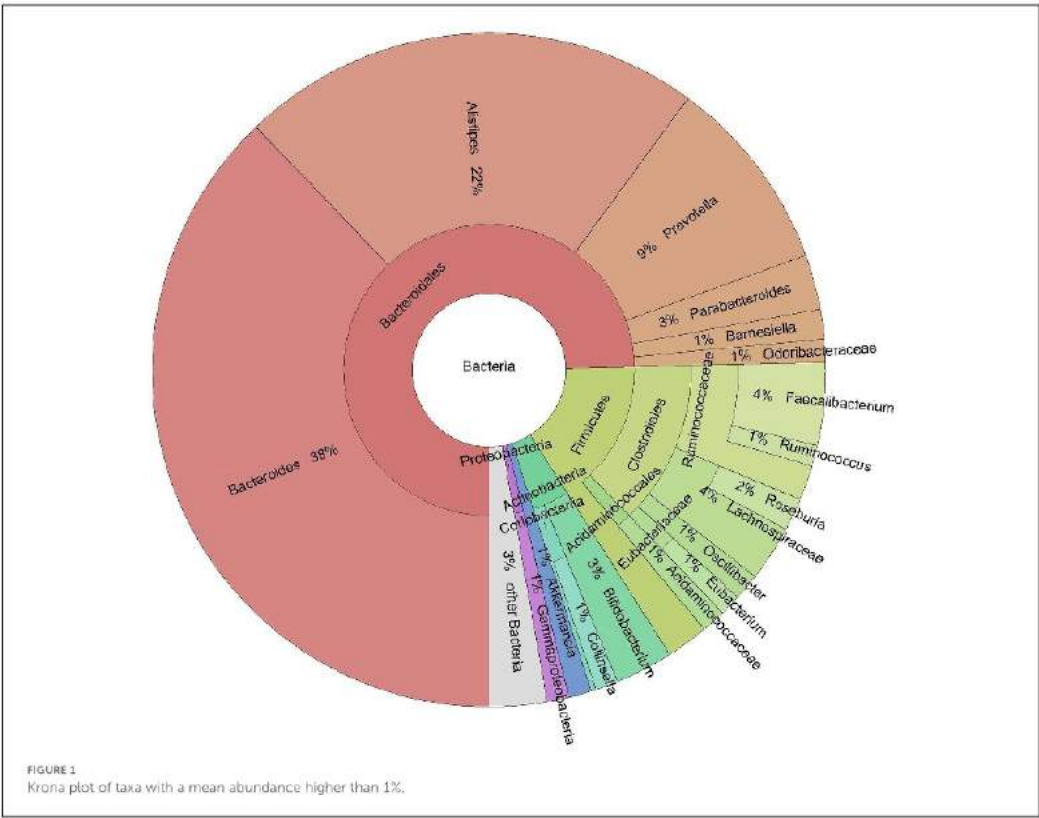


TABLE 1. Enterotype abundance in students, esports players, and professional athletes.

|                       | 1 (B)    | 2 (A)     | 3 (P)     |
|-----------------------|----------|-----------|-----------|
| Students              | 16 (44%) | 13 (36%)  | 7 (19%)   |
| Esports players       | 48 (44%) | 40 (37%)  | 20 (18%)  |
| Professional athletes | 0***     | 15 (60%)* | 10 (40%)* |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

(Supplementary Figure 1, Supplementary Table 4). As presented in Table 1, while the enterotype frequency was almost identical in esports players and students, enterotype 1 was not found in professional athletes. In contrast, enterotypes 2 and 3 were significantly more prevalent in athletes than in esports players and students (Table 1). Furthermore, professional athletes exhibited a significantly lower B/F ratio than both esports players and students (Figure 2).

When esports players and students were subdivided according to physical activity level, we found statistically significant differences in enterotype distribution ( $p = 0.0005$ , Fisher's exact test with a simulated  $p$ -value). *Bacteroides*-associated enterotype 1 was

over-represented and *Alistipes*-associated enterotype 2 was under-represented among participants with the lowest levels of activity when compared with those with a medium activity level (Table 2).

### 3.4. Bacterial diversity

After correction by multiple hypothesis testing, neither  $\alpha$ - nor  $\beta$ -diversity differed esports players from students, while the  $\alpha$ -diversity differed esports players from professional athletes ( $p = 0.052$ , Mann-Whitney U-test, Figure 3A), and there were statistically significant community dissimilarities between both esports players and students, and professional athletes, as measured by ANOSIM (Analysis of Similarities) ( $R = 0.14$ ,  $p = 0.0013$ , Figure 3B, Table 3).

### 3.5. Bacterial abundance

On the species level, nine bacteria (*Parabacteroides distasonis*, *Lactinospira pectinoschiza*, *Parabacteroides merdae*, *Bacteroides faecis*, *Paraprevotella xyliniphila*, *Veillonella atypica*, *Veillonella parvula*, *Streptococcus salivarius*, and *Streptococcus parasanguinis*) differentiated esports players from students, and 31 and 45 bacteria



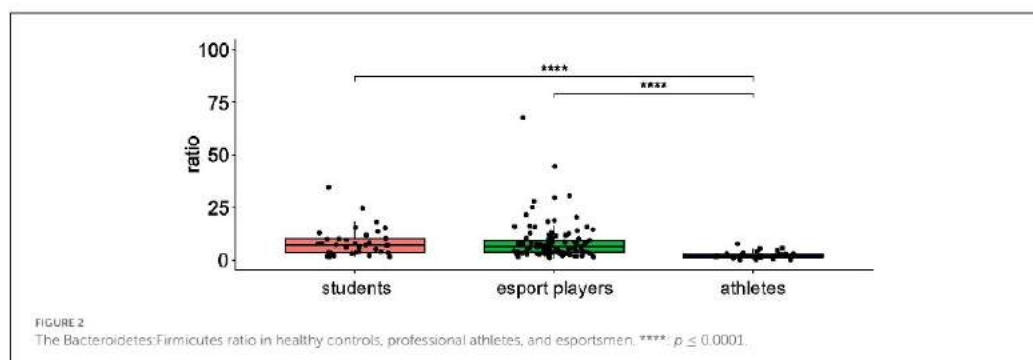


TABLE 2 Enterotype distribution in different physical activity levels in combined groups of esports players and students.

| Physical activity | Enterotype |            |          |
|-------------------|------------|------------|----------|
|                   | 1 (B)      | 2 (A)      | 3 (P)    |
| Level 1           | 34 (52%)** | 18 (28%)** | 13 (20%) |
| Level 2           | 15 (38%)   | 21 (53%)   | 4 (10%)* |
| Level 3           | 8 (35%)    | 8 (35%)    | 7 (30%)  |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ; level 1 = low; level 2 = medium; level 3 = high physical activity.

differentiated professional athletes from students and esports players, respectively. *Parabacteroides distasonis* was the only bacteria that differentiated all groups; professional athletes had a lower abundance than esports players and students, while esports players had a lower abundance than students (Figure 4, Supplementary Table 5). Species belonging to the genera *Parabacteroides* and *Bacteroides* were under-represented in professional athletes. Esports players were differentiated from professional athletes mainly by the abundance of bacteria belonging to the *Bacteroides* genus, which was over-represented in esports players.

### 3.6. SCFA levels

While the concentration of non-SCFAs differentiated the study groups (Supplementary Table 6), five SCFAs differentiated the enterotypes of esports players and students subdivided according to physical activity levels. Of these, isobutyric, pentanoic, and hexanoic acids differentiated between enterotypes 1 and 2; acetic acid differentiated between enterotypes 2 and 3; and pentanoic acid differentiated between enterotypes 1 and 3. Propanoic acid differentiated all enterotypes (Figure 5).

### 3.7. Amino acid levels

The concentration of each of nine amino acids differentiated esports players from students, four amino acids differentiated professional athletics from students, and methionine

differentiated esports players from both students and athletes (Figure 6).

Only phenylalanine did not differentiate between enterotypes in esports players and students (Figure 7). The Kruskal-Wallis test identified methionine as being statistically significant, but neither pairwise comparison was significant, probably due to loss of statistical power. Alanine differentiated enterotypes 1 and 2, leucine and glutamic acid differentiated enterotypes 2 and 3, and glycine, valine, isoleucine, and proline differentiated enterotype 2 from the remaining two enterotypes (Figure 7).

### 3.8. Correlation analysis between bacteria and metabolites

We calculated the sparCC correlation coefficient to evaluate the correlation between the abundance of bacteria and the concentrations of SCFAs and amino acids. Of 161 bacterial species with a mean abundance  $> 0.01\%$ , 21 (including genus *Bacteroides*, and *Prevotella*) (Figure 8A) and 12 species (Figure 8B) correlated with SCFAs and amino acids, respectively. *Bacteroides vulgaris*, *Barnesiella intestinihominis*, and *Prevotella copri* correlated with at least five of seven SCFAs studied, and *Alistipes finegoldii* correlated positively with all nine amino acids studied. *Faecalibacterium prausnitzii* correlated negatively with seven amino acids.

### 3.9. Microbiome-related functional analyses

Metagenome functional content was assessed using the MetaCyc pathway database. In total, 370 pathways were tested to make functional comparisons between esports players, students, and professional athletes. While we found no functional differences between esports players and students, 77 and 158 metabolic pathways differentiated professional athletes from students and esports players, respectively (Supplementary Table 7, Figure 9). Of these, 71 pathways were common in both comparisons. The differential pathways mainly were associated with *Fermentation*, *Amino acid Biosynthesis and Degradation*, *Carbohydrate Biosynthesis and Degradation*, *Fatty Acid Biosynthesis and Degradation*, and *TCA Cycle* pathways. Of note, compared with athletes, all differential pathways associated with

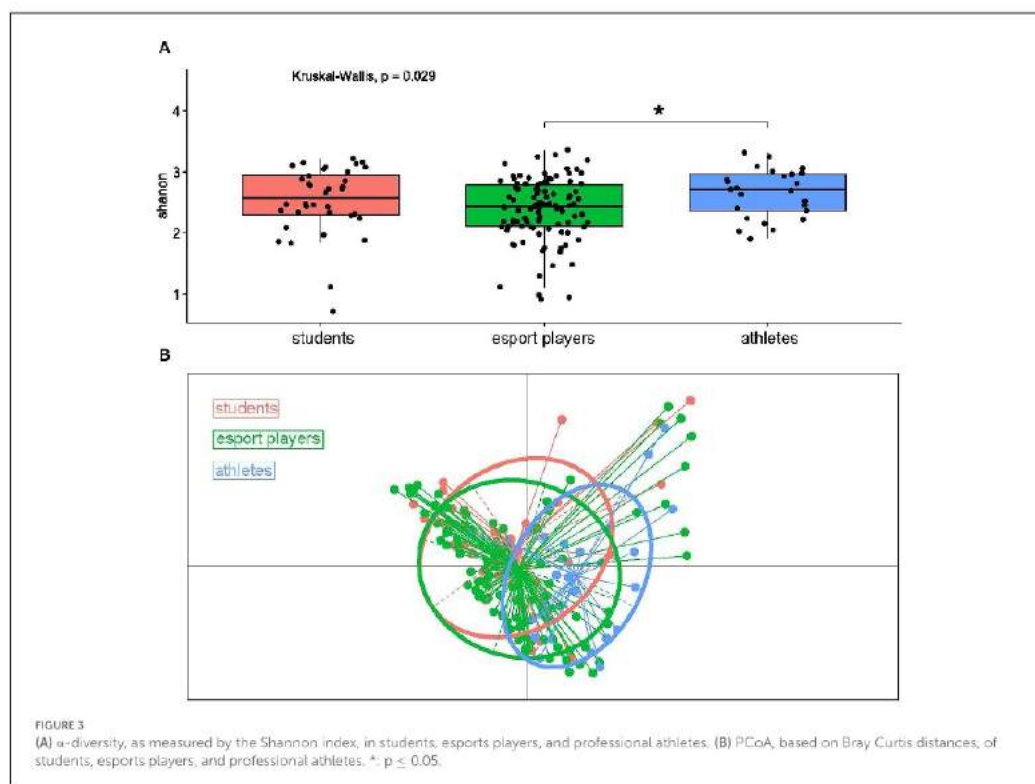


TABLE 3 Community dissimilarities, as measured by ANOSIM R (number of permutations: 9999).

| Comparison                               | R        | Significance |
|------------------------------------------|----------|--------------|
| Esport players vs. students              | -0.00546 | 5.25E-01     |
| Esport players vs. professional athletes | 0.2719   | 1.00E-04     |
| Students vs. professional athletes       | 0.2288   | 7.00E-04     |

*Fermentation*, the *TCA Cycle*, and *Fatty Acid beta-Oxidation* were under-represented in students and esports players.

### 3.10. Correlations between dietary variables, gut taxa, and metabolites

Two hundred fifty-three macronutrient-species pairs were showing Spearman's rank correlation coefficients between 0.2 and 0.39. Of these, at least one of the 25 dietary measures is associated with the abundance of at least one of the 91 bacterial species (Figure 10). Nine species were associated with seven or more nutrients. *Veillonella parvula*, *Haemophilus patainfluenzae*, *Bifidobacterium pseudocatenulatum*, and *Bacteroides xylanisolvens* correlated positively with 16, 11, 10, and eight nutrients,

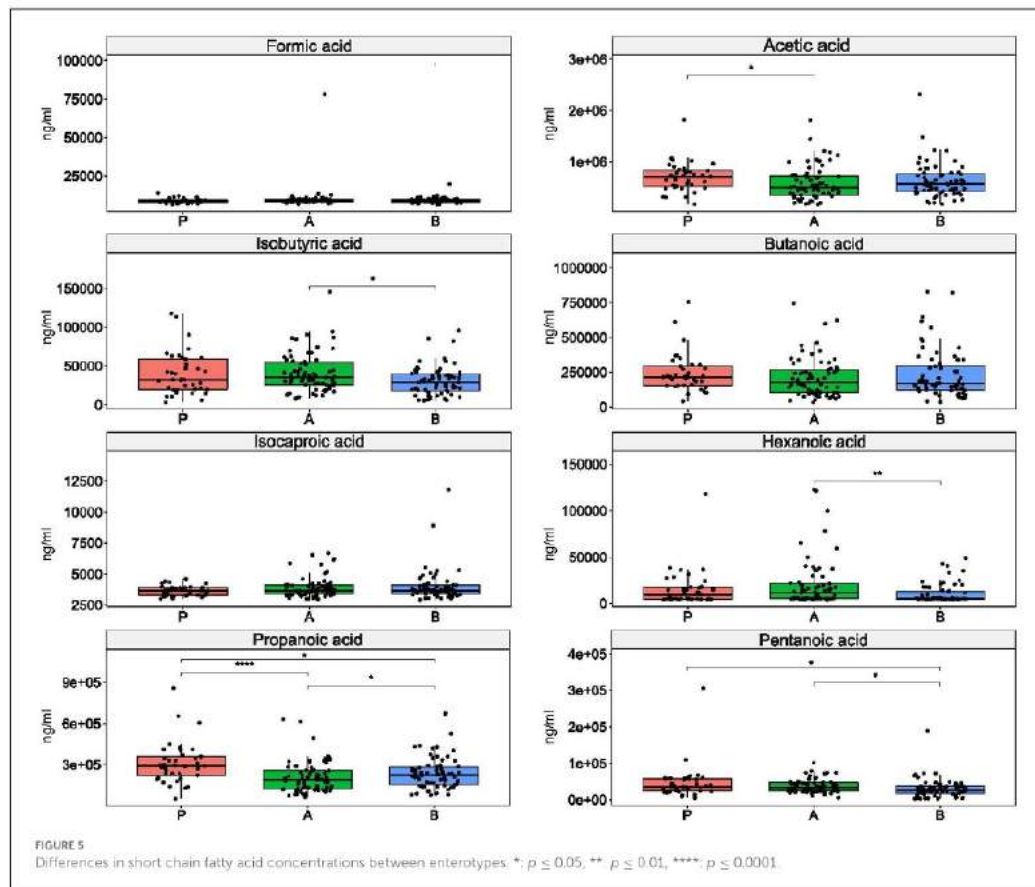
respectively, and *Desulfovibrio naceabacterium*, *Alistipes putredinis*, *Ruminococcus sp CAG330*, and *Bilophila muris* correlated negatively with nine different nutrients. These findings confirm the key role of diet in the functional composition of the gut microbiota.

The correlation between species abundance and nutrients was also assessed using LINDA. As shown in Table 4, nine species (*Bacteroides coprocola*, *Bacteroides faecis*, *Bacteroides sp CAG443*, *Bifidobacterium pseudocatenulatum*, *Lachnospira pectinoschiza*, *Parabacteroides merdae*, *Paraprevotella xylaniphila*, *Prevotella copri*, and *Veillonella parvula*) were correlated with eight nutrient measures, whereas seven species correlated with the amount of drinking water. All associations were positive.

## 4. Discussion

Both host genetics and environmental factors modulate the structure and function of the gut microbial community. Of the latter, exercise and diet affect the gut microbiota of professional athletes and highly fit individuals, who show more dynamic changes compared with their less fit or sedentary counterparts (43). For the first time, our study presents an integrated view of the relationship between physical activity levels and dietary habits of esports players and the composition and function of their gut microbiome. The study

*Bacteroides*-driven enterotype 1 is typical for a "Western" type diet enriched in protein and animal fat, whereas *Alistipes*-driven enterotype 2 is associated with long-term consumption of carbohydrate-rich diets (8). Furthermore, while the bacterial cluster



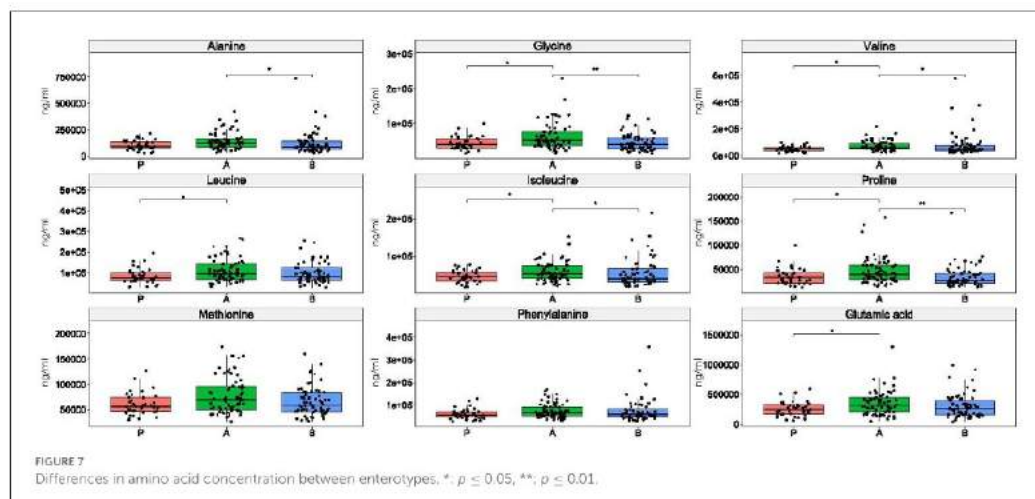
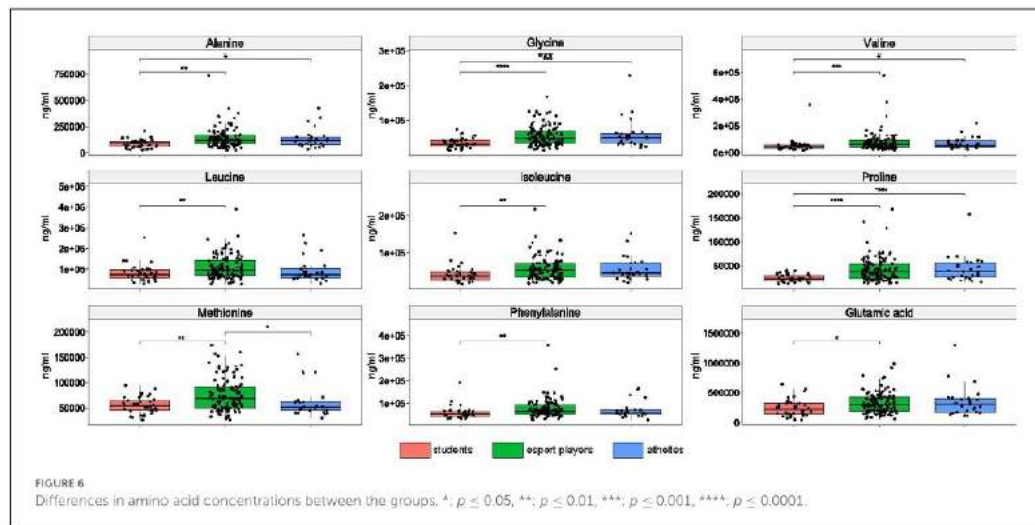
of enterotype 1 acquires energy primarily from carbohydrates via the glycolysis and pentose phosphate pathways, bacteria clusters of enterotype 2 and 3 may also degrade mucin glycoproteins of the gut mucosal layer (7). The three dominant enterotype clusters were identical in the esports player and student groups, but enterotype 1 was dominant; however, enterotype 1 was under-represented and enterotype 2 was over-represented in male participants with medium to high levels of physical activity compared with those with low levels. Consistent with this, enterotype 1 was not found in the athlete group. By contrast, previous studies show that neither continuous physical activity performed at low doses by premenopausal women (12), nor extensive exercise training conducted by female endurance runners (45), modified the enterotype clusters. In addition, while the B/F ratio did not differentiate esports players from students, professional athletes had a significantly lower B/F ratio than both of these groups. This confirms our earlier findings showing that Polish athletes have a higher abundance of Firmicutes than controls (33). In healthy young adults, the B/F ratio correlates significantly with cardiorespiratory fitness, a powerful indicator of athletic performance and health, but not with other fitness parameters, nutritional intake,

or anthropometric variables (43). Also, daily exercise enriches Firmicutes in the gut of young children and adolescents (47). However, some studies report a decreased B/F ratio in obese individuals, although other studies showed no changes, or even an increased B/F ratio, in obese animals and humans (47). Further studies are needed to assess whether an altered B/F ratio can be used as an exercise signature.

On the species level, the abundance of nine bacteria differentiated esports players from students; all were under-represented in esports players, while as many as 31 and 45 bacteria differentiated professional athletes from students and esports players, respectively. However, only *Parabacteroides distasonis* species differentiated all three experimental groups from each other, with the lowest abundance in esports players and the highest in controls. This species contributes indirectly to methane, acetic acid, and anti-inflammatory succinic acid production (48), thereby playing a protective role against colon cancer development and human obesity (49). Its contribution to autoinflammatory diseases remains ambiguous (50).

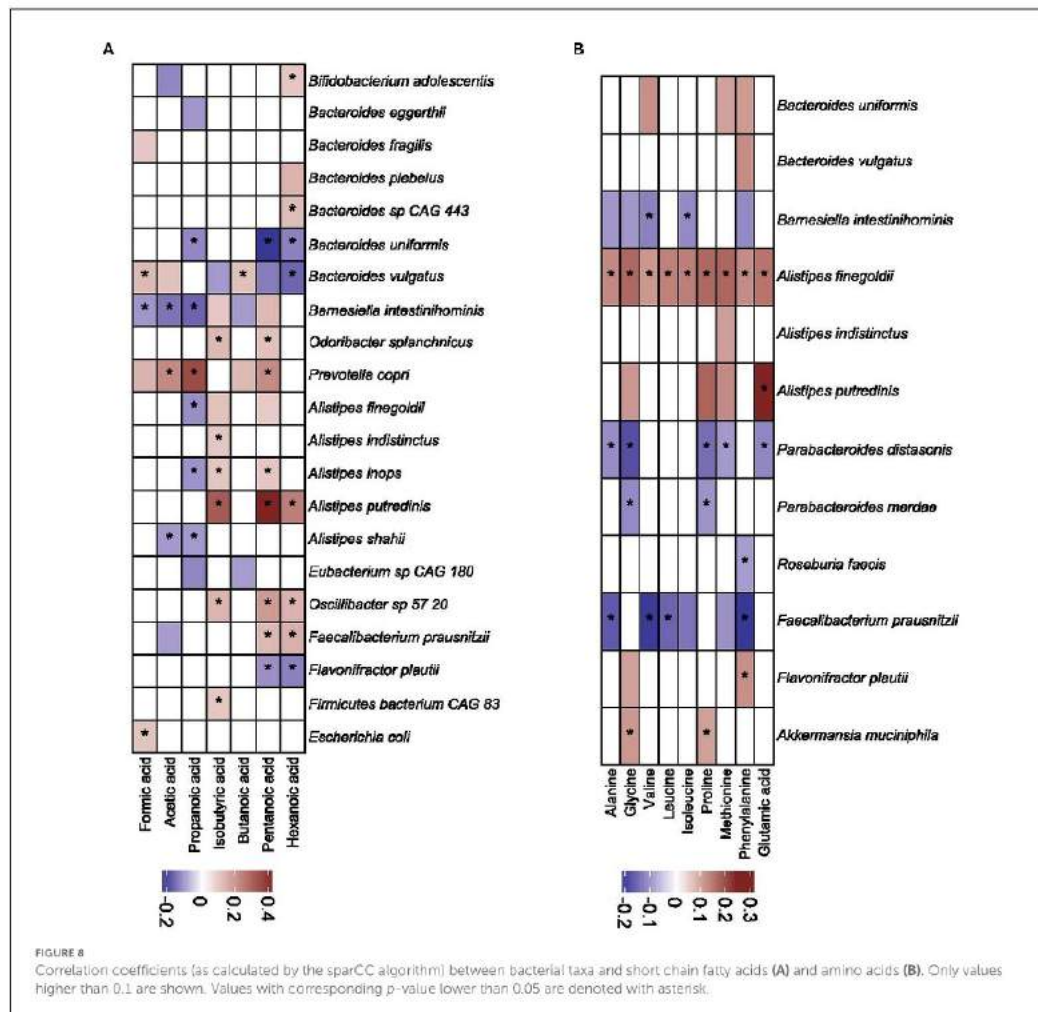
A higher abundance of *Akkermansia* species, which have potentially beneficial effects, were found in athletes when compared





with the two other groups. *Akkermansia* is associated with overall good health and is less abundant among obese individuals (51). Additionally, *A. muciniphila* increases gut barrier function (52), promotes the release of human glucagon-like peptide-1 (GLP-1), downregulates the production of pro-inflammatory cytokines, and controls fat storage (53, 54). The following abundant species, *Roseburia hominis*, is a known producer of butyrate (55). In turn, *Anaeromassilibacillus* sp An250 is associated with both low BMI (56) and high-intensity physical activity (57). Lactate, a by-product of skeletal muscle energy metabolism during exercise, is transported to the gut, where it enhances the growth of propionate-producing bacteria, including *Veillonella* (58). Here, we found that the *Veillonella* genus correlated positively with muscle mass and fiber and

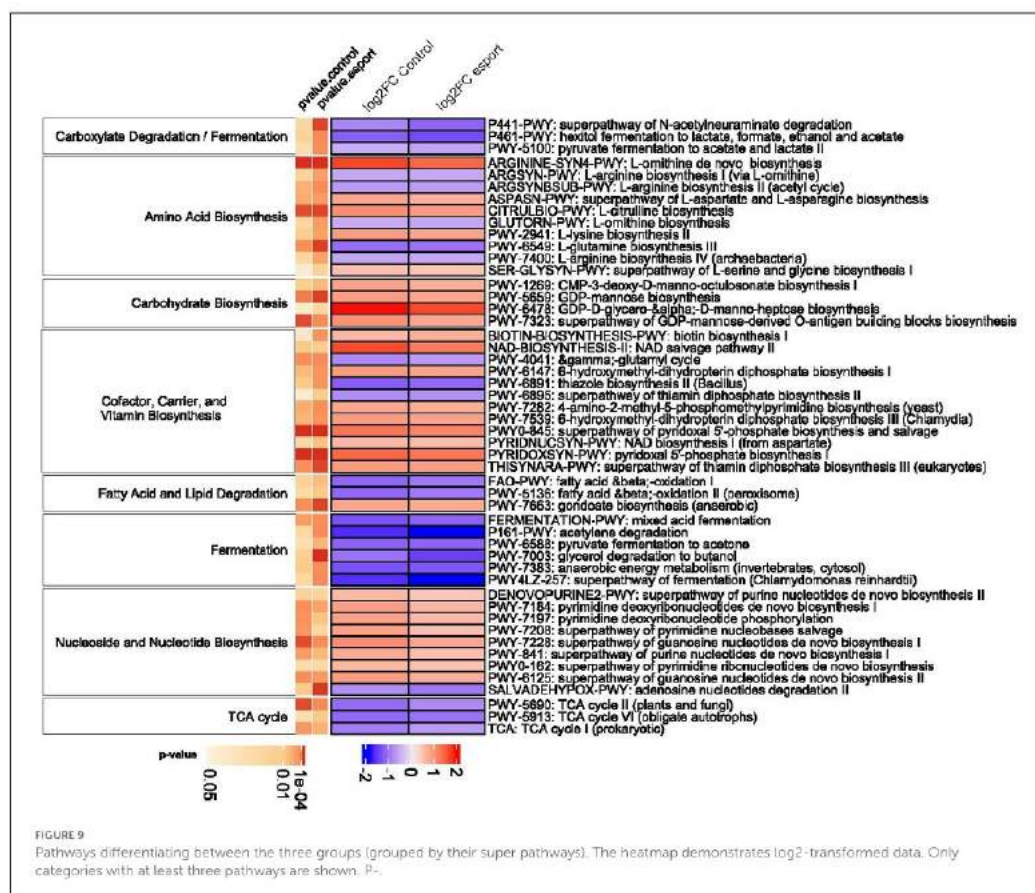
carbohydrate consumption. Additionally, two potentially harmful bacteria, *Bilophila wadsworthia* and *Ruminococcus gnavus*, were under-represented in professional athletes. *Bilophila wadsworthia* is a bile-tolerant and sulfite-reducing bacteria associated with a high-fat animal-based diet. Hydrogen sulfide produced by *B. wadsworthia* is a well-known pro-inflammatory factor (59, 60). *Ruminococcus gnavus* is connected to Crohn's disease through its pro-inflammatory product, glucorhamnan polysaccharide (61), and is associated with metabolic syndrome (62). By contrast, the microbiome of esports players and students was enriched in beneficial *Bacteroides* species: *B. thetaiotaomicron* contributes to an increase in mucus production and strengthening of the epithelial barrier (63), and has anti-inflammatory properties that inhibit the development of Crohn's



disease (64), while *B. uniformis* is negatively correlated with physical activity in older adults (65), alleviates obesity in conjunction with an appropriate diet (66) and enhances endurance exercise performance (67). To summarize, our findings confirm changes in the relative abundance of different taxa reported in professional rugby players (44), marathon runners (58), professional cyclists (68), and other sports persons (69), as well as in elderly healthy individuals with a lifelong history of endurance training (46) and premenopausal women after continuous physical activity (12).

The metabolic activity of the gut microbiota results from the degradation of dietary carbohydrates, lipids, and proteins that exert both local and systemic activity; these include SCFAs and branched-chain fatty acids, alcohols, ammonia, amines, sulfur compounds, phenols and indoles, glycerol, and choline derivatives (3). SCFAs,

like butyrate, acetate, and propionate, are the most abundant fecal metabolites. Butyrate serves as an energy source for colonocytes, improves the integrity of intestinal epithelial cells, increases mucin and cytokine production, and induces differentiation of naive T cells. Acetate and propionate also aid in anti-inflammatory processes and cytokine production. In addition, after adsorption from the gut lumen, SCFAs modulate metabolic responses at different sites, including skeletal muscle (70), and their excess can be incorporated into the gluconeogenic and lipogenic processes (71). As SCFAs play a pivotal role in whole-body energy metabolism, and their levels correlate with variations in the gut microbiota (7), it is not surprising that high levels of physical activity enrich taxa known to participate in SCFA production (70). However, although a 6-week exercise training program in lean sedentary people



enhanced fecal SCFA concentrations (13), and a literature search confirmed increased production of gut SCFAs in response to exercise (51), none of the SCFAs differentiated our studied groups. Instead, five SCFAs differentiated between enterotypes. Of these, propanoic, isobutyric, pentanoic, and hexanoic acid differentiated between *Alistipes*- and *Bacteroides*-driven enterotypes, acetic and propanoic acid differentiated between *Prevotella*- and *Alistipes*-driven enterotypes, and pentanoic acid differentiated between *Prevotella*- and *Bacteroides*-driven enterotypes.

Increased bacterial metabolic processes in the distal parts of the colon may also result from higher availability of amino acids (72). In contrast to fecal SCFAs, the amounts of each of the nine amino acids studied herein differentiated esports players from students, whereas the amounts of four amino acids differentiated professional athletes from students, while methionine differentiated esports players from the two other groups. However, the role of interrelationships between gut amino acid levels and the structure and function of the gut microbiome has not been clarified.

On the functional level, we found no differences between esports players and students, although several metabolic pathways

were over-represented in professional athletes compared with esports players and students; these included *Fermentation*, *Amino acid Biosynthesis and Degradation*, *Carbohydrate Biosynthesis and Degradation*, *Fatty Acid Biosynthesis and Degradation*, and the *TCA Cycle* pathways. The other pathways, including *Cell Structure Biosynthesis*, *Nucleoside and Nucleotide Biosynthesis*, and *Generation of Precursor Metabolites and Energy*, appears to differentiate between enterotypes. The results of our functional analysis correspond with other findings. As demonstrated previously, the diverse responses of glycemic control and insulin sensitivity to training results from shifts in microbial fermentation (73). Similarly, high-intensity interval training enhances amino acid biosynthesis pathways (74). Likewise, the microbiomes of rugby players are enriched for carbohydrate metabolism, amino acid biosynthesis, and SCFAs synthesis pathways (44). SCFAs, as precursors for lipid or carbohydrate synthesis, enter the TCA and are used as substrates for lipogenesis or gluconeogenesis, respectively (70). Therefore, the bioavailability of gut SCFAs is considered to be a potential regulator of skeletal muscle metabolism. Peak oxygen uptake during cardiorespiratory fitness exercise correlates with changes in gut microbiota diversity. Diversity



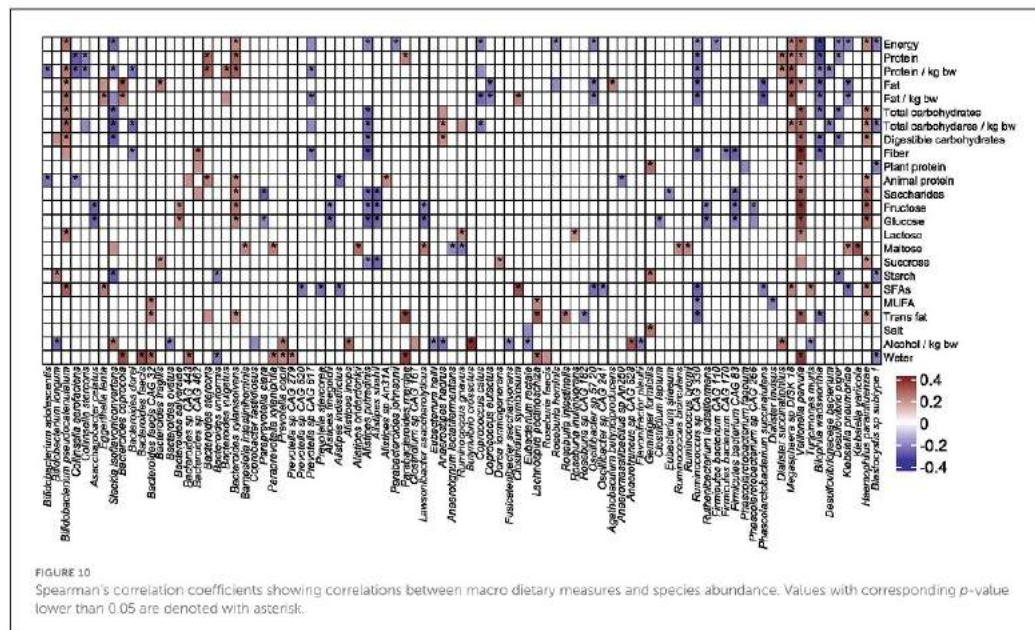


TABLE 4 Bacterial species associated with nutrient parameters, as signified by the LINDA model.

| Species                                  | Nutrient                    | log2-FC |
|------------------------------------------|-----------------------------|---------|
| <i>Bacteroides coprocola</i>             | Fat                         | 0.85    |
| <i>Veillonella parvula</i>               | Total carbohydrates         | 1.03    |
| <i>Bifidobacterium pseudocatenulatum</i> | Total carbohydrates g/kg bw | 1.45    |
| <i>Veillonella parvula</i>               | Fructose                    | 1.14    |
| <i>Veillonella parvula</i>               | Glucose                     | 1.15    |
| <i>Bifidobacterium pseudocatenulatum</i> | Lactose                     | 1.40    |
| <i>Bacteroides</i> sp CAG443             | Alcohol g/kg bw             | 0.72    |
| <i>Prevotella copri</i>                  | Alcohol g/kg bw             | 1.82    |
| <i>Veillonella parvula</i>               | Water                       | 1.172   |
| <i>Bacteroides coprocola</i>             | Water                       | 0.80    |
| <i>Parabacteroides merdae</i>            | Water                       | 1.24    |
| <i>Lachnospira pectinosticta</i>         | Water                       | 1.18    |
| <i>Bacteroides faecis</i>                | Water                       | 0.91    |
| <i>Paraprevotella xylaniphila</i>        | Water                       | 0.87    |
| <i>Bacteroides</i> sp CAG443             | Water                       | 0.67    |

is associated with microbial metabolic functions, including fatty acid biosynthesis (75). Additionally, the microbiome of athletes showed a significant increase in the capacity for nucleotide biosynthesis and improved cell structure, which play a role in energy demands essential in endurance sports (44).

## 4.1. Conclusion

Overall, although our findings are consistent with those of previous reports in many respects, the differences between esports players and physical education students concerning lifestyle and dietary habits appear to have little effect on most gut microbiota parameters. Nevertheless, differences in the abundance of several bacterial species and marked differences in fecal amino acid concentrations between these two groups were noted. However, the main limitation of this study, as well as other similar studies, relates to the self-reporting of physical activity time and dietary habits. People tend to overestimate their activity levels (76) and underestimate their food intake. Therefore, future studies should be conducted based on strictly controlled dietary intake and physical activity levels to fully determine their effect on gut microbiota composition.

## Data availability statement

The data presented in the study are deposited in the SRA at <http://www.ncbi.nlm.nih.gov/bioproject/885289>, repository, accession number PRJNA885289.

## Ethics statement

The studies involving human participants were reviewed and approved by Institute of Oncology Local Bioethics Board. The patients/participants provided their written informed consent to participate in this study.



## Author contributions

MK: data curation, formal analysis, visualization, writing—original draft, and writing—review and editing. BF: conceptualization, methodology, resources, validation, writing—original draft, and writing—review and editing. AB, PC, KB, MG, AK, and MP: investigation. NZ-L: investigation, visualization, and writing—review and editing. BZ and MSK: resources. MSZ: resources and writing—review and editing. MM: visualization and writing—review and editing. JO: conceptualization, funding acquisition, project administration, resources, writing—original draft, and writing—review and editing. All authors contributed to the article and approved the submitted version.

## Funding

This work was supported by the National Science Centre (Poland) under Grant 2018/29/B/NZ7/00809.

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers.

## References

- Sender R, Fuchs S, Milo R. Revised estimates for the number of human and bacterial cells in the body. *PLoS Biol.* (2016) 14:e1002533. doi: 10.1371/journal.pbio.1002533
- Li J, Jia H, Cai X, Zhong H, Feng Q, Sunagawa S, et al. An integrated catalog of reference genes in the human gut microbiome. *Nat Biotechnol.* (2014) 32:834–41. doi: 10.1038/nbt.2942
- Ghosh S, Pramanik S. Structural diversity, functional aspects and future therapeutic applications of human gut microbiome. *Arch Microbiol.* (2021) 203:5281–308. doi: 10.1007/s00203-021-02516-y
- Gomes AC, Hoffmann C, Mota JF. The human gut microbiota: metabolism and perspective in obesity. *Gut Microbes.* (2018) 9:308–25. doi: 10.1080/19490976.2018.1465157
- Kho ZY, Lal SK. The human gut microbiome – a potential controller of wellness and disease. *Front Microbiol.* (2018) 9:1835. doi: 10.3389/fmicb.2018.01835
- Heiss CN, Olofsson LE. Gut microbiota-dependent modulation of energy metabolism. *J Innate Immun.* (2018) 10:163–71. doi: 10.1159/000481519
- Rinninella E, Raoul P, Cintoni M, Franceschi F, Miglino GAD, Gasbarrini A, et al. What is the healthy gut microbiota composition? a changing ecosystem across age, environment, diet, and diseases. *Microorganisms.* (2019) 7:E14. doi: 10.3390/microorganisms7010014
- Wu GD, Chen J, Hoffmann C, Bittinger K, Chen Y-Y, Keilbaugh SA, et al. Linking long-term dietary patterns with gut microbial enterotypes. *Science.* (2011) 334:105–8. doi: 10.1126/science.1208344
- David LA, Materna AC, Friedman J, Campos-Baptista MI, Blackburn MC, Perrotta A, et al. Host lifestyle affects human microbiota on daily timescales. *Genome Biol.* (2014) 15:R89. doi: 10.1186/gb-2014-15-7-r89
- Mohr AE, Jäger R, Carpenter KC, Kerkick CM, Purpura M, Townsend JR, et al. The athletic gut microbiota. *J Int Soc Sports Nutr.* (2020) 17:24. doi: 10.1186/s12970-020-00353-w
- Mitchell CM, Davy BM, Hulver MW, Neilson AP, Bennett BJ, Davy KP. Does exercise alter gut microbial composition? a systematic review. *Med Sci Sports Exerc.* (2019) 51:160–7. doi: 10.1249/MSS.0000000000001760
- Bressa C, Bailén-Andrino M, Pérez-Santiago J, González-Soltero R, Pérez M, Montalvo-Lominchar MG, et al. Differences in gut microbiota profile between women with active lifestyle and sedentary women. *PLoS ONE.* (2017) 12:e0171352. doi: 10.1371/journal.pone.0171352
- Allen JM, Mailing LJ, Niemi GM, Moore R, Cook MD, White BA, et al. Exercise alters gut microbiota composition and function in lean and obese humans. *Med Sci Sports Exerc.* (2018) 50:747–57. doi: 10.1249/MSS.0000000000001495
- The Games Market Will Decline – 4.3% to \$184.4 Billion in 2022; Long-Term Outlook Remains Positive. Newzoo. Available online at: <https://newzoo.com/insights/articles/the-games-market-will-decline-4-3-to-184-4-billion-in-2022> (accessed December 1, 2022).
- Bonnar D, Castine B, Kakoschke N, Sharp G. Sleep and performance in athletes: for the win! *Sleep Health.* (2019) 5:647–50. doi: 10.1016/j.sleh.2019.06.007
- Toth AJ, Kowal M, Campbell MJ. The color-word stroop task does not differentiate cognitive inhibition ability among esports gamers of varying expertise. *Front Psychol.* (2019) 10:2852. doi: 10.3389/fpsyg.2019.02852
- Mach N, Fuster-Botella D. Endurance exercise and gut microbiota: a review. *J Sport Health Sci.* (2017) 6:179–97. doi: 10.1016/j.jshs.2016.05.001
- Thivel D, Chaput JP. [Food consumption in children and youth: effect of sedentary activities]. *Rev Epidemiol Sante Publique.* (2013) 61:399–405. doi: 10.1016/j.respe.2013.01.098

Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

## Supplementary material

The Supplementary Material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fnut.2022.1092846/full#supplementary-material>

**SUPPLEMENTARY FIGURE 1**  
Between-class analysis visualization, including representation of cluster drivers (C) and individual samples within clusters (B), as well as the choice of optimal cluster number (A).

**SUPPLEMENTARY TABLE 1**  
Gaming experience of esports players.

**SUPPLEMENTARY TABLE 2**  
Characteristics of esports players and control groups.

**SUPPLEMENTARY TABLE 3**  
Energy and nutritional value of the diets of esports players and students.

**SUPPLEMENTARY TABLE 4**  
Network parameters, calculated by NetConfer, for three enterotypes: *Prevotella* (P)-, *Alistipes* (A)-, and *Bacteroides* (B)-driven.

**SUPPLEMENTARY TABLE 5**  
Differences between esportsmen and healthy students, and professional sportsman, calculated by the LINDA model.

**SUPPLEMENTARY TABLE 6**  
Kruskal-Wallis test p-values for comparison of short chain fatty acid levels in students and esports players, presented as the median and IQR (in parentheses).

**SUPPLEMENTARY TABLE 7**  
Functional differences between professional sportsmen, esportsmen, and healthy control students, as calculated by the LINDA model.

19. Puolitaival T, Sieppi M, Pyky R, Enwald H, Korpelainen R, Nurikala M. Health behaviours associated with video gaming in adolescent men: a cross-sectional population-based MOPO study. *BMC Public Health*. (2020) 20:415. doi: 10.1186/s12889-020-08522-z
20. DiFrancesco-Donoghue J, Werner WG, Douris PC, Zwiibel H. Esports players, got muscle? Competitive video game players' physical activity, body fat, bone mineral content, and muscle mass in comparison to matched controls. *J Sport Health Sci*. (2022) 11:725–30. doi: 10.1016/j.jshs.2020.07.006
21. Giakoni-Ramirez F, Merellano-Navarro E, Duclos-Bastias D. Professional esports players: motivation and physical activity levels. *Int J Environ Res Public Health*. (2022) 19:2256. doi: 10.3390/ijerph19042256
22. Yamagata K, Yamagata LM, Abela M. A review article of the cardiovascular sequelae in sport athletes: A cause for concern? *Hellenic J Cardiol*. (2022) 68:40–5. doi: 10.1016/j.hjc.2022.06.005
23. Martin-Niedecken AL, Schüttin A. Let the body'n/brain games begin: toward innovative training approaches in esports athletes. *Front Psychol*. (2020) 11:138. doi: 10.3389/fpsyg.2020.00138
24. Bayraktar A, Yıldız Y, Bayraktar I. Do e-athletes move? A study on physical activity level and body composition in elite e-sports. *Phys Educ Stud*. (2020) 24:259–64. doi: 10.1556/120755279.2020.0501
25. Trotter MG, Coulter TJ, Davis PA, Poulos DR, Polman R. The association between esports participation, health and physical activity behaviour. *Int J Environ Res Public Health*. (2020) 17:37329. doi: 10.3390/ijerph17197329
26. AG EB. International physical activity questionnaire – polish long version. *Polish J Sport Med*. (2013) 29:1–15. doi: 10.1123/jisnem.2018-0024
27. Martin CK, Han H, Coulton SM, Allen HR, Champagne CM, Anton SD, et al. Novel method to remotely measure food intake of free-living individuals in real time: the remote food photography method. *Br J Nutr*. (2009) 101:446–56. doi: 10.1017/S0007114508027438
28. Jarosz M, Rychlik E, Stos K, Chazewska J. *Normy żywienia dla populacji Polski i ich zastosowanie*. Poland: Narodowy Instytut Zdrowia Publicznego-Państwowy Zakład Higieny Warsaw (2020).
29. Benardot D. *Advanced Sports Nutrition*. Champaign, IL: Human Kinetics (2012). p. 411.
30. Thomas DT, Erdman KA, Burke LM. American college of sports medicine joint position statement. Nutrition and athletic performance. *Med Sci Sports Exerc*. (2016) 48:543–68. doi: 10.1249/MSS.0000000000000852
31. Kerkisk CM, Wilborn CD, Roberts MD, Smith-Ryan A, Kleiner SM, Jager R, et al. ISSN exercise and sports nutrition review update: research and recommendations. *J Int Soc Sports Nutr*. (2018) 15:28. doi: 10.1186/s12970-018-0242-y
32. Authority (EFSA). EFSA Dietary Reference Values for nutrients Summary report. *EFSA Support Pub*. (2017) 14:e15121E. doi: 10.2903/sp.efsa.2017.e15121
33. Kulecka M, Fraczek B, Mikula M, Zeber-Lubecka N, Karczmarski J, Paziewska A, et al. The composition and richness of the gut microbiota differentiate the top Polish endurance athletes from sedentary controls. *Gut Microbes*. (2020) 11:1374–84. doi: 10.1080/19490976.2020.1758009
34. Ambroziewicz E, Karczmarski J, Kulecka M, Paziewska A, Niemira M, Zeber-Lubecka N, et al. In search for interplay between stool microRNAs, microbiota and short chain fatty acids in Crohn's disease – a preliminary study. *BMC Gastroenterol*. (2020) 20:307. doi: 10.1186/s12876-020-01444-3
35. Dixon P. Vegan a package of R functions for community ecology. *J Veget Sci*. (2003) 14:927–30. doi: 10.1111/j.1654-1103.2003.tb02228.x
36. Beghini F, Melzer LJ, Blanco-Míguez A, Dubois L, Asnicar E, Maharjan S, et al. Integrating taxonomic, functional, and strain-level profiling of diverse microbial communities with bioBakery 3. *Elife*. (2021) 10:e65088. doi: 10.7554/eLife.65088
37. Arumugam M, Raes J, Pelletier E, Le Paslier D, Yamada T, Mende DR, et al. Enterotypes of the human gut microbiome. *Nature*. (2011) 473:174–80. doi: 10.1038/nature09944
38. Nagpal S, Baksi KD, Kuntal BK, Mande SS. NetConfer: a web application for comparative analysis of multiple biological networks. *BMC Biol*. (2020) 18:53. doi: 10.1186/s12915-020-00781-9
39. Shan G, Gerstenberger S. Fisher's exact approach for post hoc analysis of a chi-squared test. *PLoS ONE*. (2017) 12:e0188709. doi: 10.1371/journal.pone.0188709
40. Zhou H, He K, Chen J, Zhang X. LinDA: linear models for differential abundance analysis of microbiome compositional data. *Genome Biol*. (2022) 23:95. doi: 10.1186/s13059-022-02655-5
41. Benjamini Y, Hochberg Y. Controlling the false discovery rate: a practical and powerful approach to multiple testing. *J Royal Stat Soc Series B*. (1995) 57:289–300. doi: 10.1111/j.2517-6161.1995.tb02031.x
42. Caspi R, Billington R, Keseler IM, Kothari A, Krummenacker M, Midford PE, et al. The MetaCyc database of metabolic pathways and enzymes – a 2019 update. *Nucleic Acids Res*. (2020) 48:D445–53. doi: 10.1093/nar/gkz862
43. Durk RP, Castillo E, Márquez-Magaña L, Grosicki GJ, Bolter ND, Lee CM, et al. Gut Microbiota composition is related to cardiorespiratory fitness in healthy young adults. *Int J Sport Nutr Exerc Metab*. (2019) 29:249–53.
44. Barton W, Penney NC, Cronin O, García-Pérez I, Molloy MG, Holmes E, et al. The microbiome of professional athletes differs from that of more sedentary subjects in composition and particularly at the functional metabolic level. *Gut*. (2018) 67:625–33. doi: 10.1136/gutjnl-2016-313627
45. Morishima S, Aoi W, Kawamura A, Kawase T, Takagi T, Naito Y, et al. Intensive, prolonged exercise seemingly causes gut dysbiosis in female endurance runners. *J Clin Biochem Nutr*. (2021) 68:253–8. doi: 10.3164/jcbs.20-131
46. Šoltys K, Lendvorský L, Hric I, Baranovičová E, Penesová A, Mikula I, et al. Strenuous physical training, physical fitness, body composition and bacteroides to prevotella ratio in the gut of elderly athletes. *Front Physiol*. (2021) 12:670989. doi: 10.3389/fphys.2021.670989
47. Magne F, Gotteland M, Gauthier L, Zazulka A, Pesoa S, Navarrete P, et al. The firmicutes/bacteroidetes ratio: a relevant marker of gut dysbiosis in obese patients? *Nutrients*. (2020) 12:E1474. doi: 10.3390/nu12051474
48. Sakamoto M, Benno Y. Reclassification of *Bacteroides distans*, *Bacteroides goldsteini* and *Bacteroides merdae* as *Parabacteroides distans* gen. nov. comb. nov., *Parabacteroides goldsteini* comb. nov. and *Parabacteroides merdae* comb. nov. *Int J Syst Evol Microbiol*. (2006) 56:1599–605. doi: 10.1099/ijs.0.64192-0
49. Palmas V, Pisanu S, Madau V, Casula E, Deledda A, Cusano R, et al. Gut microbiota markers associated with obesity and overweight in Italian adults. *Sci Rep*. (2021) 11:5532. doi: 10.1038/s41598-021-84928-w
50. Ezeji JC, Sarikonda DK, Hopperton A, Erkkila HL, Cohen DE, Martinez SP, et al. *Parabacteroides distans*: intriguing aerotolerant gut anaerobe with emerging antimicrobial resistance and pathogenic and probiotic roles in human health. *Gut Microbes*. (2021) 13:1922241. doi: 10.1080/19490976.2021.1922241
51. Lenu S, Pekala S. Gut microbiota, microbial metabolites and human physical performance. *Metabolites*. (2021) 11:716. doi: 10.3390/metabo1110716
52. Bian X, Wu W, Yang L, Lv L, Wang Q, Li Y, et al. Administration of *Akkermansia muciniphila* ameliorates dextran sulfate sodium-induced ulcerative colitis in mice. *Front Microbiol*. (2019) 10:2259. doi: 10.3389/fmicb.2019.02259
53. Si J, Kang H, You HJ, Ko G. Revisiting the role of *Akkermansia muciniphila* as a therapeutic bacterium. *Gut Microbes*. (2022) 14:2078619. doi: 10.1080/19490976.2022.2078619
54. Everard A, Belzer C, Geurts L, Ouwerkerk JP, Druart C, Bindels LB, et al. Cross-talk between *Akkermansia muciniphila* and intestinal epithelium controls diet-induced obesity. *Proc Natl Acad Sci U S A*. (2013) 110:9066–71. doi: 10.1073/pnas.1219451110
55. Machiels K, Joossens M, Sabino J, De Preter V, Aerts J, Eckhaut V, et al. A decrease of the butyrate-producing species *Roseburia hominis* and *Faecalibacterium prausnitzii* defines dysbiosis in patients with ulcerative colitis. *Gut*. (2014) 63:1275–83. doi: 10.1136/gutjnl-2013-304833
56. Chanda D, De D. Meta-analysis reveals obesity associated gut microbial alteration patterns and reproducible contributors of functional shift. *bioRxiv [Preprint]*. doi: 10.1101/2022.06.05.494850
57. Waleriańczyk W, Stolarski M, Matthews G. Perfectionism moderates the effects of goal-realization on post-competition mood in amateur runners. *J Sports Sci Med*. (2022) 21:1–12. doi: 10.52062/jssm.2022.1
58. Scheiman J, Luber JM, Chavkin TA, MacDonald T, Tung A, Pham L-D, et al. Metagenomics analysis of elite athletes identifies a performance-enhancing microbe that functions via lactate metabolism. *Nat Med*. (2019) 25:1104–9. doi: 10.1038/s41591-019-0485-4
59. Feng Z, Long W, Hao B, Ding D, Ma X, Zhao L, et al. human stool-derived *Bifidobacterium wadsworthii* strain caused systemic inflammation in specific-pathogen-free mice. *Gut Pathog*. (2017) 9:59. doi: 10.1186/s13099-017-0208-7
60. Natividad JM, Lamas B, Pham HP, Michel M-L, Rainteau D, Bridonneau C, et al. *Bifidobacterium wadsworthii* aggravates high fat diet induced metabolic dysfunctions in mice. *Nat Commun*. (2018) 9:2802. doi: 10.1038/s41467-018-05249-7
61. Henke MT, Kenny DJ, Cassilly CD, Vlamakis H, Xavier RJ, Clardy J. *Ruminococcus gnavus*, a member of the human gut microbiome associated with Crohn's disease, produces an inflammatory polysaccharide. *Proc Natl Acad Sci U S A*. (2019) 116:12672–7. doi: 10.1073/pnas.1904099116
62. Grahmema L, Nethander M, Coward E, Gabrielsen ME, Stree S, Billod J-M, et al. Cross-sectional associations between the gut microbe *Ruminococcus gnavus* and features of the metabolic syndrome. *Lancet Diabetes Endocrinol*. (2022) 10:481–5. doi: 10.1016/S2213-8587(22)00113-9
63. Wrzosek L, Miguel S, Noordine M-L, Bouet S, Joncquel Chevalier-Curt M, Robert V, et al. *Bacteroides thetaiotaomicron* and *Faecalibacterium prausnitzii* influence the production of mucus glycans and the development of goblet cells in the colonic epithelium of a gnotobiotic model rodent. *BMC Biol*. (2013) 11:61. doi: 10.1186/1741-7007-11-61
64. Delday M, Mulder I, Logan ET, Grant G. *Bacteroides thetaiotaomicron* ameliorates colon inflammation in preclinical models of Crohn's disease. *Inflamm Bowel Dis*. (2019) 25:85–96. doi: 10.1093/ibd/izy281
65. Magzal F, Shochat T, Haimov I, Tamir S, Asraf K, Tuchner-Azieli M, et al. Increased physical activity improves gut microbiota composition and reduces short-chain fatty acid concentrations in older adults with insomnia. *Sci Rep*. (2022) 12:2265. doi: 10.1038/s41598-022-05099-w

66. López-Almela I, Román-Pérez M, Bullich-Vilarrubias C, Benítez-Pérez A, Gómez Del Pulgar EM, Francés R, et al. *Bacteroides uniformis* combined with fiber amplifies metabolic and immune benefits in obese mice. *Gut Microbes*. (2021) 13:1–20. doi: 10.1080/19490976.2020.1865706
67. Morita H, Kato C, Ishii C, Kagata N, Ishikawa T, Uchiyama Y, et al. *Bacteroides uniformis* enhances endurance exercise performance through gluconeogenesis. *bioRxiv [Preprint]*. doi: 10.1101/2020.03.04.975730
68. Petersen LM, Bautista EJ, Nguyen H, Hanson BM, Chen L, Lek SH, et al. Community characteristics of the gut microbiomes of competitive cyclists. *Microbiome*. (2017) 5:98. doi: 10.1186/s40168-017-0320-4
69. O'Donovan CM, Madigan SM, Garcia-Perez I, Rankin AJ, O'Sullivan O, Cotter PD. Distinct microbiome composition and metabolome exists across subgroups of elite Irish athletes. *J Sci Med Sport*. (2020) 23:63–8. doi: 10.1016/j.jsams.2019.08.290
70. Frampton J, Murphy KG, Frost G, Chambers ES. Short-chain fatty acids as potential regulators of skeletal muscle metabolism and function. *Nat Metab*. (2020) 2:840–8. doi: 10.1038/s42255-020-0188-7
71. Oliphant K, Allen-Vercoe E. Macronutrient metabolism by the human gut microbiome: major fermentation by-products and their impact on host health. *Microbiome*. (2019) 7:91. doi: 10.1186/s40168-019-0704-8
72. Macfarlane S, Quigley ME, Hopkins MJ, Newton DE, Macfarlane GT. Polysaccharide degradation by human intestinal bacteria during growth under multi-substrate limiting conditions in a three-stage continuous culture system. *FEMS Microbiol Ecol*. (1998) 26:231–43. doi: 10.1111/j.1574-6941.1998.tb00508.x
73. Liu Y, Wang Y, Ni Y, Cheung CKY, Lam KSL, Wang Y, et al. Gut microbiome fermentation determines the efficacy of exercise for diabetes prevention. *Cell Metabol*. (2020) 31:77–91.e5. doi: 10.1016/j.cmet.2019.11.001
74. Zhao J, Wang Y, Zhao D, Zhang L, Chen P, Xu X. Integration of metabolomics and proteomics to reveal the metabolic characteristics of high-intensity interval training. *Analyst*. (2020) 145:6500–10. doi: 10.1039/D0AN01287D
75. Estaki M, Pither J, Baumcister P, Little JP, Gill SK, Ghosh S, et al. Cardiorespiratory fitness as a predictor of intestinal microbial diversity and distinct metagenomic functions. *Microbiome*. (2016) 4:42. doi: 10.1186/s40168-016-0189-7
76. Prince SA, Adamo KB, Hamel ME, Hardt J, Connor Gorber S, Tremblay M, et al. Comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int J Behav Nutr Phys Act*. (2008) 5:56. doi: 10.1186/1479-5868-5-56





## Assessment of physical activity, exercise capacity and fitness level of the Polish esports players

Barbara Frączek <sup>1</sup>ABCD, Monika Szot <sup>2</sup>BCD, Andrzej Sagalara <sup>3</sup>D, Sebastian Krzepota <sup>4</sup>E, Maciek Skorko <sup>5</sup>AE, Dariusz Błachnio <sup>6</sup>AB, Bartosz Bertrandt <sup>7</sup>D, Krzysztof Szymaniuk <sup>4</sup>B, Andrzej Klimek <sup>8</sup>D

<sup>1</sup> Department of Sports Medicine and Human Nutrition, Institute of Biomedical Sciences, University of Physical Education in Krakow

<sup>2</sup> Department of Sports Dietetics, Gdansk University of Physical Education and Sport

<sup>3</sup> Department of Physical Education, Kaimes School, Edinburgh, UK

<sup>4</sup> AGO Esports sp z o.o, Warszawa, Poland

<sup>5</sup> Institute of Psychology, Polish Academy of Sciences, Warszawa, Poland

<sup>6</sup> SET Sport Edukacja Trening, Warszawa, Poland

<sup>7</sup> Amber Nutrition, Michałowice, Poland

<sup>8</sup> Department of Physiology and Biochemistry, Institute of Biomedical Sciences, University of Physical Education in Krakow

Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection

**Abstract:** Professional esports requires players to maintain mental skills at a high level and health-promoting physical condition. The aim of this study was to analyze the levels of physical activity (PA), exercise capacity and physical fitness. The study included 196 male Polish esports players (mean: 20.5±2.4 years), who completed the International Physical Activity Questionnaire (IPAQ) (n= 187), underwent exercise test using a cycle ergometer (n= 141) and participated in selected tests of physical fitness (n= 175). The average total energy expenditure was 1040 MET·min·week<sup>-1</sup>. The results show that most esports players had low (38%) and moderate (36.4%) levels of PA, and were characterized by an average level of cardiorespiratory fitness ( $VO_{2max}$  = 41.92±5.41 mL·kg<sup>-1</sup>·min<sup>-1</sup>), and the amount of muscle power generated at the level of AeT (90.98±27.19 W), AnT (149.91±29.91 W) and  $VO_{2max}$  (210.29±42.63 W) was lower than published evidence on physically-active men. Physical fitness of the players was assessed as being satisfactory, but more research needed to clearly confirm this.

**Keywords :** esports, IPAQ, exercise capacity, total energy expenditure

Corresponding author: Monika Szot, email: monika.szot@awf.gda.pl

Copyright: © 2024  
by the authors.  
Submitted for  
possible open  
access publication  
under the terms and  
conditions of the  
Creative Commons  
Attribution (CC BY)  
license  
[<http://creativecommons.org/licenses/by/4.0/>].



Received: 01.07.2023; Accepted: 21.08.2023; Published online: 3.01.2024

Citation: Frączek B, Szot M, Sagalara A, Krzepota S, Skorko M, Błachnio D, Bertrandt B, Szymaniuk K, Klimek A. Assessment of physical activity, exercise capacity and fitness level of the Polish esports players. Phys Act Rev 2024; 12(1): 32-46. doi: 10.16926/par.2024.12.04



## INTRODUCTION

Esports is a form of organized competitive video gaming that is gaining increasing recognition and millions of fans worldwide [1,2]. The requirements of esports competitors focus on various cognitive domains (attention, perception, and visuospatial skills) and physical abilities [1,3]. To be successful, esports players must also collaborate and cooperate with other teammates, which in turn requires additional communication skills (oral and verbal) and the expression of these skills in a dynamic and stressful environment. Esports can be divided into different genres (e.g., multiplayer online battle arenas, first-person shooters), which include special skills used in the virtual environment [4]. Previous studies have reported that esports players spend between 5.5 and 14 hours per day in the same seated position [5,6,7]; therefore, there are serious concerns that prolonged time spent in front of a computer screen may have negative physical and psychosocial consequences for these athletes [8].

It has been documented that some health-related behaviors that characterize esports players, such as prolonged sitting [9], sleep restriction and disturbance [10,11], unhealthy dietary habits [12], or video game addiction [13], may negatively affect their health and general well-being.

Some studies have focused on analyzing the level of physical activity (PA) among esports players [9,13-19] and, in the last five years, the most common pain complaints reported by this population [14,20-24]. However, accurate measures of exercise capacity and physical fitness are lacking in the literature, including direct comparisons between esports players at different performance levels (e.g., professional, semi-professional). We addressed these issues, therefore, this study was intended by analyzing the levels of PA, exercise capacity and physical fitness.

## MATERIAL AND METHODS

### *Participants*

The study sample consisted of 196 elite Polish male eSports players with at least 2 years of gaming experience (average  $6.4 \pm 2.6$  years). The players trained and participated in tournaments such as Counter-Strike:Global Offensive (CS:GO), League of Legends (LoL), and StarCraft. About 19.9% of the participants had professional experience, defined as receiving financial rewards and specialized training, and the rest were semi-professional (80.1%). Professionals spent more time playing than semi-professionals ( $6 \pm 1.95$  h·day<sup>-1</sup> vs.  $4 \pm 1.15$  h·day<sup>-1</sup>). One third of the group (33.2%) were college players, 22.9% were high school students, and 43.8% of the participants were non-students. The age of the participants ranged from 18 to 29 years (mean:  $20.5 \pm 2.4$  years), with a body weight of  $76.3 \pm 15.5$  kg and a height of  $180.3 \pm 6.3$  cm (Table 1). A body mass index (BMI) was calculated from the height (cm) and weight (kg) data. Based on the WHO recommendation for BMI [kg/m<sup>2</sup>] [25], it was found that the majority (62.8%) of esports players had a normal BMI, 20.9% were overweight, 8.7% were underweight, and 7.7% were obese.

Inclusion criteria for the study were: 1) male gender and at least 18 years old; 2) training in a professional or semi-professional team; 3) good general health (no chronic diseases); 4) provide signed written informed consent to participate in this research. The study was conducted in 2020-2022, approved by the Bioethics Committee of the Regional Medical Society in Gdansk (KB-63/22), and conducted in accordance with the Declaration of Helsinki.

Using a cross-sectional design, this study examined the level of PA in 187 esports players, the physical fitness qualities of 141 participants, and 175 players who participated in selected physical fitness tests. For each dependent variable, our sample was divided into professional and semi-professional players for comparative analysis.

Table 1. Characteristics of esports players

| Variable                 |                    | Total<br>(n= 196) | Professional<br>(n= 40) | Semi-professionals<br>(n= 156) |
|--------------------------|--------------------|-------------------|-------------------------|--------------------------------|
| Age (years)              |                    | 20.5±2.4          | 21.1±2.6                | 20.3±2.3                       |
| Height (cm)              |                    | 180.3±6.3         | 179.7±6.1               | 180.4±6.4                      |
| Weight (kg)              |                    | 76.3±15.5         | 76.1±15.6               | 76.4±15.6                      |
| BMI (kg/m <sup>2</sup> ) |                    | 23.4±4.2          | 23.5±4.1                | 23.4±4.3                       |
| Games                    | CS:GO              | 64.3 (126)        | 32.5 (13)               | 73.1 (114)                     |
|                          | LoL                | 35.2 (69)         | 65 (26)                 | 26.9 (42)                      |
|                          | StarCraft          | 0.5 (1)           | 2.5 (1)                 | 0 (0)                          |
| Education                | Secondary students | 22.9 (45)         | 0 (0)                   | 28.8 (45)                      |
|                          | Collegiate players | 33.2 (65)         | 2.5 (1)                 | 41.0 (64)                      |
|                          | Non-students       | 43.8 (86)         | 97.5 (39)               | 30.1 (47)                      |

Data presented as mean±SD or % (n)

### Measures

#### Assessment of physical activity

The Polish version of the International Physical Activity Questionnaire (IPAQ) was used to assess subjects' PA levels [26]. Participants reported the frequency and duration of sitting, walking, or moderate-to-vigorous physical activity that lasted at least 10 minutes (without interruption) during the previous seven days. Activities lasting less than 10 minutes were not included. Energy expenditure (expressed as MET·min·week<sup>-1</sup>) was calculated by multiplying the number of activity days per week by the corresponding MET value and the average duration of that activity in minutes. The individual results obtained for all activities performed during the week were summed to obtain the weekly energy expenditure. Each participant was classified into one of three levels based on the following criteria: (1) high: if they met at least one of the following criteria: three or more days of vigorous exercise, including at least 1500 MET·min·week<sup>-1</sup>, or seven or more days of any combination of activities (vigorous, moderate, or walking) exceeding 3000 MET·min·week<sup>-1</sup>; (2) moderate: if they met at least one of the following criteria: three or more days of vigorous activity (at least 20 minutes per day), or five or more days of moderate activity or walking (at least 30 minutes per day), or five or more days of any combination of PA (walking, moderate, or vigorous) exceeding 600 MET·min·week<sup>-1</sup>; (3) low: if they did not meet the criteria for the moderate or high categories.

#### Assessment of exercise capacity

In order to determine the subject's aerobic capacity (maximum oxygen uptake and the levels of aerobic and anaerobic thresholds), the direct method was used by means of a gradually increasing workload test performed on a Monark 894E cycle ergometer. The test began with a 3-minute warm-up of unloaded cycling and the load was increased by 50 W every 3 minutes until voluntary exhaustion was reached. The cadence was 60 rpm. Heart rate was simultaneously recorded with a pulse oxymeter (Polar Electro, model S410). During the test, oxygen uptake (VO<sub>2</sub>), minute ventilation (VE), and heart rate (HR) were recorded every 30 s. Aerobic and anaerobic thresholds were analyzed based on the dynamic changes of respiratory parameters. Overall, the following indicators of exercise capacity were evaluated: maximum oxygen uptake (VO<sub>2max</sub>), maximum HR (HR<sub>max</sub>), HR at aerobic threshold (HR at AeT) and anaerobic threshold (HR at AnT), HR recovery time to AeT, power at oxygen threshold (PO at AeT) and anaerobic threshold (PO at AnT), maximum power at VO<sub>2max</sub> (PO at VO<sub>2max</sub>), total work (kJ).

#### Assessment of physical fitness

The physical fitness of the participants was assessed by selected tests from the tests developed by the International Committee on the Standardization of Physical Fitness

Tests (ICSPFT) and the European Fitness Test (EUROFIT) [27]. To assess physical fitness, we performed a series of modified fitness tests: upper body strength/endurance push-ups (bending and straightening arms in support), muscular fitness, trunk abdominal strength (bending forward from lying backward), and grip strength using a dynamometer (Jamar), preceded by a presentation of correct exercise technique and a standardized warm-up. The following criteria were used to evaluate correctly performed exercises 30 or more arm bends (very good); 20-29 arm bends (good), 10-19 arm bends (fair/inadequate), and <10 arm bends (poor). Right and left hand grip strength was referenced to normative values found in the literature. The classification for each age group was adopted: 18-19 years (poor score: <35.7, normal score: 35.7-55.5, strong score: >55.5); 20-24 years (poor score: <36.8, normal score: 36.8-56.6, strong score: >56.6); 25-29 years (poor score: <37.7, normal score: 37.7-57.5, strong score: >57.5).

#### Statistical analysis

Statistical analysis of the study data was performed using Statistica 12.0 (StatSoft Inc., USA). The characteristics of the group and the results obtained are presented as numerical data (n), percentages (%), descriptive statistics in the form of means ( $\bar{x}$ ), standard deviations (SD), and medians (Me). When there was a large number of variables in the analysis, the results are presented as medians. The dependencies of the variables studied were tested and statistically compared using the Pearson chi-square test of independence (professional vs. semi-professional eSports players). The level of statistical significance was set at  $p < 0.05$ .

## RESULTS

The total energy expenditure associated with sports PA was 1040 MET·min·week<sup>-1</sup>. Both groups were not statistically different in terms of PA (walking, moderate and vigorous activities). The results of the present study indicate that professionals spent significantly more time sitting than semi-professionals (600 min vs. 400 min,  $\chi^2 = 60.4$ ;  $p = .04$ ). A quarter of the participants showed a high level of PA, while 38% of the esports players were characterized by moderate activity and 36.4% by low activity. Among the professionals, the highest percentage were participants with moderate activity (54.1%), while semi-professionals dominated the players with low PA (37.9%) (Table 2).

The relative  $\text{VO}_{2\text{max}}$  in our male sample was  $41.92 \pm 5.41 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  and showed no difference between semi-professional ( $41.98 \pm 5.50 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) and professional ( $41.64 \pm 4.91 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) players. The maximum  $\text{HR}_{\text{max}}$  of the men studied was  $191 \pm 10 \text{ beats} \cdot \text{min}^{-1}$  and was similar in each of the study subgroups ( $191 \pm 10$  and  $192 \pm 7 \text{ beats} \cdot \text{min}^{-1}$ ). Subgroup performance on these indices was not significantly different. The maximum power achieved at the  $\text{VO}_{2\text{max}}$  level was  $210.29 \pm 42.63 \text{ W}$  for all players tested and was similar in the semi-professional and professional subgroups, at  $210.73 \pm 43.20$  and  $208.15 \pm 39.70 \text{ W}$ , respectively.

HR values at the AeT level were  $146.20 \pm 6.94 \text{ beats} \cdot \text{min}^{-1}$  in all subjects and showed no intergroup differentiation between semi-professional ( $146.00 \pm 7.20 \text{ beats} \cdot \text{min}^{-1}$ ) and professional ( $147.17 \pm 5.38 \text{ beats} \cdot \text{min}^{-1}$ ) players. The relative HR values, expressed in relation to  $\% \text{HR}_{\text{max}}$  at the aerobic threshold level, were  $76.47 \pm 2.00\%$  among the subjects and were similar in the semi-professional and professional groups, amounting to  $76.46 \pm 1.97$  and  $76.53 \pm 2.04\%$ , respectively. The mean rate of heart contractions at the anaerobic threshold was  $174.16 \pm 7.87 \text{ beats} \cdot \text{min}^{-1}$  for all subjects and was similar in both subgroups ( $174.03 \pm 8.22$  and  $174.83 \pm 5.80 \text{ beats} \cdot \text{min}^{-1}$ ). HR values expressed as  $\% \text{HR}_{\text{max}}$  at the were approximately  $91.09 \pm 1.10\%$  for all subjects and were independent of playing level. Similarly, power values at AnT were similar in both athlete subgroups ( $149.89 \pm 31.20$  and  $150.04 \pm 22.58 \text{ W}$ ), with mean values of  $149.91 \pm 29.91 \text{ W}$  when data were pooled (Table 3).

Regarding the perception of physical fitness, most participants achieved a very good (45.09%) or good (38.73%) result. However, it is worth noting that among those who performed <10 arm bends, some did not perform a single correct repetition and they accounted for 9.25% of all respondents. On the other hand, more than 94% of the participants obtained a good or very good grade in the forward trunk bending test, and 1.73% of the subjects did not perform any technically correct repetitions (<10 bends) (Table 4). Individual results for the professional and semi-professional subgroups are shown in Table 5.

The grip strength of the study participants was assessed for both the left and right hand as a normative result in comparison to men aged 18-19 years (60% and 61.42%) and 20-24 years (61.42% and 59.34%) (Figure 1). The grip strength of the professional and semi-professional athletes is shown in Figures 2 and 3.

Table 2. Levels of physical activity depending on esports status based on the IPAQ questionnaire

| Sport level | Total<br>(n= 187) | Professionals<br>(n= 37) | Semi-professionals<br>(n= 150) | p     |
|-------------|-------------------|--------------------------|--------------------------------|-------|
| Low         | 36.4 (68)         | 29.7 (11)                | 38.0 (57)                      | 0.488 |
| Moderate    | 37.9 (71)         | 54.1 (20)                | 34.0 (51)                      | 0.444 |
| High        | 25.7 (48)         | 16.2 (6)                 | 28.0 (42)                      | 0.431 |

Data are expressed as percentages (n); significant difference between groups  $p < 0.05$

Table 3. Physiological responses at exercise graded intensity during cycling

| Physiological parameters                                                | Total<br>(n= 141) | Professional<br>(n= 24) | Semi-Professional<br>(n= 117) | P     |
|-------------------------------------------------------------------------|-------------------|-------------------------|-------------------------------|-------|
| $VO_{2\max}$ ( $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) | 41.92±5.41        | 41.64±4.91              | 41.98±5.50                    | 0.100 |
| $VE_{\max}$ ( $\text{L} \cdot \text{min}^{-1}$ )                        | 111.66±4.18       | 111.97± 11.77           | 111.60±14.62                  | 0.373 |
| $HR_{\max}$ ( $\text{beats} \cdot \text{min}^{-1}$ )                    | 191.28±9.83       | 192.38±7.16             | 191.05±10.28                  | 0.855 |
| PO at $VO_{2\max}$ (W)                                                  | 210.29±42.63      | 208.15±39.70            | 210.73±43.20                  | 0.611 |
| HR at AeT ( $\text{beats} \cdot \text{min}^{-1}$ )                      | 146.20±6.94       | 147.17±5.00             | 146.00±7.20                   | 0.960 |
| % $HR_{\max}$ at AeT                                                    | 76.47±2.00        | 76.53±2.04              | 76.46±1.97                    | 0.072 |
| PO at AeT (W)                                                           | 90.98±27.19       | 93.03± 26.08            | 90.56±27.40                   | 0.823 |
| HR at AnT ( $\text{beats} \cdot \text{min}^{-1}$ )                      | 174.16±7.87       | 174.83±5.80             | 174.03 ± 8.22                 | 0.974 |
| % $HR_{\max}$ at AnT                                                    | 91.09±1.10        | 90.90±1.03              | 91.13±1.11                    | 0.223 |
| PO at AnT (W)                                                           | 149.91±29.91      | 150.04±22.58            | 149.89±31.20                  | 0.899 |
| Total Work (kJ)                                                         | 74.29±28.45       | 74.67±22.87             | 74.22±29.46                   | 0.858 |
| HR recovery time to AeT (s)                                             | 113.55±33.41      | 114.33±31.24            | 113.38±33.83                  | 0.144 |

Data are presented as mean ± SD; significant difference between groups  $p < 0.05$ ;  $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  milliliters per kilogram per minute;  $\text{L} \cdot \text{min}^{-1}$  - liters per minute;  $VO_{2\max}$ - maximum oxygen uptake;  $VE_{\max}$ - maximum minute ventilation;  $HR_{\max}$ - maximum heart rate; PO at  $VO_{2\max}$ - power output at maximum oxygen rate, HR- heart rate, AeT- aerobic threshold, %  $HR_{\max}$ - percentage of maximum heart rate, PO at AeT- power output at aerobic threshold, HR at AnT- heart rate at anaerobic threshold, %  $HR_{\max}$  at AnT- percentage of maximum heart rate at anaerobic threshold; PO at AnT- power output at anaerobic threshold.

Table 4. Results of individual fitness tests

| Fitness test | Rating % (n) |            |            |           |
|--------------|--------------|------------|------------|-----------|
|              | Very good    | Good       | Adequate   | Poor      |
| Arm bending  | 34.68 (60)   | 38.73 (67) | 17.34 (30) | 9.25 (16) |
| Slopes       | 55.49 (96)   | 38.73 (67) | 4.05 (7)   | 1.73 (3)  |
| Average      | 45.09 (78)   | 38.73 (67) | 10.70 (19) | 5.49 (10) |



Table 5. Results of individual fitness tests according to sport status

| Individual fitness tests | Professionalists (n= 39)<br>Rating % (n) |               |               |              | Semi-professionals (n= 134)<br>Rating % (n) |               |               |              |
|--------------------------|------------------------------------------|---------------|---------------|--------------|---------------------------------------------|---------------|---------------|--------------|
|                          | Very good                                | Good          | Adequate      | Poor         | Very good                                   | Good          | Adequate      | Poor         |
| Arm bending              | 17.95<br>(7)                             | 41.03<br>(16) | 25.64<br>(10) | 15.38<br>(6) | 39.55<br>(53)                               | 38.06<br>(51) | 14.93<br>(20) | 7.46<br>(10) |
| Slopes                   | 20.51<br>(8)                             | 58.97<br>(23) | 12.82<br>(5)  | 7.69<br>(3)  | 65.67<br>(88)                               | 32.84<br>(44) | 1.49<br>(2)   | 0<br>(0)     |
| Average                  | 19.23<br>(8)                             | 50.00<br>(20) | 19.23<br>(13) | 11.54<br>(5) | 52.61<br>(71)                               | 34.45<br>(48) | 8.21<br>(11)  | 3.73<br>(5)  |

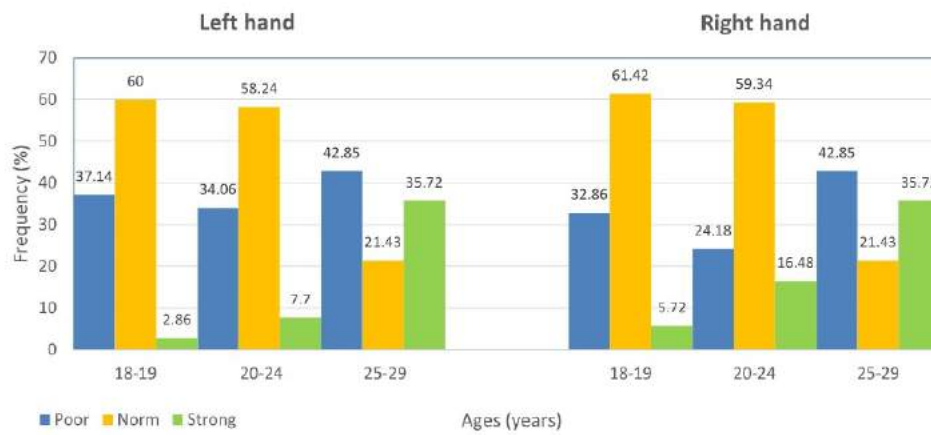


Figure 1. Comparison of grip strength in a group of esports players by age group

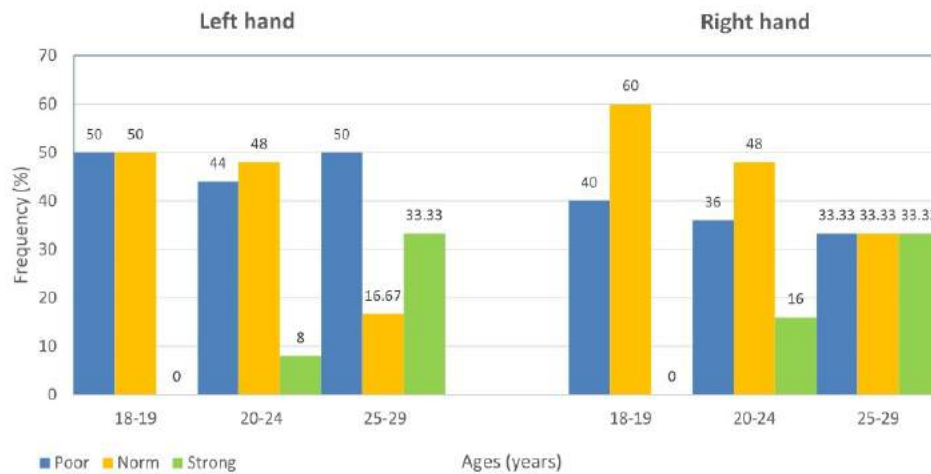


Figure 2. Comparison of grip strength in a group of professionals

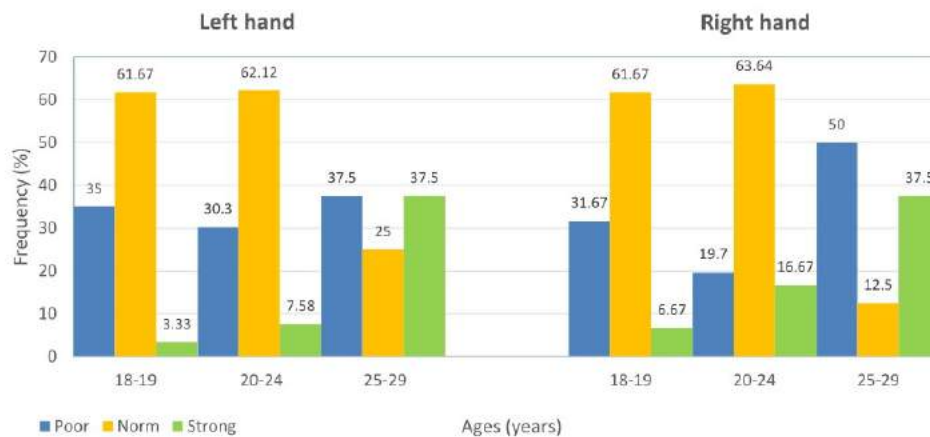


Figure 3. Comparison of grip strength in a group of semi-professionals

## DISCUSSION

Previous studies have investigated PA levels among Spanish, German, Swedish, Chilean, Argentinean, Brazilian, Mexican, Arabic, Danish, Indonesian, Portuguese, American, and Malawian esports players [14-16,18,19,22,28,29]. The aim of the present study was to evaluate PA among Polish esports players. Most respondents reported moderate (37.9%) to low (36.4%) levels of PA, and no significant group differences in PA levels were found between professional and semi-professional esports players. These findings contrast with previous reports of professionals demonstrating moderate to high levels of PA with higher MET-min-week<sup>-1</sup>, based on esports players from Europe, Latin America and Indonesia [15,16], Germany [9], and virtual footballers participating in the Portuguese Football Federation (FPF) [18,19].

One study also reported that 97% of collegiate esports players engaged in intensive PA [29]. Our study shows that Polish professionals were less physically active and spent significantly more time in a sedentary position than semi-professionals, due to more frequent and longer training sessions [8] and additional activities related to professional esports (e.g. meetings with a team, coach, participation in international tournaments). Trotter et al. 2020 found that players ranked in the top 10% had higher levels of PA compared to the remaining 90% of lower ranked players. In our study, professional esports players were significantly less active (1017 MET-min-week<sup>-1</sup>) compared to the top 50 Indonesian MOBA players (3120.2 MET) [15] and professional esports players from Europe and Latin America (2429-2533 MET-min-week<sup>-1</sup>) [16]. Others have shown that 80% of esports players did not meet WHO guidelines for PA [13], while 40% of college students did not engage in any form of physical activity [20].

Esports players, for example, may be at higher risk for health hazards and other common complaints (e.g., eye fatigue, musculoskeletal pain) than men of similar age [20]. It has been suggested that prolonged game playing may correlate with a higher BMI [30], but a strong association between game playing and the development of the obesity syndrome has not been conclusively established [31]. In the current study, male gamers were mostly of normal body weight (62.8%), which was a higher percentage than observed in German esports players (51%) [9]. A smaller proportion of Polish gamers were overweight (20.9%) and obese (7.7%). Similar results were reported by Giakoni-Ramírez et al. 2022, where 49.6% of the players had a normal body mass and 7.3% were

obese. According to Trotter et al. 2020, esports players from the United States, Australia, Canada, Germany, and the United Kingdom were mostly of normal weight and obese.

Exercise capacity is largely determined by the proper functioning of the cardiovascular and respiratory systems. Determining the maximal physiological parameters of esports players provides a quantitative assessment of the health status of the subjects. The  $\text{VO}_{2\text{max}}$  values of  $41.92 \pm 5.41 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  in the present study indicate an average level (according to the standards of the American College of Sports Medicine and the American Heart Association) of cardiorespiratory fitness in the study of esports players [32-34]. Similarly, according to the accepted norms for 20-29 year old Finnish men (as part of the FinFit-2017 study), the  $\text{VO}_{2\text{max}}$  values obtained here allow us to classify male esports players with an average level of cardiorespiratory fitness (range 41.64 to 41.98  $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) [35]. It is worth noting that according to the somewhat more "rigorous"  $\text{VO}_{2\text{max}}$  classification developed by Irma Astrand in 1960 [36], esports players could be defined as men with an adequate (range 39 to 43  $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) level of aerobic capacity. The reported average level of cardiorespiratory fitness is most likely due to the prevalence of moderate (38%) and low (36.4%) PA in our assessment of esports players.

Comparing the current recorded  $\text{VO}_{2\text{max}}$  with other findings in young men (using a bicycle ergometer), it can be seen that aerobic capacity tends to increase with higher levels of self-reported PA. Similar mean  $\text{VO}_{2\text{max}}$  values ( $44.2 \pm 2.8 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) were found by Marsh and Martin et al. 1997 and Claytor et al. 1988 ( $45.5 \pm 1.0 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) in young cohorts reporting low and moderate levels of PA [37,38]. In recreationally active students,  $\text{VO}_{2\text{max}}$  values averaged between 45 and 50  $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  [39-41].  $\text{VO}_{2\text{max}}$  values of  $45 \pm 8 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  were recorded in the study by Hodgson et al. 2018, which included 25-year-old students who reported PA levels of approximately four recreational training sessions per week [41]. Higher  $\text{VO}_{2\text{max}}$  values have been reported in recreationally active students by Wilkerson et al. 2004 ( $50.0 \pm 1.7 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) and Majerczak et al. 2006 ( $50.9 \pm 5.2 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ). An even higher level of aerobic capacity ( $\text{VO}_{2\text{max}} = 52.9 \pm 4.7 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) has been demonstrated in college athletes [42]. The highest  $\text{VO}_{2\text{max}}$  values (60 to more than 70  $\text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) have been reported in young male endurance athletes (runners, cyclists and cross-country skiers) [38,43-46]. Conversely, very low  $\text{VO}_{2\text{max}}$  values ( $33.6 \pm 5.4 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$ ) were found in a study of young people (women and men aged 18-28 years) with a sedentary lifestyle [47].

It should be noted that the mode of exercise can affect cardiorespiratory performance. In particular, during exercise tests performed on a cycle ergometer, subjects typically achieved lower  $\text{VO}_{2\text{max}}$  values (by a few to several percent) compared to running efforts performed on a mechanical treadmill [48,49]. This is due in part to greater local fatigue of the lower limb muscles during exercise on the cycle ergometer, resulting in premature termination of the exercise test, as well as greater activation of muscle mass during these running efforts [49,50]. In one such example, a group of non-training young men ( $21.6 \pm 1.4$  years old) recorded  $\text{VO}_{2\text{max}}$  values of  $54.5 \pm 3.6 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  during a running test on a mechanical treadmill [51], which were more than 20% higher than those observed in the esports players in the present study. It is also worth noting that indirect methods of  $\text{VO}_{2\text{max}}$  assessment can yield similar results to those reported here. Bragada et al. 2022 used a step test (StepTest4all) to estimate a  $\text{VO}_{2\text{max}}$  volume of  $47.75 \pm 6.71 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  in nontraining young men [52], and Khammassi et al. 2018 estimated a  $\text{VO}_{2\text{max}}$  volume of  $42.7 \pm 5.3 \text{ mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1}$  in overweight and obese ( $\text{BMI} = 29.9 \pm 2.2 \text{ kg/m}^2$ ) 20-year-old men based on the results of a field running test (VAMEVAL test) [53].

The maximal  $\text{VO}_{2\text{max}}$  achieved in these studies ( $210.29 \pm 42.63 \text{ W}$ ) was lower than in exercise tests (including cycle ergometry) in healthy young men of similar age [39-41,54] and much lower than in peers training for running trials [43,45,55-56]. In studies of recreationally active men of similar age, maximal aerobic power was significantly higher than that recorded in the esports players in the present study. Wilkerson et al. 2004 reported PO at  $\text{VO}_{2\text{max}}$  of  $356 \pm 8 \text{ W}$  and Hodgson et al. 2018  $333 \pm 55 \text{ W}$ . Higher PO at  $\text{VO}_{2\text{max}}$  ( $293 \pm 29 \text{ W}$ ) was also reported by Majerczak et al. 2006 and Grandys et al. 2009 in

students of the Academy of Physical Education ( $256 \pm 24$  W). Much higher PO values at  $\text{VO}_{2\text{max}}$  were, as expected, recorded in endurance athletes. Lucia et al. 2001 conducted studies in professional road cyclists and recorded more than twice the maximum aerobic power of  $517 \pm 11$  W compared to our results, while Michalik et al. 2021 recorded  $388 \pm 40$  W in younger (16 to 18 year old) cyclists, slightly higher than Pallarés et al. 2020 ( $366 \pm 26$  W) in their study in triathletes and cyclists.

In the current study, HR at AeT ( $146.20 \pm 6.94$  beats·min<sup>-1</sup>;  $76.47 \pm 2.00$  %HR<sub>max</sub>) was lower than that of sprinters ( $159$  beats·min<sup>-1</sup>;  $86.0$  %HR<sub>max</sub>) and distance runners ( $156$  beats·min<sup>-1</sup>;  $86.6$  %HR<sub>max</sub>) of similar age (21 years) [57]. However, a comparison of the cardiovascular response to AeT in young (16-18 year old) cyclists, in whom HR was measured at an intensity corresponding to maximal fat oxidation (FAT<sub>max</sub>), showed a lower AeT intensity ( $124 \pm 15$  beats·min<sup>-1</sup>;  $63.5 \pm 7.7$  %HR<sub>max</sub>) than in esports players, but the power generated by the cyclists at this intensity was on average 14 W higher ( $104.4 \pm 52.8$  W) [45].

Compared to physically active but not athletically trained 20-year-olds, the power generated by gamers at the AeT level ( $90.80 \pm 27.19$  W) at a cadence of 60 rpm was significantly lower than the power achieved at the LT threshold level in studies by Majerczak et al. 2006 ( $160 \pm 36$  W), Majerczak et al. 2017 ( $123 \pm 9$  W) [58], and Grandys et al. 2009 (average 120 W). In the cited 2006 study, the HR at the LT threshold was slightly lower ( $140 \pm 13$  beats·min<sup>-1</sup>) than in the esports players in the present study ( $147 \pm 7$  beats·min<sup>-1</sup>), while the mean relative workload (74% HR<sub>max</sub>) was similar to that of the esports players (76% HR<sub>max</sub>) [40]. In this case, the lower value of power generated at the AeT level by esports players compared to physically active men, despite a comparable relative load (%HR<sub>max</sub> at AeT), may indicate a lower mechanical efficiency of the lower limb muscles in this group. However, to further explain this phenomenon, studies with direct analysis of respiratory gas exchange are needed to compare the relationship between  $\text{VO}_2$  increase and power produced [59-61].

The power produced at AnT in the esports group ( $149.91 \pm 29.91$  W) was lower than that reported in other studies of physically active young men. For example, Wilkerson et al. 2004 reported a critical power of  $280 \pm 8$  W and Thorland et al. 1994 [62] reported a power at onset of blood lactate accumulation (OBLA) of  $211.4 \pm 46.5$  W in 20-year-old men. Power values at the 4 mM OBLA threshold ( $161 \pm 4$  W) in nontrained ( $\text{VO}_{2\text{max}} < 50$  mL·kg<sup>-1</sup>·min<sup>-1</sup>) young men were similar to those reported by Messonnier et al. 2013, and HR at OBLA ( $158 \pm 5$  beats·min<sup>-1</sup>) and load ( $83 \pm 3$  %HR<sub>max</sub>) were lower than in the esports players in our study. The effect of training on power output is particularly evident in studies of cyclists, for whom exercise testing on a cycle ergometer has greater training specificity. One such study (in cyclists) reported similar HRs to esports players at VT2 ( $176 \pm 2$  beats·min<sup>-1</sup>;  $91.7 \pm 0.9$  %HR<sub>max</sub>), but the power generated at VT2 ( $449.2 \pm 0.3$  W) [43] was almost three times higher than that at AnT in esports players. Another study in a cycling cohort observed power values (at the OBLA level) of  $259 \pm 10$  W, and the cardiovascular response (HR  $168 \pm 3$  beats·min<sup>-1</sup>;  $89 \pm 1$  %HR<sub>max</sub>) was similar to that recorded in the current esports sample of men [63].

We found that most of the esports players had a very good (45.09%) and good (58.73%) physical fitness status. However, only 10.70% of players were in the fair category and 5.5% were in the poor category. The results of the present study showed that the grip strength of gamers in the 18-19 (60% and 61.42%) and 20-24 (58.24% and 59.34%) age groups was at a normal level compared to gamers in the 25-29 age group, who mostly had poor strength (42.85%) (Figure 1). The preliminary results of this study indicate that esports players can potentially be considered fit, which is important scientific evidence. Currently, there is very limited research on the physical fitness of esports players. Therefore, the results of our sample may provide useful information for future research. In a related study on Palu City esports players, most were classified as having a sufficient category of physical fitness, but none reached a high level [64].



The physical demands of esports players are three times higher than those of office workers and depend on the type of esports games, different platforms, and performance levels [65]. Similar to traditional sports, exercise and increased physical fitness can help meet the physical demands of professional esports players and influence their success [66,67]. Exercise and physical fitness may also be essential for various aspects of gaming performance, including attention, memory, information processing, task-switching abilities [66], mood, stress and/or anxiety [68], and sleep [69,70]. It has been suggested that health-promoting behaviors, such as stretching and strengthening tendons, hand, arm, and shoulder muscles, may prevent injuries and even end a professional gamer's career [67].

Data from authors who have studied other groups are interesting. Tammelin et al. 2002 examined the effectiveness of young men in terms of grip strength and core muscle strength and showed that young men engaged in heavy physical work had higher grip strength and core muscle endurance than young men engaged in light work [71]. In turn, Osailan 2021 demonstrated that effective use of smartphones in a group of young men from Saudi Arabia resulted in stronger hand grip and pinch grip strength [72]. Our findings should be compared with research on academic adolescents. Studies in groups of medical and psychotherapy students have shown conflicting results indicating low PA levels. [73-75]. On the other hand, other analyses have pointed out that students with a higher PA had better results in the strength test and the long jump [76], and also showed a higher general fitness compared to those with a lower level [77]. A low level of physical fitness was also found in the group of drivers in one of the recent studies [78]. Some evidence suggests that esports players pay little attention to improving their physical fitness, which we believe is due to a lack of understanding of how it affects different aspects of game performance [79].

This article presents the first comprehensive findings on the cognition of physical activity, exercise capacity and physical fitness assessment among Polish professional and semi-professional esports players. Our findings fit into a growing interest of esports considering the fact that the majority of the world's gamers are adolescents and young adults who compete in a physically and mentally demanding virtual environment associated with potential adverse health-related effects [80]. PA is an intrinsic and integral part of a healthy lifestyle, and its adequate levels influence physical fitness, which determines health status, mobility, and overall functioning [81-83]. For gamers, PA is significant and has a positive impact on capacity and performance [66,84]. For esports players, these benefits are supported by a balanced diet adapted to daily energy expenditure and the consumption of products that may affect health and brain function [85], especially psychobiotics [86]. To our knowledge, many studies have focused on profiling health and PA in esports, while physical fitness in esports players seems to be overlooked, so further research in this area is needed. More and more professional players and their trainers are becoming aware of the importance of maintaining an adequate level of physical fitness for esports, which helps to increase concentration during the game [87,88]. There is no doubt that people involved in professional esports should be physically fit.

#### *Study limitations*

The current study is not without its limitations. First, the sample size was small and the groups unbalanced, which may lead to biased results. Although the IPAQ questionnaire is recommended and widely used to assess PA, the number of activities reported by esports players may be overestimated/underestimated compared to an objective measurement (e.g. wearable sensor) and the data obtained may be less reliable. Second, not all possible fitness tests were performed, so it is questionable whether the results obtained fully characterize the broader fitness capacity of the studied population. Therefore, there is a clear need for further monitoring of physiological parameters related to physical health using direct methods. Nevertheless, the information gained from the

current experiment may still have prescriptive value for training staff involved in the preparation of eSports players, i.e. doctors, nutritionists, physiotherapists or psychologists.

## CONCLUSION

1. The results of this study suggest that Polish esport players achieved low and moderate levels of PA. Esports players were characterized by an average level of cardiorespiratory fitness, and the amount of muscle power generated at the level of AeT, AnT and  $VO_{2max}$  was lower than published evidence on physically active men.
2. The physical fitness of the players was judged to be satisfactory, but further research is needed to confirm this unequivocally.
3. As esport becomes more professional and a viable career option, players should be encouraged to engage in regular PA, which is likely to correlate with improvements in exercise capacity and physical fitness, which are critical for health and esport performance.

**Funding:** Researcher grant project no. POIR.01.02.00-00-0205/20.

**Declarations:** All authors declare that they do not have any conflict of interest.

## REFERENCES

1. Wagner MG. On the Scientific Relevance of Esports. Proceedings of the 2006 International Conference on Internet Computing and Conference on Computer Game Development; 2006 June 26-29; Las Vegas, Nevada, USA: CSREA Press
2. Franks RR, King D, Bodine W, Chisari E, Heller A, Jamal F 4th, Luksch J, Quinn K, Singh R, Solomon M. AOASM Position Statement on Esports, Active Video Gaming, and the Role of the Sports Medicine Physician. *Clin J Sport Med* 2022; 32: e221-e229
3. Martin-Niedecken AL, Schättin A. Let the Body'n'Brain Games Begin: Toward Innovative Training Approaches in eSports Athletes. *Front Psychol* 2020; 11: 138. doi: 10.3389/fpsyg.2020.00138
4. Pluss MA, Novak AR, Bennett JM, Panchuk D, Coutts AJ, Franssen J. Perceptual-motor abilities underlying expertise in esports. *Journal of Expertise* 2020; 3: 133-143.
5. DiFrancisco-Donoghue J, Balentine J, Schmidt G, Zwibel H. Managing the Health of the ESport Athlete: An Integrated Health Management Model. *BMJ Open Sport Exerc Med* 2019; 5: e000467. doi: 10.1136/bmjsem-2018-000467
6. Emara AK, Ng MK, Cruickshank JA, Kampert MW, Piuze NS, Schaffer JL, King D. Gamer's Health Guide: Optimizing Performance, Recognizing Hazards, and Promoting Wellness in Esports. *Curr Sports Med Rep* 2020; 19: 537-545. doi: 10.1249/JSR.0000000000000787
7. Truong P, Truong L, Le TKK. Orthopedic Injuries from Video Games: A Literature Review and Implications for the Future. *Int. Arch. Orthop. Surg* 2020; 3: 020. doi: 10.23937/2643-4016/1710020
8. Chung T, Sum S, Chan M, Lai E, Cheng N. Will Esports Result in a Higher Prevalence of Problematic Gaming? A Review of the Global Situation. *J Behav Addict* 2019; 8: 384-394. doi: 10.1556/2006.8.2019.46
9. Rudolf K, Bickmann P, Probst I, Tholl C, Wechsler K, Grieben C. Demographics and Health Behavior of Video Game and eSports Players in Germany: The eSports Study 2019. *Int J Environ Res Public Health* 2020; 17: 1870. doi: 10.3390/ijerph17061870
10. Bonnar D, Lee S, Roane BM, Roane BM, Blum DJ, Kahn M, Jang E, Dunican IC, Gradisar M, Suh S. Evaluation of a Brief Sleep Intervention Designed to Improve the Sleep, Mood, and Cognitive Performance of Esports Athletes. *Int J Environ Res Public Health* 2022; 19: 4146. doi: 10.3390/ijerph19074146
11. Lee S, Bonnar D, Roane B, Blum DJ, Kahn M, Jang E, Dunican IC, Gradisar M, Suh S. Sleep Characteristics and Mood of Professional Esports Athletes: A Multi-National Study. *Int J Environ Res Public Health* 2021; 18: 664. doi: 10.3390/ijerph18020664
12. Szot M, Frączek B, Tyrała F. Nutrition Patterns of Polish Esports Players. *Nutrients* 2022; 15: 149. doi: 10.3390/nu15010149

13. Trotter MG, Coulter TJ, Davis PA, Poulus DR, Polman R. The Association between Esports Participation, Health and Physical Activity Behaviour. *Int J Environ Res Public Health* 2020; 7: 7329. doi: 10.3390/ijerph17197329
14. Seng PH, Affandi MABN, Kamaruzzaman NNB, Panierselvam DKA/P, Mohammed AF. A Cross Sectional Study On The Benefit And Health Issues Among Esports Players. *Nat. Volatiles & Essent. Oils* 2021; 8: 3922-3938
15. Paramitha ST, Hasan MF, Ihsya MNF, Anggraeni L, Ramadhan MG. Level of Physical Activity of Indonesian Esport Athletes in the Piala Presiden Esport 2019. *J. SPORTIF J Penelit. Pembelajaran* 2021; 7: 71-83
16. Giakoni-Ramírez F, Merellano-Navarro E, Duclos-Bastías D. Professional Esports Players: Motivation and Physical Activity Levels. *Int J Environ Res Public Health* 2022; 19: 2256. doi: 10.3390/ijerph19042256
17. DiFrancisco-Donoghue J, Werner WG, Douris PC. Esports players, got muscle? Competitive video game players' physical activity, body fat, bone mineral content, and muscle mass in comparison to matched controls. *J Sport Health Sci* 2022; 11: 725-730. doi: 10.1016/j.jshs.2020.07.006
18. Pereira AM, Figueiredo P, Seabra A, Brito J. Evaluation of physical activity levels in FPF eSports e-athletes. *Motricidade* 2019; 15: 188
19. Pereira AM, Verhagen E, Figueiredo P, Seabra A, Martins A, Brito J. Physical Activity Levels of Adult Virtual Football Players. *Front Psychol* 2021; 12: 596434
20. DiFrancisco-Donoghue J, Balentine J, Schmidt G, Zwibel H. Managing the Health of the ESport Athlete: An Integrated Health Management Model. *BMJ Open Sport Exerc. Med* 2019; 5: e000467. doi: 10.1136/bmjsem-2018-000467
21. Clements AJ, Paul RW, Lencer AJ, Seigerman DA, Erickson BJ, Bishop ME. Analysis of Musculoskeletal Injuries Among Collegiate Varsity Electronic Sports Athletes. *Cureus* 2022; 14: e31487
22. Lindberg L, Nielsen SB, Dagmaard M, Sloth OR, Rathleff MS, Straszek CL. Musculoskeletal pain is common in competitive gaming: a cross-sectional study among Danish esports athletes. *BMJ Open Sport Exerc. Med* 2020; 6: :000799. doi: 10.1136/bmjsem-2020-000799
23. Lam WK, Liu RT, Chen B, Huang XZ, Yi J, Wong DW. Health Risks and Musculoskeletal Problems of Elite Mobile ESports Players: A Cross-Sectional Descriptive Study. *Sports Med Open* 2022; 8: 65. doi: 10.1186/s40798-022-00458-3
24. Zwibel H, DiFrancisco-Donoghue J, DeFeo A, Yao S. An Osteopathic Physician's Approach to the Esports Athlete. *J Osteopath Med* 2019; 119: 756-762. doi: 10.7556/jaoa.2019.125
25. WHO [World Human Organization]. Mean Body Mass Index (BMI). <https://www.who.int/data/gho/data/themes/topics/topic-details/GHO/body-mass-index> (accessed 2023 June 27)
26. Biernat E, Stupnicki R, Gajewski AK. Międzynarodowy Kwestionariusz Aktywności Fizycznej (IPAQ) - wersja polska [International Physical Activity Questionnaire (IPAQ) - Polish version]. *Wychowanie Fizyczne i Sport* 2007; 51: 47-54
27. Talaga, J. *Sprawność Fizyczna Ogólna-Testy; Zysk i S-ka: Poznań, Poland*, 2004.
28. AlMarzooqi MA, Alhaj OA, Alrasheed MM, Helmy M, Trabelsi K, Ebrahim A, Hattab S, Jahrami HA, Ben Saad H. Symptoms of Nomophobia, Psychological Aspects, Insomnia and Physical Activity: A Cross-Sectional Study of ESports Players in Saudi Arabia. *Healthcare* 2022; 10: 257. doi: 10.3390/healthcare10020257
29. Roncone J, Kornspan AS, Hayden EW, Fay M. The Relationship of Physical Activity and Mental Toughness in Collegiate Esports Varsity Student-Athletes. *OAHPERD* 2020; XXXI: 31-40
30. Ketelhut S, Martin-Niedecken AL, Zimmermann P, Nigg CR. Physical Activity and Health Promotion in Esports and Gaming—Discussing Unique Opportunities for an Unprecedented Cultural Phenomenon. *Front. Sports Act. Living* 2021; 3: 693700. doi: 10.3389/fspor.2021.693700
31. Marker C, Gnambs T, Appel M. Exploring the myth of the chubby gamer: A meta-analysis on sedentary video gaming and body mass. *Social science & medicine* 2019: 112325
32. Fletcher GF, Balady GJ, Amsterdam EA, Chaitman B, Eckel R, Fleg J, Froelicher VF, Leon AS, Piña IL, Rodney R, Simons-Morton DA, Williams MA, Bazzarre T. Exercise standards for testing and training: a statement for healthcare professionals from the American Heart Association. *Circulation* 2001; 104: 1694-1740. doi: 10.1161/hc3901.095960
33. Thompson WR, Gordon NF, Pescatello LS. ACSM's Guidelines for exercise testing and prescription. 8th ed. Philadelphia: Lippincott Williams and Wilkins; 2010: 85
34. Kaminsky LA, Arena R, Beckie TM, Brubaker PH, Church TS, Forman DE, Franklin BA, Gulati M, Lavie CJ, Myers J, Patel MJ, Piña IL, Weintraub WS, Williams MA. The importance of cardiorespiratory fitness in the United States: the need for a national registry: a policy statement from the American Heart Association. *Circulation* 2013; 127: 652-662

35. Vähä-Yppä H, Sievänen H, Husu P, Tokola K, Vasankari T. Intensity Paradox-Low-Fit People Are Physically Most Active in Terms of Their Fitness. *Sensors* (Basel) 2021; 21: 206. doi: 10.3390/s21062063
36. Astrand I. Aerobic work capacity in men and women with special reference to age. *Acta Physiol Scand Suppl* 1960; 49: 1-92
37. Claytor RP, Cox RH, Howley ET, Lawler KA, Lawler JE. Aerobic power and cardiovascular response to stress. *J Appl Physiol* (1985) 1988; 65: 1416-1423. doi: 10.1152/jappl.1988.65.3.1416
38. Marsh AP, Martin PE. Effect of cycling experience, aerobic power, and power output on preferred and most economical cycling cadences. *Med Sci Sports Exerc* 1997; 1225-1232. doi: 10.1097/00005768-199709000-00016
39. Wilkerson DP, Kopko K, Barstow TJ, Jones AM. Effect of work rate on the functional 'gain' of Phase II pulmonary O<sub>2</sub> uptake response to exercise. *Respir Physiol Neurobiol* 2004; 142: 211-223. doi: 10.1016/j.resp.2004.06.001
40. Majerczak J, Szkutnik Z, Karasinski J, Duda K, Kolodziejski L, Zoladz JA. High content of MYHC II in vastus lateralis is accompanied by higher VO<sub>2</sub>/power output ratio during moderate intensity cycling performed both at low and at high pedalling rates. *J Physiol Pharmacol* 2006; 57:199-215
41. Hodgson MD, Keir DA, Copithorne DB, Rice CL, Kowalchuk JM. Power reserve following ramp-incremental cycling to exhaustion: implications for muscle fatigue and function. *J Appl Physiol* (1985). 2018; 125: 304-312. doi: 10.1152/jappphysiol.00722.2017
42. Tabata I, Nishimura K, Kouzaki M, Hirai Y, Ogita F, Miyachi M, Yamamoto K. Effects of moderate-intensity endurance and Sports Exerc 1996; 28: 1327-1330
43. Lucia A, Hoyos J, Chicharro JL. Preferred pedalling cadence in professional cycling. *Med Sci Sports Exerc* 2001; 1361-1366. doi: 10.1097/00005768-200108000-00018
44. Ruiz-Alias SA, Olaya-Cuartero J, Nancupil-Andrade AA, García-Pinillos F. 9/3-Minute Running Critical Power Test: Mechanical Threshold Location With Respect to Ventilatory Thresholds and Maximum Oxygen Uptake. *Int. J. Sports Physiol. Perform* 2022; 17: 1-8. doi: 10.1123/ijsp.2022-0069
45. Michalik K, Danek N, Zatoń M. Comparison of the Ramp and Step Incremental Exercise Test Protocols in Assessing the Maximal Fat Oxidation Rate in Youth Cyclists. *J Hum Kinet* 2021; 80: 163-172. doi: 10.2478/hukin-2021-0104
46. Fabre N, Passelergue P, Bouvard M, Perrey S. Comparison of heart rate deflection and ventilatory threshold during a field cross-country roller-skiing test. *J Strength Cond Res* 2008; 22: 1977-1984. doi:10.1519/JSC.0b013e3181874ae9
47. Foster C, Farland CV, Guidotti F, Harbin M, Roberts B, Schuette J, Tuuri A, Doberstein ST, Porcari JP. The Effects of High Intensity Interval Training vs Steady State Training on Aerobic and Anaerobic Capacity. *J Sports Sci Med* 2015; 14: 747-755
48. Millet G, Vleck V, Bentley D. Physiological Differences Between Cycling and Running. *Sports Med* 2009; 39: 179-206
49. Price S, Wiecha S, Cieślinski I, Šliž D, Kasiak PS, Lach J, Gruba G, Kowalski T, Mamcarz A. Differences between Treadmill and Cycle Ergometer Cardiopulmonary Exercise Testing Results in Triathletes and Their Association with Body Composition and Body Mass Index. *Int J Environ Res Public Health* 2022; 19: 3557. doi: 10.3390/ijerph19063557
50. Cunningham DA, Nancekivell EA, Paterson DH, Donner AP, Rechnitzer PA. Ventilation threshold and aging. *J Gerontol* 1985; 40: 703-702
51. Christie CJ, Lock BL. Impact of training status on maximal oxygen uptake criteria attainment during running. *SAJSM* 2009; 21. doi: 10.17159/2078-516X/2009/v21i1a303
52. Bragada, JA, Bartolomeu RF, Rodrigues PM, Magalhães PM, Bragada JP, Morais JE. Validation of StepTest4all for Assessing Cardiovascular Capacity in Young Adults. *Int J Environ Res Public Health* 2022; 19: 11274. doi: 10.3390/ijerph191811274
53. Khammassi M, Ouerghi N, Hady-Taieb S, Feki M, Thivel D, Bouassida A. Impact of a 12-week high-intensity interval training without caloric restriction on body composition and lipid profile in sedentary healthy overweight/obese youth. *J Exerc Rehabil* 2018; 14: 118-125. doi: 10.12965/jer.1835124.562
54. Grandys M, Majerczak J, Duda K, Zapart-Bukowska J, Kulpa J, Zoladz JA. Endurance training of moderate intensity increases testosterone concentration in young, healthy men. *Int J Sports Med* 2009; 489-495. doi: 10.1055/s-0029-1202340
55. Pallarés JG, Lillo-Bevia JR, Morán-Navarro R, Cerezueta-Espejo V, Mora-Rodríguez R. Time to exhaustion during cycling is not well predicted by critical power calculations. *Appl Physiol Nutr Metab* 2020; 45: 753-760. doi: 10.1139/apnm-2019-0637.



56. Sharma AP, Bentley DJ, Mejuto G, Etxebarria N. A Contemporary Variable-Power Cycling Protocol to Discriminate Race-Specific Performance Ability. *Int J Sports Physiol Perform* 2020; 1-6. doi: 10.1123/ijsp.2019-0558
57. Mukhopadhyay S, Sidhu LS, Verma SK. A Comparison of Cardiopulmonary Response of Elite Indian Distance Athletes with Certain Selected Elite Power Event Groups. *The Anthropologist* 2001; 3: 91-97. doi: 10.1080/09720073.2001.11890695
58. Majerczak J, Grandys M, Duda K, Zakrzewska A, Balcerczyk A, Kolodziejski L, Szymoniak-Chochol D, Smolenski RT, Bartosz G, Chlopicki S, Zoladz JA. Moderate-intensity endurance training improves endothelial glycocalyx layer integrity in healthy young men. *Exp Physiol* 2017; 102: 70-85. doi: 10.1113/EP085887
59. Joyner MJ, Coyle EF. Endurance exercise performance: the physiology of champions. *J Physiol* 2008; 586: 35-44. doi: 10.1113/jphysiol.2007.143834
60. Chwała W, Klimek A, Mirek W. Changes in energy cost and total external work of muscles in elite race walkers walking at different speeds. *J Hum Kinet* 2014; 44: 129-136. doi: 10.2478/hukin-2014-0118
61. Grassi B, Rossiter HB, Zoladz JA. Skeletal Muscle Fatigue and Decreased Efficiency: Two Sides of the Same Coin? *Exercise and Sport Sciences Reviews* 2015; 43: 75-83
62. Thorland W, Podolin DA, Mazzeo RS. Coincidence of lactate threshold and HR-power output threshold under varied nutritional states. *Int J Sports Med* 1994; 15: 301-304. doi: 10.1055/s-2007-1021064
63. Messonnier LA, Emhoff CA, Fattor JA, Horning MA, Carlson TJ, Brooks GA. Lactate kinetics at the lactate threshold in trained and untrained men. *J Appl Physiol* (1985) 2013; 114: 1593-1602. doi: 10.1152/jappphysiol.00043.2013
64. Alam RRI, Rahayu S, Raharjo A. Relationship Between Physical Activity, Healthy Lifestyle Behavior And Physical Fitness Of Palu City Esport Players. *JUARA: Jurnal Olahraga* 2023; 8: 511-522
65. McGee C, Hwu M, Nicholson L. More than a game: musculoskeletal injuries and a key role for the physical therapist in Esports. *JOSPT* 2021; 51: 415-417
66. Toth AJ, Ramsbottom N, Kowal M, Campbell MJ. Converging Evidence Supporting the Cognitive Link between Exercise and Esport Performance: A Dual Systematic Review. *Brain Sci* 2020; 10: 859. doi: 10.3390/brainsci10110859
67. Saputra DS, Manongga D. The Concept and Future of Intelligent Personal Assistant Based on Artificial Autonomy for Gamers in Indonesia. *Design Engineering* 2021: 1940-1956.
68. Callaghan P. Exercise: a neglected intervention in mental health care? *J. Psychiatr. Ment. Health Nurs* 2004; 11: 476-483. doi: 10.1111/j.1365-2850.2004.00751.x
69. Chennaoui M, Arnal PJ, Sauvet F, Léger D. Sleep and exercise: a reciprocal issue? *Sleep Med Rev* 2015; 20: 59-72. doi: 10.1016/j.smrv.2014.06.008
70. Oudegeest-Sander MH, Eijsvogels TH, Verheggen RJ, Poelkens F, Hopman MT, Jones H, Thijssen DH. Impact of physical fitness and daily energy expenditure on sleep efficiency in young and older humans. *Gerontology* 2013; 59: 8-16. doi: 10.1159/000342213
71. Tammelin T, Näyhä S, Rintamäki H, Zitting P. Occupational physical activity is related to physical fitness in young workers. *Med Sci Sports Exerc* 2002; 34: 158-165. doi: 10.1097/00005768-200201000-00024
72. Osailan A. The relationship between smartphone usage duration (using smartphone's ability to monitor screen time) with hand-grip and pinch-grip strength among young people: an observational study. *BMC Musculoskelet Disord* 2021; 22: 86. doi: 10.1186/s12891-021-04054-6
73. Chaudhary S, Khadka R, Pandey KR, Paudel BH, Shah GJ, Chaudhary HP. Assessment of Physical Fitness in Medical Students. *JNGMC* 2022; 19: 84-88. doi: 10.3126/jngmc.v19i1.40432
74. Polina SV, Jayamala AK, Priyadarshini KU, Subhashri S, Pavitra B, Saraswathi M. Assessment of physical activity and physical fitness among undergraduate medical students. *Natl J Physiol Pharm Pharmacol* 2023; 13: 47-53. doi: 10.5455/njppp.2023.13.05219202226052022
75. Mirza FT, Noor N, Noor IH, Latir A. Level of Physical Fitness among Physiotherapy Students in Public Universities in Malaysia. *MJMHS* 2022; 16: 36-42. doi: 10.47836/mjmhs18.s15.6
76. Wang J. The association between physical fitness and physical activity among Chinese college students. *J. Am. Coll. Health* 2019; 67: 602-609. doi: 10.1080/07448481.2018.1515747
77. Osipov AY, Potop V, Nagovitsyn RS, Zemba EA, Knyazev AP, Orlova II, Ratmanskaya TI, Iermakov SS. Indicators of physical activity and fitness of male students at Russian universities. *Phys Educ Stud* 2020; 24: 40-46. doi: 10.15561/20755279.2020.0105
78. Portela BS, Zannin PHT. The Whole-Body Vibration in Bus Drivers: Association with Physical Fitness and Low Back Pain. *IJIER* 2021; 9: 44-56. doi: 10.31686/ijer.vol9.iss2.2938
79. Nagorsky E, Wiemeyer J. The Structure of Performance and Training in Esports. *PLoS ONE* 2020; 15: e0237584. doi: 10.1371/journal.pone.0237584

80. Yin K, Zi Y, Zhuang W, Gao Y, Tong Y, Song L, Liu Y. Linking Esports to health risks and benefits: Current knowledge and future research needs. *J Spoert Health Sci* 2020; 9: 485-488. doi: 10.1016/j.jshs.2020.04.006
81. Vanhees L, Lefevre J, Philippaerts R, Martens M, Huygens W, Troosters T, Beunen G. How to assess physical activity? How to assess physical fitness? *Eur J Cardiovasc Prev Rehabil* 2005; 12: 102-114
82. Özkan A, Bozkus T, Özkan, Kayihan G. Determination of energy intake and dietary habits and their relationship with physical activity levels and healthy lifestyle behaviours of primary education and pre-service teachers *Balt J Health Phys Act* 2021; 13: 17-27
83. Lelonek M, Przychodni A. Level of physical activity during school recess within aspect of available dedicated playing space. *Phys Act Rev* 2020; 8(2): 30-37. doi: 10.16926/par.2020.08.19
84. De Las Heras B, Li O, Rodrigues L, Nepveu JF, Roig M. Exercise Improves Video Game Performance: A Win-Win Situation. *Med. Sci. Sports Exerc* 2020; 52: 1595-1602. doi: 10.1249/MSS.0000000000002277
85. Szot M, Karpecka-Gałka E, Drózd R, Frączek B. Can Nutrients and Dietary Supplements Potentially Improve Cognitive Performance Also in Esports? *Healthcare* 2022; 10: 186. doi: 10.3390/healthcare10020186
86. Pratt J, Hromadkova J, Malmuthuge N, Guan LL. Gut Microbiota and the Gut-Brain Axis in Neonatal Calves: Implications for Psychobiotic Usage for Stress Regulation. *Gut Microbiota, Immunity, and Health in Production Animals*. Cham: Springer International Publishing; 2022: 299-325
87. Sánchez-Miguel PA, Leo FM, Amado D, Pulido JJ, Sánchez-Oliva D. Relationships between Physical Activity Levels, Self-Identity, Body Dissatisfaction and Motivation among Spanish High School Students. *J Hum Kinet* 2017; 59: 29-38. doi: 10.1515/hukin-2017-0145
88. Kostrzewa M, Laskowski R, Wilk M, Błach W, Ignatjeva A, Nitychoruk M. Significant Predictors of Sports Performance in Elite Men Judo Athletes Based on Multidimensional Regression Models. *Int J Environ Res Public Health* 2020; 17(21): 8192. doi: 10.3390/ijerph17218192

## Załącznik 2. Oświadczenia współautorów publikacji



**SZKOŁA DOKTORSKA**

### OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Szot, M., Karpecka-Gałka, E., Dróżdż, R., Frączek, B. (2022). Can nutrients and dietary supplements potentially improve cognitive performance also in esports? *Healthcare*, 10, 186.  
<https://doi.org/10.3390/healthcare10020186>

*Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:*

| Autor              | Wkład % | Opis (formularz AWFIS)* | Udział Autorów określony w publikacji czasopisma (Author contributions)** | Podpis             |
|--------------------|---------|-------------------------|---------------------------------------------------------------------------|--------------------|
| Monika Szot        | 60      | A,B,C,D,E,F             | B,L,Wo                                                                    | MSzot              |
| Ewa Karpecka-Gałka | 30      | D,E,F                   | B,L,Wo                                                                    | Ewa Karpecka-Gałka |
| Remigiusz Dróżdż   | 5       | F                       | L                                                                         | R. Dróżdż          |
| Barbara Frączek    | 5       | A,E                     | K,Wo                                                                      | B. Frączek         |

\* A – przygotowanie projektu badania, B – przeprowadzanie badań, C – analiza statystyczna, D – interpretacja wyników, E – przygotowanie publikacji, F – opracowanie piśmiennictwa, G – pozyskanie funduszy

\*\* K – koncepcja projektu (conceptualization), B – przeprowadzenie badań (investigation), L – wyszukiwanie i przegląd literatury przedmiotu (performed the literature search), Wo – współuczestniczenie w przygotowaniu manuskryptu na etapie recenzji/korekty (writing – review and editing)

Monika Szot

podpis doktoranta

B. Frączek

podpis promotora



## SZKOŁA DOKTORSKA

W publikacji autorstwa Szot, M., Karpecka-Galka, E., Drózd, R., Frączek, B. (2022) pt. *Can nutrients and dietary supplements potentially improve cognitive performance also in esports? Healthcare, 10, 186. [IF 2.8; 40 pkt]* (A,B,D,E,F,L,Wo) wkład mgr inż. Moniki Szot polegał na: przygotowaniu projektu badania, przeprowadzeniu badań, interpretacji wyników, przygotowaniu publikacji, opracowaniu piśmiennictwa, wyszukiwaniu i przeglądzie literatury przedmiotu, współuczestniczeniu w przygotowaniu manuskryptu na etapie recenzji/korekty.

In the article by authorship Szot, M., Karpecka-Galka, E., Drózd, R., Frączek, B. (2022) entitled *Can nutrients and dietary supplements potentially improve cognitive performance also in esports? Healthcare, 10, 186. [IF 2.8; 40 pts]* (A,B,D,E,F,L,Wo) MSc Monika Szot's contribution consisted of: design of the study, investigation, interpretation of the results, publication preparation, compilation of a bibliography, performed the literature search, writing – review and editing.

Monika Szot

podpis doktoranta

Frączek

podpis promotora





SZKOŁA DOKTORSKA

### OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Szot, M., Frączek, B., Tyrła, F. Nutrition Patterns of Polish Esports Players. (2023). *Nutrients*, 15, 149. <https://doi.org/10.3390/nu15010149>

*Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:*

| Autor            | Wkład % | Opis (formularz AWFIS)* | Udział Autorów określony w publikacji czasopisma (Author contributions)** | Podpis |
|------------------|---------|-------------------------|---------------------------------------------------------------------------|--------|
| Monika Szot      | 60      | A,B,C,D,E,F             | B,K,M,P,Wa,Fa,Z,Wr                                                        | MSzot  |
| Florentyna Tyrła | 30      | C,D                     | T                                                                         | Tyrła  |
| Barbara Frączek  | 10      | A                       | K,Wr,Wo                                                                   | pfra   |

\* A – przygotowanie projektu badania, B – przeprowadzanie badań, C – analiza statystyczna, D – interpretacja wyników, E – przygotowanie publikacji, F – opracowanie piśmiennictwa, G – pozyskanie funduszy

\*\* K – koncepcja projektu (conceptualization), B – przeprowadzenie badań (investigation), M – opracowanie metodologii badań (methodology), Wa – walidacja (validation), P – programowanie (software), Fa – analiza formalna (formal analysis), Z – zasoby (resources); dostarczenie materiałów badawczych (provision of study materials), T – tworzenie metadanych i zachowywanie danych badawczych (data curation), Wr – przygotowanie wstępnej wersji artykułu (writing - original draft preparation), Wo – współuczestniczenie w przygotowaniu manuskryptu na etapie recenzji/korekty (writing – review and editing)

Monika Szot

podpis doktoranta

pfra

podpis promotora

Biuro Spraw Doktoranckich  
szkola.doktorska@awf.gda.pl  
+48 58 55 47 262, +48 603 766 393  
ul. K. Górnkiego 1, 80-336 Gdańsk

Strona 1 z 2



W publikacji autorstwa Szot, M., Frączek, B., Tyrała, F. (2023) pt. *Nutrition Patterns of Polish Esports Players. Nutrients*, 15, 149. [IF 5.9; 140 pkt] (B,C,E,F,K,M,P,Wa,Fa,Z,Wr) wkład mgr inż. Moniki Szot polegał na: przeprowadzeniu badań, analizie statystycznej, przygotowaniu publikacji, opracowaniu piśmiennictwa, koncepcji projektu, opracowaniu metodologii badań, programowaniu, walidacji, analizie formalnej, zasobach, przygotowaniu wstępnej wersji artykułu.

In the article by Szot, M., Frączek, B., Tyrała, F. (2023) entitled *Nutrition Patterns of Polish Esports Players. Nutrients*, 15, 149. [IF 5.9; 140 pts] (B,C,E,F,K,M,P,Wa,Fa,Z,Wr) MSc Monika Szot's contribution consisted of: investigation, statistical analysis, publication preparation, compilation of a bibliography, conceptualization, methodology, software, validation, formal analysis, resources and writing - original draft preparation.

Monika Szot

podpis doktoranta

prof. dr hab. B. Frączek

podpis promotora



## OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Kulecka, M., Fraczek, B., Balabas, A., Czarnowski, P., Zeber-Lubecka, N., Zapala, B., Baginska, K., Glowienka, M., Szot, M., Skorko, M., Kluska, A., Piatkowska, M., Mikula, M., Ostrowski, J. Characteristics of the gut microbiome in esports players compared with those in physical education students and professional athletes. (2023). *Frontiers in Nutrition*, 9, 1092846. <https://doi.org/10.3389/fnut.2022.1092846>

Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:

| Autor                 | Wkład % | Opis (formularz AWFIS)* | Udział Autorów określony w publikacji czasopisma (Author contributions)** | Podpis                         |
|-----------------------|---------|-------------------------|---------------------------------------------------------------------------|--------------------------------|
| Maria Kulecka         |         | C,D,E,F                 | T,Fa, W, Wr, Wo                                                           | <i>M. Kulecka</i>              |
| Barbara Fraczek       |         | C,D,E                   | K,M,Z, Wa, Wr, Wo                                                         |                                |
| Aneta Balabas         |         | B                       | M                                                                         | <i>Aneta Balabas</i>           |
| Paweł Czarnowski      |         | B                       | M                                                                         | <i>Paweł Czarnowski</i>        |
| Natalia Zeber-Lubecka |         | B, D, E                 | M, W, Wo                                                                  | <i>Natalia Zeber-Lubecka</i>   |
| Barbara Zapala        |         |                         | Z                                                                         |                                |
| Katarzyna Baginska    |         | B                       | M                                                                         | <i>K. Baginska-Drobisz</i>     |
| Maria Glowienka       |         | B                       | M                                                                         | <i>M. Glowienka-Skłodowska</i> |
| Monika Szot           |         | E                       | Z, Wo                                                                     |                                |
| Maciek Skorko         |         |                         | Z                                                                         |                                |
| Anna Kluska           |         | B                       | M                                                                         | <i>A. Kluska</i>               |
| Magdalena Piatkowska  |         | B                       | M                                                                         | <i>M. Piatkowska</i>           |
| Michał Mikula         |         | E                       | W, Wo                                                                     | <i>M. Mikula</i>               |
| Jerzy Ostrowski       |         | A, E, G                 | K,Z, Wr, Wo, Zp                                                           | <i>J. Ostrowski</i>            |

\* **A** – przygotowanie projektu badania, **B** – przeprowadzanie badań, **C** – analiza statystyczna, **D** – interpretacja wyników, **E** – przygotowanie publikacji, **F** – opracowanie piśmiennictwa, **G** – pozyskanie funduszy

\*\* **K** – koncepcja projektu (conceptualization), **M** – opracowanie metodologii badań (methodology), **Wa** – walidacja (validation), **Fa** – analiza formalna (formal analysis), **W** – wizualizacja graficzna (visualization), **Z** – zasoby (resources); dostarczenie materiałów badawczych (provision of study materials), **T** – tworzenie metadanych i zachowywanie danych badawczych (data curation), **Wr** – przygotowanie wstępnej wersji artykułu (writing - original draft preparation), **Wo** – współuczestniczenie w przygotowaniu manuskryptu na etapie recenzji/korekty (writing – review and editing), **Zp** – zarządzanie projektem (project administration)

Monika Skot

podpis doktoranta

ptFqde

podpis promotora/promotorów





## OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Kulecka, M., Fraczek, B., Balabas, A., Czarnowski, P., Zeber-Lubecka, N., Zapala, B., Baginska, K., Glowienka, M., Szot, M., Skorko, M., Kluska, A., Piatkowska, M., Mikula, M., Ostrowski, J. Characteristics of the gut microbiome in esports players compared with those in physical education students and professional athletes. (2023). *Frontiers in Nutrition*, 9, 1092846. <https://doi.org/10.3389/fnut.2022.1092846>

*Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:*

| Autor                 | Wkład % | Opis<br>(formularz<br>AWFiS)* | Udział Autorów<br>określony w publikacji<br>czasopisma (Author<br>contributions)** | Podpis         |
|-----------------------|---------|-------------------------------|------------------------------------------------------------------------------------|----------------|
| Maria Kulecka         |         | C,D,E,F                       | T,Fa,W,Wr,Wo                                                                       |                |
| Barbara Fraczek       |         | C,D,E                         | K,M,Z,Wa,Wr,Wo                                                                     | <i>mfrazek</i> |
| Aneta Balabas         |         | B                             | B                                                                                  |                |
| Paweł Czarnowski      |         | B                             | B                                                                                  |                |
| Natalia Zeber-Lubecka |         | B,D,E                         | B,W,Wo                                                                             |                |
| Barbara Zapala        |         |                               | Z                                                                                  |                |
| Katarzyna Baginska    |         | B                             | B                                                                                  |                |
| Maria Glowienka       |         | B                             | B                                                                                  |                |
| Monika Szot           |         | E                             | Z,Wo                                                                               | <i>MSzot</i>   |
| Maciek Skorko         |         |                               | Z                                                                                  |                |
| Anna Kluska           |         | B                             | B                                                                                  |                |
| Magdalena Piatkowska  |         | B                             | B                                                                                  |                |
| Michał Mikula         |         | E                             | W,Wo                                                                               |                |
| Jerzy Ostrowski       |         | A,E,G                         | K,Z,Wr,Wo,Zp,Fq                                                                    |                |

\* **A** – przygotowanie projektu badania, **B** – przeprowadzanie badań, **C** – analiza statystyczna, **D** – interpretacja wyników, **E** – przygotowanie publikacji, **F** – opracowanie piśmiennictwa, **G** – pozyskanie funduszy

\*\* **K** – koncepcja projektu (conceptualization), **M** – opracowanie metodologii badań (methodology), **Wa** – walidacja (validation), **Fa** – analiza formalna (formal analysis), **W** – wizualizacja graficzna (visualization), **Z** – zasoby (resources); dostarczenie materiałów badawczych (provision of study materials), **T** – tworzenie metadanych i zachowywanie danych badawczych (data curation), **Wr** – przygotowanie wstępnej wersji artykułu (writing - original draft preparation), **Wo** – współuczestniczenie w przygotowaniu manuskryptu na etapie recenzji/korekty (writing – review and editing), **Zp** – zarządzanie projektem (project administration)

Monika Skot

podpis doktoranta

ptFqde

podpis promotora/promotorów



## OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Kulecka, M., Fraczek, B., Balabas, A., Czarnowski, P., Zeber-Lubecka, N., Zapala, B., Baginska, K., Glowienka, M., Szot, M., Skorko, M., Kluska, A., Piatkowska, M., Mikula, M., Ostrowski, J. Characteristics of the gut microbiome in esports players compared with those in physical education students and professional athletes. (2023). *Frontiers in Nutrition*, 9, 1092846. <https://doi.org/10.3389/fnut.2022.1092846>

*Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:*

| Autor                 | Wkład % | Opis<br>(formularz<br>AWFiS)* | Udział Autorów<br>określony w publikacji<br>czasopisma (Author<br>contributions)** | Podpis         |
|-----------------------|---------|-------------------------------|------------------------------------------------------------------------------------|----------------|
| Maria Kulecka         |         | C,D,E,F                       | T,Fa,W,Wr,Wo                                                                       |                |
| Barbara Fraczek       |         | C,D,E                         | K,M,Z,Wa,Wr,Wo                                                                     |                |
| Aneta Balabas         |         | B                             | B                                                                                  |                |
| Paweł Czarnowski      |         | B                             | B                                                                                  |                |
| Natalia Zeber-Lubecka |         | B,D,E                         | B,W,Wo                                                                             |                |
| Barbara Zapala        |         |                               | Z                                                                                  | Barbara Zapala |
| Katarzyna Baginska    |         | B                             | B                                                                                  |                |
| Maria Glowienka       |         | B                             | B                                                                                  |                |
| Monika Szot           |         | E                             | Z,Wo                                                                               |                |
| Maciek Skorko         |         |                               | Z                                                                                  |                |
| Anna Kluska           |         | B                             | B                                                                                  |                |
| Magdalena Piatkowska  |         | B                             | B                                                                                  |                |
| Michał Mikula         |         | E                             | W,Wo                                                                               |                |
| Jerzy Ostrowski       |         | A,E,G                         | K,Z,Wr,Wo,Zp, Fq                                                                   |                |

\* **A** – przygotowanie projektu badania, **B** – przeprowadzanie badań, **C** – analiza statystyczna, **D** – interpretacja wyników, **E** – przygotowanie publikacji, **F** – opracowanie piśmiennictwa, **G** – pozyskanie funduszy

\*\* **K** – koncepcja projektu (conceptualization), **M** – opracowanie metodologii badań (methodology), **Wa** – walidacja (validation), **Fa** – analiza formalna (formal analysis), **W** – wizualizacja graficzna (visualization), **Z** – zasoby (resources); dostarczenie materiałów badawczych (provision of study materials), **T** – tworzenie metadanych i zachowywanie danych badawczych (data curation), **Wr** – przygotowanie wstępnej wersji artykułu (writing - original draft preparation), **Wo** – współuczestniczenie w przygotowaniu manuskryptu na etapie recenzji/korekty (writing – review and editing), **Zp** – zarządzanie projektem (project administration)

Monika Skot

podpis doktoranta

ptFqde

podpis promotora/promotorów





## SZKOŁA DOKTORSKA

W publikacji autorstwa Kulecka, M., Fraczek, B., Balabas, A., Czarnowski, P., Zeber-Lubecka, N., Zapala, B., Baginska, K., Glowienka, M., **Szot, M.**, Skorko, M., Kluska, A., Piatkowska, M., Mikula, M., Ostrowski, J. (2023) pt. *Characteristics of the gut microbiome in esports players compared with those in physical education students and professional athletes. Frontiers in Nutrition, 9, 1092846. [IF 5.0; 70 pkt]* (E,Z,Wo) wkład mgr inż. Moniki Szot polegał na: przygotowaniu publikacji, – współuczestniczenie w przygotowaniu manuskryptu na etapie recenzji/korekty i zasobach.

In the article by Kulecka, M., Fraczek, B., Balabas, A., Czarnowski, P., Zeber-Lubecka, N., Zapala, B., Baginska, K., Glowienka, M., **Szot, M.**, Skorko, M., Kluska, A., Piatkowska, M., Mikula, M., Ostrowski, J. (2023) entitled *Characteristics of the gut microbiome in esports players compared with those in physical education students and professional athletes. Frontiers in Nutrition, 9, 1092846. [IF 5.0; 70 pts]* (E,Z,Wo) MSc Monika Szot's contribution consisted of: publication preparation, writing – review and editing and resources.

Monika Szot

podpis doktoranta

*[Signature]*

podpis promotora



OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Frączek, B., Szot, M., Sagalara, A., Krzepota, S., Skorko, M., Błachnio, D., Bertrandt, B., Szymaniuk K., Klimek, A. (2023). Assessment of physical activity, exercise capacity and fitness level of Polish esports players. *Physical Activity Review*, 12, 32-46. <https://doi.org/10.16926/par.2024.12.04>

Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:

| Autor               | Wkład % | Opis (formularz AWFIS)* | Udział Autorów określony w publikacji czasopisma (Author contributions)** | Podpis |
|---------------------|---------|-------------------------|---------------------------------------------------------------------------|--------|
| Barbara Frączek     | 30      | A,B,C,D,E               | A,B,C,D                                                                   |        |
| Monika Szot         | 25      | B,C,E,F                 | B,C,D                                                                     |        |
| Andrzej Sagalara    | 5       | E,F                     | D                                                                         |        |
| Sebastian Krzepota  | 5       | G                       | E                                                                         |        |
| Maciek Skorko       | 10      | A,G                     | A,E                                                                       |        |
| Dariusz Błachnio    | 10      | A                       | A,B                                                                       |        |
| Bartosz Bertrandt   | 5       | E,F                     | D                                                                         |        |
| Krzysztof Szymaniuk | 5       | C                       | B                                                                         |        |
| Andrzej Klimek      | 5       | E                       | D                                                                         |        |

\* A – przygotowanie projektu badania, B – przeprowadzanie badań, C – analiza statystyczna, D – interpretacja wyników, E – przygotowanie publikacji, F – opracowanie piśmiennictwa, G – pozyskanie funduszy

\*\* A – przygotowanie projektu badania (study design), B – gromadzenie danych (data collection), C – analiza statystyczna (statistical analysis), D – przygotowanie manuskryptu (manuscript preparation), E – gromadzenie funduszy (funds collection)

podpis doktoranta

podpis promotora



## SZKOŁA DOKTORSKA

### OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Frączek, B., Szot, M., Sagalara, A., Krzepota, S., Skorko, M., Błachnio, D., Bertrandt, B., Szymaniuk K., Klimek, A. (2023). Assessment of physical activity, exercise capacity and fitness level of Polish esports players. *Physical Activity Review*, 12, 32-46. <https://doi.org/10.16926/par.2024.12.04>

*Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:*

| Autor               | Wkład % | Opis (formularz AWFIS)* | Udział Autorów określony w publikacji czasopisma (Author contributions)** | Podpis                  |
|---------------------|---------|-------------------------|---------------------------------------------------------------------------|-------------------------|
| Barbara Frączek     | 30      | A,B,C,D,E               | A,B,C,D                                                                   |                         |
| Monika Szot         | 25      | B,C,E,F                 | B,C,D                                                                     |                         |
| Andrzej Sagalara    | 5       | E,F                     | D                                                                         | <i>Andrzej Sagalara</i> |
| Sebastian Krzepota  | 5       | G                       | E                                                                         |                         |
| Maciek Skorko       | 10      | A,G                     | A,E                                                                       |                         |
| Dariusz Błachnio    | 10      | A                       | A,B                                                                       |                         |
| Bartosz Bertrandt   | 5       | E,F                     | D                                                                         |                         |
| Krzysztof Szymaniuk | 5       | C                       | B                                                                         |                         |
| Andrzej Klimek      | 5       | E                       | D                                                                         |                         |

\* A – przygotowanie projektu badania, B – przeprowadzanie badań, C – analiza statystyczna, D – interpretacja wyników, E – przygotowanie publikacji, F – opracowanie piśmiennictwa, G – pozyskanie funduszy

\*\* A – przygotowanie projektu badania (study design), B – gromadzenie danych (data collection), C – analiza statystyczna (statistical analysis), D – przygotowanie manuskryptu (manuscript preparation), E – gromadzenie funduszy (funds collection)

*Monika Szot*

podpis doktoranta

*M. Skorko*

podpis promotora

Biurowie Sprawy Doktoranckie  
szkola.doktorska@awf.gda.pl  
+48 58 55 47 262, +48 603 766 393  
ul. X. Górskiego 1, 80-336 Gdańsk

Strona 1 z 1



OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Frączek, B., Szot, M., Sagalara, A., Krzepota, S., Skorko, M., Błachnio, D., Bertrandt, B., Szymaniuk K., Klimek, A. (2023). Assessment of physical activity, exercise capacity and fitness level of Polish esports players. *Physical Activity Review*, 12, 32-46. <https://doi.org/10.16926/par.2024.12.04>

Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:

| Autor               | Wkład % | Opis (formularz AWFIS)* | Udział Autorów określony w publikacji czasopisma (Author contributions)** | Podpis                                                                                |
|---------------------|---------|-------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Barbara Frączek     | 30      | A,B,C,D,E               | A,B,C,D                                                                   |                                                                                       |
| Monika Szot         | 25      | B,C,E,F                 | B,C,D                                                                     |                                                                                       |
| Andrzej Sagalara    | 5       | E,F                     | D                                                                         |                                                                                       |
| Sebastian Krzepota  | 5       | G                       | E                                                                         |  |
| Maciek Skorko       | 10      | A,G                     | A,E                                                                       |                                                                                       |
| Dariusz Błachnio    | 10      | A                       | A,B                                                                       |                                                                                       |
| Bartosz Bertrandt   | 5       | E,F                     | D                                                                         |                                                                                       |
| Krzysztof Szymaniuk | 5       | C                       | B                                                                         |                                                                                       |
| Andrzej Klimek      | 5       | E                       | D                                                                         |                                                                                       |

\* A – przygotowanie projektu badania, B – przeprowadzanie badań, C – analiza statystyczna, D – interpretacja wyników, E – przygotowanie publikacji, F – opracowanie piśmiennictwa, G – pozyskanie funduszy

\*\* A – przygotowanie projektu badania (study design), B – gromadzenie danych (data collection), C – analiza statystyczna (statistical analysis), D – przygotowanie manuskryptu (manuscript preparation), E – gromadzenie funduszy (funds collection)

Monika Szot

podpis doktoranta



podpis promotora





## OŚWIADCZENIE WSPÓŁAUTORÓW PUBLIKACJI

Frączek, B., Szot, M., Sagalara, A., Krzepota, S., Skorko, M., Błachnio, D., Bertrandt, B., Szymaniuk K., Klimek, A. (2023). Assessment of physical activity, exercise capacity and fitness level of Polish esports players. *Physical Activity Review*, 12, 32-46. <https://doi.org/10.16926/par.2024.12.04>

*Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:*

| Autor               | Wkład % | Opis (formularz AWFIS)* | Udział Autorów określony w publikacji czasopisma (Author contributions)** | Podpis            |
|---------------------|---------|-------------------------|---------------------------------------------------------------------------|-------------------|
| Barbara Frączek     | 30      | A,B,C,D,E               | A,B,C,D                                                                   |                   |
| Monika Szot         | 25      | B,C,E,F                 | B,C,D                                                                     |                   |
| Andrzej Sagalara    | 5       | E,F                     | D                                                                         |                   |
| Sebastian Krzepota  | 5       | G                       | E                                                                         |                   |
| Maciek Skorko       | 10      | A,G                     | A,E                                                                       |                   |
| Dariusz Błachnio    | 10      | A                       | A,B                                                                       | Donos<br>Błachnio |
| Bartosz Bertrandt   | 5       | E,F                     | D                                                                         |                   |
| Krzysztof Szymaniuk | 5       | C                       | B                                                                         |                   |
| Andrzej Klimek      | 5       | E                       | D                                                                         |                   |

\* A – przygotowanie projektu badania, B – przeprowadzanie badań, C – analiza statystyczna, D – interpretacja wyników, E – przygotowanie publikacji, F – opracowanie piśmiennictwa, G – pozyskanie funduszy

\*\* A – przygotowanie projektu badania (study design), B – gromadzenie danych (data collection), C – analiza statystyczna (statistical analysis), D – przygotowanie manuskryptu (manuscript preparation), E – gromadzenie funduszy (funds collection)

Monika Szot

podpis doktoranta

mfrazek

podpis promotora



OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Frączek, B., Szot, M., Sagalara, A., Krzepota, S., Skorko, M., Błachnio, D., Bertrandt, B., Szymaniuk K., Klimek, A. (2023). Assessment of physical activity, exercise capacity and fitness level of Polish esports players. *Physical Activity Review*, 12, 32-46. <https://doi.org/10.16926/par.2024.12.04>

Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:

| Autor               | Wkład % | Opis (formularz AWFIS)* | Udział Autorów określony w publikacji czasopisma (Author contributions)** | Podpis            |
|---------------------|---------|-------------------------|---------------------------------------------------------------------------|-------------------|
| Barbara Frączek     | 30      | A,B,C,D,E               | A,B,C,D                                                                   |                   |
| Monika Szot         | 25      | B,C,E,F                 | B,C,D                                                                     |                   |
| Andrzej Sagalara    | 5       | E,F                     | D                                                                         |                   |
| Sebastian Krzepota  | 5       | G                       | E                                                                         |                   |
| Maciek Skorko       | 10      | A,G                     | A,E                                                                       |                   |
| Dariusz Błachnio    | 10      | A                       | A,B                                                                       |                   |
| Bartosz Bertrandt   | 5       | E,F                     | D                                                                         | Bartosz Bertrandt |
| Krzysztof Szymaniuk | 5       | C                       | B                                                                         |                   |
| Andrzej Klimek      | 5       | E                       | D                                                                         |                   |

\* A – przygotowanie projektu badania, B – przeprowadzanie badań, C – analiza statystyczna, D – interpretacja wyników, E – przygotowanie publikacji, F – opracowanie piśmiennictwa, G – pozyskanie funduszy

\*\* A – przygotowanie projektu badania (study design), B – gromadzenie danych (data collection), C – analiza statystyczna (statistical analysis), D – przygotowanie manuskryptu (manuscript preparation), E – gromadzenie funduszy (funds collection)

Monika Szot  
podpis doktoranta

MFraczek  
podpis promotora



## OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Frączek, B., Szot, M., Sagalara, A., Krzepota, S., Skorko, M., Błachnio, D., Bertrand, B., Szymaniuk K., Klimek, A. (2023). Assessment of physical activity, exercise capacity and fitness level of Polish esports players. *Physical Activity Review*, 12, 32-46. <https://doi.org/10.16926/par.2024.12.04>

Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:

| Autor               | Wkład % | Opis (formularz AWFIS)* | Udział Autorów określony w publikacji czasopisma (Author contributions)** | Podpis                 |
|---------------------|---------|-------------------------|---------------------------------------------------------------------------|------------------------|
| Barbara Frączek     | 30      | A,B,C,D,E               | A,B,C,D                                                                   |                        |
| Monika Szot         | 25      | B,C,E,F                 | B,C,D                                                                     |                        |
| Andrzej Sagalara    | 5       | E,F                     | D                                                                         |                        |
| Sebastian Krzepota  | 5       | G                       | E                                                                         |                        |
| Maciek Skorko       | 10      | A,G                     | A,E                                                                       |                        |
| Dariusz Błachnio    | 10      | A                       | A,B                                                                       |                        |
| Bartosz Bertrand    | 5       | E,F                     | D                                                                         |                        |
| Krzysztof Szymaniuk | 5       | C                       | B                                                                         | Szymaniuk<br>Krzysztof |
| Andrzej Klimek      | 5       | E                       | D                                                                         |                        |

\* A – przygotowanie projektu badania, B – przeprowadzanie badań, C – analiza statystyczna, D – interpretacja wyników, E – przygotowanie publikacji, F – opracowanie piśmiennictwa, G – pozyskanie funduszy

\*\* A – przygotowanie projektu badania (study design), B – gromadzenie danych (data collection), C – analiza statystyczna (statistical analysis), D – przygotowanie manuskryptu (manuscript preparation), E – gromadzenie funduszy (funds collection)

Monika Szot  
podpis doktoranta

MTA  
podpis promotora



## SZKOŁA DOKTORSKA

W publikacji autorstwa Frączek, B., Szot, M., Sagalara, A., Krzepota, S., Skorko, M., Błachnio, D., Bertrandt, B., Szymaniuk, K., Klimek A. (2024) pt. *Assessment of physical activity, exercise capacity and fitness level of Polish esports players. Physical Activity Review*, 12, 32-46. [IF 0.9; 70 pkt] (C,E,F,Gd) wkład mgr inż. Moniki Szot polegał na: analizie statystycznej, przygotowaniu manuskryptu, opracowaniu piśmiennictwa, gromadzeniu danych.

In the article by Frączek, B., Szot, M., Sagalara, A., Krzepota, S., Skorko, M., Błachnio, D., Bertrandt, B., Szymaniuk, K., Klimek A. (2024) entitled *Assessment of physical activity, exercise capacity and fitness level of Polish esports players. Physical Activity Review*, 12, 32-46. [IF 0.9; 70 pts] (C,E,F,Gd) MSc Monika Szot's contribution consisted of: statistical analysis, manuscript preparation, compilation of a bibliography, data collection.

Monika Szot

podpis doktoranta

prof. dr hab. inż. Andrzej Ciel

podpis promotora





## OŚWIADCZENIE WSPÓLAUTORÓW PUBLIKACJI

Szot, M., Frączek, B. Evaluation of the eating habits of Polish esports players using the Quick Diet Survey (QDS). *Journal of Kinesiology and Exercise Sciences*, 107, 1-14. <https://doi.org/10.5604/01.3001.0054.5121>

*Niniejszym oświadczamy, że indywidualny wkład w powstanie ww publikacji jest następujący:*

| Autor           | Wkład % | Opis<br>(formularz<br>AWFiS)* | Udział Autorów<br>określony w publikacji<br>czasopisma (Author<br>contributions)** | Podpis          |
|-----------------|---------|-------------------------------|------------------------------------------------------------------------------------|-----------------|
| Monika Szot     | 50      | A,B,C,D,E,F                   | A,B,C,D,E,F                                                                        | <i>MSzot</i>    |
| Barbara Frączek | 50      | A,B,C,D,E,F                   | A,B,C,D,E,F                                                                        | <i>BFrączek</i> |

\* A – przygotowanie projektu badania, B – przeprowadzanie badań, C – analiza statystyczna, D – interpretacja wyników, E – przygotowanie publikacji, F – opracowanie piśmiennictwa, G – pozyskanie funduszy

\*\* A – przygotowanie projektu badania (study design/planning), B – gromadzenie danych (data collection/entry), C – analiza statystyczna (data analysis/statistics), D – interpretacja wyników (data interpretation), E – przygotowanie manuskryptu (preparation of manuscript), F – przegląd literatury (literature analysis/search), G – gromadzenie funduszy (funds collection)

*Monika Szot*

podpis doktoranta

*BFrączek*

podpis promotora



W publikacji autorstwa Szot, M., Frączek, B. (2024) pt. *Evaluation of the eating habits of Polish esports players using the Quick Diet Survey (QDS). Journal of Kinesiology and Exercise Sciences* 107, 1-14. [70 pkt] (A,B,C,D,E,F,A,B,C,D,E,F) wkład mgr inż. Moniki Szot polegał na: przygotowaniu projektu badania przeprowadzeniu badań, analizie statystycznej, interpretacji wyników, przygotowaniu publikacji, opracowaniu piśmiennictwa, gromadzeniu danych.

In the article by Szot, M., Frączek, B., Tyrała, F. (2023) entitled *Evaluation of the eating habits of Polish esports players using the Quick Diet Survey (QDS). Journal of Kinesiology and Exercise Sciences* 107, 1-14. [70 pts] (A,B,C,D,E,F,A,B,C,D,E,F) MSc Monika Szot's contribution consisted of: study design, investigation, data analysis, data interpretation, preparation of manuscript, literature search, data collection.

Monika Szot

podpis doktoranta

PiFrączek

podpis promotora

### Załącznik 3. Skan opinii Komisji Bioetycznej



#### KOMISJA BIOETYCZNA

KB – 63 / 22

Gdańsk, dnia 13 grudnia 2022 r.

**Główny Badacz:** mgr Monika Szot

**Miejsce prowadzenia badania:**

Akademia Wychowania Fizycznego i Sportu w Gdańsku, Zakład Dietetyki Sportowej,  
ul. Kazimierza Górskiego 1, 80-336 Gdańsk

**Tytuł badania:** „Ocena wybranych elementów stylu życia grupy polskich e-sportowców.”

*Komisja Bioetyczna przy Okręgowej Izbie Lekarskiej w Gdańsku nie zgłasza zastrzeżeń dla przeprowadzenia w/w pracy naukowej zgodnie z nadesłaną dokumentacją.*

PRZEWODNICZĄCY  
KOMISJI BIOETYCZNEJ  
przy Okręgowej Izbie Lekarskiej w Gdańsku  
Dr hab. n. med. Wojciech Makarewicz

Komisja działa zgodnie z Zasadami Good Clinical Practice.

## Załącznik 4. Kwestionariusze ankiet

### Kwestionariusz szybkiej oceny sposobu żywienia- Quick Diet Survey (QDS)

Proszę uzupełnić tabelkę wstawiając znak „X” w odpowiednią kolumnę, zaznaczając odpowiedź na postawione pytania dotyczące Pana/Pani zwyczajowego sposobu żywienia.

|     | Pytanie                                                                                                                                                                                                                                                                                                                            | Tak | Nie | Nie wiem |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----|----------|
| 1.  | Czy dostarczasz z dietą taką ilość energii, jaką potrzebujesz, tak, aby Twoja masa ciała była prawidłowa?                                                                                                                                                                                                                          |     |     |          |
| 2.  | Czy spożywasz codziennie, co najmniej 3 posiłki, maksymalnie 5 posiłków?                                                                                                                                                                                                                                                           |     |     |          |
| 3.  | Czy spożywanie posiłków jest oddzielone, co najmniej 3 godzinną przerwą, nie dłuższą niż 5 godzin?                                                                                                                                                                                                                                 |     |     |          |
| 4.  | Czy spożywasz śniadanie do godziny od pobudki?                                                                                                                                                                                                                                                                                     |     |     |          |
| 5.  | Czy ostatni posiłek spożywasz nie później niż 1.5-2 godziny przed snem (optymalnie do godz. 20)?                                                                                                                                                                                                                                   |     |     |          |
| 6.  | Czy Twój najbardziej kaloryczny posiłek spożywany jest w czasie podwyższonej aktywności dziennej (np. przed/po treningu fizycznym)?                                                                                                                                                                                                |     |     |          |
| 7.  | Czy warzywa (łącznie ok. 250 g) znajdują się w Twoim jadłospisie codziennie, co najmniej, w dwóch posiłkach?                                                                                                                                                                                                                       |     |     |          |
| 8.  | Czy przynajmniej raz dziennie spożywasz różnokolorowe warzywa w formie surowej?                                                                                                                                                                                                                                                    |     |     |          |
| 9.  | Czy spożywasz codziennie co najmniej 2-3 porcje warzyw?                                                                                                                                                                                                                                                                            |     |     |          |
| 10. | Czy spożywasz codziennie 1-2 porcje owoców?                                                                                                                                                                                                                                                                                        |     |     |          |
| 11. | Czy produkty zbożowe (tj. pieczywo, płatki, makaron, kasza, ziemniaki, ryż) znajdują się w każdym głównym posiłku spożywanym przez Ciebie?                                                                                                                                                                                         |     |     |          |
| 12. | Czy spożywasz produkty zbożowe pełnoziarniste (pieczywo pełnoziarniste, płatki zbożowe, gruboziarniste kasze, makarony pełnoziarniste, otręby) co najmniej dwa razy w ciągu dnia?                                                                                                                                                  |     |     |          |
| 13. | Czy mleko lub produkty mleczne spożywasz dwa razy dziennie?                                                                                                                                                                                                                                                                        |     |     |          |
| 14. | Czy wybierasz najzdrowsze źródła białka pełnowartościowego?<br><i>czyli te, w których zawartość tłuszczów i cukrów jest najmniejsza- chude sery twarogowe, fermentowane produkty mleczne (kefir, maślanka, jogurty naturalne), jaja, drób, chuda młoda wołowina, chude gatunki ryb (tuńczyk, pstrąg, dorsz, sola, flądra itp.)</i> |     |     |          |
| 15. | Czy z mięs wybierasz tylko gatunki chude, tj. indyk, kurczak, królik, chuda wołowina, cielęcina?                                                                                                                                                                                                                                   |     |     |          |
| 16. | Czy dostarczasz białka pełnowartościowego w postaci jajek lub mięsa w ilości nie większej niż 150 g tych produktów dziennie?<br><i>Średnie jajo- 50g; porcja mięsa surowego- 100g</i>                                                                                                                                              |     |     |          |
| 17. | Czy spożycie przetworzonych produktów mięsnych (wędlin) ograniczasz do 2-3 krotnego spożycia w tygodniu?                                                                                                                                                                                                                           |     |     |          |
| 18. | Czy często zastępujesz mięso jego zamiennikami, tzn. chudymi rybami, roślinami strączkowymi, jajami i niskotłuszczowymi produktami mlecznymi?                                                                                                                                                                                      |     |     |          |
| 19. | Czy spożywasz rośliny strączkowe (fasola, fasolka, groch, soja, ciecierzycza, soczewica, bób) co najmniej 2 razy w tygodniu?                                                                                                                                                                                                       |     |     |          |
| 20. | Czy spożywasz ryby raz lub dwa razy w tygodniu?                                                                                                                                                                                                                                                                                    |     |     |          |



|     |                                                                                                                                                                                                                                                                                                                                                                                                                  |  |  |  |
|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|--|--|
| 21. | Czy ograniczasz spożywanie tłuszczów zwierzęcych?<br><i>tzn. wybierasz niskotłuszczowe produkty mleczne; mięso/wędliny drobiowe, cielęce, chude wołowe są częściej spożywane niż mięso/wędliny wieprzowe; ograniczasz używanie tłuszczów do smarowania pieczywa, smażenia itp.?</i>                                                                                                                              |  |  |  |
| 22. | Czy spożywasz prawie codziennie porcję tłuszczów pochodzenia roślinnego, np. algi, nasiona lnu, słonecznika, pestki dyni, orzechy, migdały, oliwę, oliwki, awokado, olej rzepakowy?                                                                                                                                                                                                                              |  |  |  |
| 23. | Czy spożywasz codziennie produkty spożywcze stanowiące źródło probiotyków?<br><i>Źródła probiotyków: kiszonki (kiszzone ogórki, kapusta, buraki i in.), fermentowane produkty mleczne (kefir, jogurt naturalny, maślanka), kwas chlebowy, pieczywo żytnie na zakwasie, fermentowane nasiona roślin strączkowych, fermentowane produkty sojowe.</i>                                                               |  |  |  |
| 24. | Czy w ciągu dnia nawadniasz się odpowiednią ilością płynów (30ml/kg mc nie wliczając nawadniania okołowysiłkowego)?                                                                                                                                                                                                                                                                                              |  |  |  |
| 25. | Czy nawadniasz się odpowiednio w trakcie podejmowanych wysiłków (około litr, minimum 800 ml napoju izotonicznego/wody średnio- lub wysokozmineralizowanej na godzinę treningu)?                                                                                                                                                                                                                                  |  |  |  |
| 26. | Czy nawadniasz się odpowiednio po wysiłku fizycznym (ok. 450-700 ml płynów na każde 0,5 kg utraconej masy ciała)?                                                                                                                                                                                                                                                                                                |  |  |  |
| 27. | Czy najczęściej wypijanymi przez Ciebie płynami są wody mineralne?                                                                                                                                                                                                                                                                                                                                               |  |  |  |
| 28. | Czy unikasz spożywania napojów słodzonych i gazowanych?                                                                                                                                                                                                                                                                                                                                                          |  |  |  |
| 29. | Czy nie pijesz napojów energetyzujących?                                                                                                                                                                                                                                                                                                                                                                         |  |  |  |
| 30. | Czy unikasz i sporadycznie (1-2 razy w miesiącu) spożywasz produkty typu „fast-food”?                                                                                                                                                                                                                                                                                                                            |  |  |  |
| 31. | Czy spożywasz wyroby cukiernicze i słone przekąski w sposób umiarkowany (okazjonalnie, tj. kilka razy w miesiącu)?                                                                                                                                                                                                                                                                                               |  |  |  |
| 32. | Czy unikasz spożycia cukru i słodczy?                                                                                                                                                                                                                                                                                                                                                                            |  |  |  |
| 33. | Czy stosujesz właściwe metody przygotowywania potraw, tj. smażenie zastępujesz pieczeniem, duszeniem, ewentualnie grillowanie na patelni/w piekarniku?                                                                                                                                                                                                                                                           |  |  |  |
| 34. | Czy Twoje posiłki są zbilansowane?<br><i>Posiłek zbilansowany to taki, w którym znajdują się produkty spożywcze stanowiące zalecane źródło białka (B), węglowodanów (W) i tłuszczów (T) oraz warzyw (Wa)/owoców (Owo) w odpowiednich proporcjach. Zgodnie z zasadą racjonalnego żywienia posiłek zbilansowany stanowi: 1 porcja B + co najmniej 1,5 porcji W + 1,5 porcji Wa + 0,5 porcji T/ewentualnie Owo.</i> |  |  |  |
| 35. | Czy Twoje odżywianie jest urozmaicone (dieta obejmuje produkty z różnych grup żywności)?                                                                                                                                                                                                                                                                                                                         |  |  |  |
| 36. | Czy starannie wybierasz produkty spożywcze (jak najmniej przetworzone) kierując się informacją na etykietach i zasadami prawidłowego odżywiania?                                                                                                                                                                                                                                                                 |  |  |  |
| 37. | Czy rozsądnie stosujesz suplementację diety i konsultujesz ją z lekarzem lub dietetykiem?                                                                                                                                                                                                                                                                                                                        |  |  |  |

## Międzynarodowy Kwestionariusz Aktywności Fizycznej - The International Physical Activity Questionnaire (IPAQ)

### MIĘDZYNARODOWY KWESTIONARIUSZ AKTYWNOŚCI FIZYCZNEJ

Kwestionariusz dotyczy czasu poświęconego na aktywność fizyczną w ciągu ostatnich 7 dni. Proszę wziąć pod uwagę **tylko** taki wysiłek, który jednorazowo trwał co najmniej 10 minut.

W pytaniach użyto niżej wymienionych określeń:

- **Intensywna** aktywność fizyczna oznacza ciężki wysiłek, zmuszający do silnie wzmożonego oddychania (i przyspieszonej akcji serca);
- **Umiarkowana** aktywność fizyczna oznacza wysiłek przeciętny z nieco wzmożonym oddychaniem (i nieco przyspieszoną akcją serca).

### CZĘŚĆ 1: AKTYWNOŚĆ FIZYCZNA ZWIĄZANA Z PRACĄ ZAWODOWĄ

*Pytania w część I dotyczą wysiłku fizycznego w Państwa pracy zawodowej, w rolnictwie, nauce, pracy społecznej i każdej innej aktywności społecznej (w tym niepłatnej), którą wykonują Państwo poza domem. Proszę **nie brać** pod uwagę czynności, które wykonują Państwo wokół domu, np. prac domowych, pracy w ogródku, ogólnych prac porządkowych oraz opieki nad rodziną. Tematykę tę obejmuje część 3.*

1. Proszę podać czy aktualnie pracuje Pan/i zawodowo, uczy się lub wykonuje pracę bez wynagrodzenia poza domem.

1. Tak
2. Nie → **prześć do części 2**

*Następne pytania dotyczą wszelkiego wysiłku fizycznego wykonywanego w ciągu ostatnich 7 dni w ramach pracy bez wynagrodzenia lub zawodowej oraz nauki. Proszę wziąć pod uwagę tylko taki wysiłek, który jednorazowo trwał co najmniej 10 minut. Tematyka tych pytań nie dotyczy chodzenia do pracy i z powrotem.*

2. Proszę podać liczbę dni w ciągu ostatnich 7, w których wykonywał Pan/i w ramach pracy zawodowej lub nauki **intensywny** wysiłek fizyczny, np. : podnoszenie ciężkich rzeczy, kopanie, prace budowlane, chodzenie po schodach.

1. Dni w tygodniu .....
2. Nie wykonywałam/em takiej czynności → **prześć do pytania 4**

3. Proszę podać, ile czasu w jednym z takich (przeciętnych) dni poświęca Pan/i zwykle na intensywny wysiłek fizyczny w ramach pracy.

1. Godzin dziennie .....
- Minut dziennie .....

4. Proszę podać liczbę dni w ciągu ostatnich 7, w których wykonywał Pan/i w ramach pracy zawodowej umiarkowany wysiłek fizyczny, porównywalny z przenoszeniem lekkich rzeczy, jazdą na rowerze w normalnym tempie. Proszę nie brać pod uwagę chodzenia.
1. Dni w tygodniu .....
  2. Nie wykonywałam/em takiej czynności → *przejsć do pytania 6*
5. Proszę podać, ile czasu w jednym z takich (przeciętnych) dni poświęca Pan/i zwykle na umiarkowany wysiłek fizyczny wykonywany w ramach pracy zawodowej.
1. Godzin dziennie .....  
Minut dziennie .....
6. Proszę podać liczbę dni w ciągu ostatnich 7, w których chodził Pan/i co najmniej 10 minut (jednorazowo) w czasie pracy zawodowej. Proszę nie wliczać do tego czasu dojścia do pracy i z powrotem.
1. Dni w tygodniu .....
  2. Nie wykonywałam/em takiej czynności → *przejsć do części 2*
7. Proszę podać, ile czasu poświęca Pan/i na chodzenie w jednym z takich (przeciętnych) dni w ramach pracy zawodowej.
1. Godzin dziennie .....  
Minut dziennie .....

## CZĘŚĆ 2: AKTYWNOŚĆ FIZYCZNA ZWIĄZANA Z PRZEMIESZCZANIEM SIĘ

*Pytania w kolejnej części dotyczą sposobu przemieszczania się z miejsca na miejsce, włączając w to przemieszczanie się do pracy, na zakupy, w miejsca rozrywki itp. (dotyczy czynności nie wykonywanych w czasie wolnym). Proszę wziąć pod uwagę tylko taką aktywność, która jednorazowo trwała co najmniej 10 minut.*

8. Proszę podać liczbę dni w ciągu ostatnich 7, w których jeździł Pan/i pojazdem takim jak samochód, autobus, pociąg, tramwaj lub inny pojazd (*proszę nie brać pod uwagę jazdy na rowerze*).
1. Dni w tygodniu .....
  2. Nie wykonywałam/em takiej czynności → *przejsć do pytania 10*
9. Proszę podać, ile czasu spędza Pan/i podczas jednego z takich (przeciętnych) dni, jeżdżąc samochodem, autobusem, pociągiem, tramwajem lub innym pojazdem (*proszę nie brać pod uwagę jazdy na rowerze*).
1. Godzin dziennie .....  
Minut dziennie .....
10. Proszę podać liczbę dni w ciągu ostatnich 7, w których jechał Pan/i rowerem przez co najmniej 10 minut.

*Proszę wziąć pod uwagę jedynie jazdę na rowerze: do pracy i z powrotem, lub w innych celach.*

1. Dni w tygodniu .....
2. Nie wykonywałam/em takiej czynności. → **przejsć do pytania 12**

**11. Proszę podać, ile czasu jeździ Pan/i rowerem podczas jednego z takich (przeciętnych) dni.**

1. Godzin dziennie .....
- Minut dziennie .....

**12. Proszę podać liczbę dni w ciągu ostatnich 7, w których chodził Pan/i co najmniej 10 minut jednorazowo.**

*Proszę wziąć pod uwagę jedynie chodzenie: do pracy i z powrotem, lub w innych celach.*

1. Dni w tygodniu .....
2. Nie wykonywałam/em takiej czynności → **przejsć do części 3**

**13. Proszę podać, ile czasu chodzi Pan/i w jednym z takich (przeciętnych) dni.**

1. Godzin dziennie .....
- Minut dziennie .....

### **CZĘŚĆ 3: PRACE DOMOWE, OGÓLNE PRACE PORZĄDKOWE I OPIEKA NAD RODZINĄ**

*Pytania w kolejnej części dotyczą wysiłku fizycznego w ciągu ostatnich 7 dni, który wykonywał Pan/Pani w domu i wokół domu, np.: prace domowe, opieka nad rodziną, ogólne prace porządkowe, uprawa ogródka.*

*Proszę wziąć pod uwagę tylko taki wysiłek fizyczny, który zajmuje jednorazowo co najmniej 10 minut.*

**14. Proszę podać liczbę dni w ciągu ostatnich 7, w których wykonywał Pan/i w ogródku lub wokół domu intensywny wysiłek fizyczny, np. przenoszenie ciężkich rzeczy, rąbanie drewna, odśnieżanie lub kopanie.**

1. Dni w tygodniu .....
2. Nie wykonywałam/em takiej czynności. → **przejsć do pytania 18**

**15. Proszę podać, ile czasu poświęca Pan/i zwykle w jednym z takich (przeciętnych) dni na intensywny wysiłek fizyczny w ogródku lub wokół domu.**

1. Godzin dziennie .....
- Minut dziennie .....

**16. Proszę podać liczbę dni, w ciągu ostatnich 7, w których wykonywał Pan/i umiarkowany wysiłek fizyczny w ogródku lub wokół domu, p.. przenoszenie lekkich rzeczy, zamykanie, mycie okien, grabienie i sprzątanie wokół domu.**

1. Dni w tygodniu .....
2. Nie wykonywałam/em takiej czynności. → **przejsć do pytania 18**



17. Proszę podać, ile czasu poświęca Pan/i zwykle w jednym z takich (przeciętnych) dni na umiarkowany wysiłek fizyczny w przydomowym ogródku lub wokół domu.

1. Godzin dziennie .....
- Minut dziennie .....

18. Proszę podać liczbę dni w ciągu ostatnich 7, w których wykonywał Pan/i w domu umiarkowany wysiłek fizyczny, np. przenoszenie lekkich rzeczy, mycie okien, mycie podłóg, oraz sprząatanie

1. Dni w tygodniu .....
2. Nie wykonywałam/em takiej czynności. → **przejsć do części 4**

19. Proszę podać, ile czasu poświęca Pan/i w jednym z takich (przeciętnych) dni na umiarkowany wysiłek fizyczny w domu.

1. Godzin dziennie .....
- Minut dziennie .....

#### CZĘŚĆ 4: REKREACJA, SPORT I AKTYWNOŚĆ FIZYCZNA W CZASIE WOLNYM

*Pytania w następnej części dotyczą aktywności fizycznej w czasie wolnym w ciągu ostatnich 7 dni poświęconej na sport, rekreację, ćwiczenia lub rozrywkę i wypoczynek. Odpowiadając na pytania, proszę **nie brać** pod uwagę tych rodzajów aktywności fizycznej, o której Państwo już wspomnieli. Proszę wziąć pod uwagę tylko aktywność fizyczną, która trwała jednorazowo co najmniej 10 minut.*

20. Proszę podać liczbę dni w ciągu ostatnich 7, w których chodził Pan/i jednorazowo co najmniej 10 minut w czasie wolnym.

*Nie należy brać pod uwagę żadnego chodzenia, o którym była mowa dotychczas.*

1. Dni w tygodniu .....
2. Nie wykonywałam/em takiej czynności. → **przejsć do pytania 22**

21. Proszę podać, ile czasu przeznaczył Pan/i w jednym z takich (przeciętnych) dni na chodzenie w czasie wolnym.

1. Godzin dziennie .....
- Minut dziennie .....

22. Proszę podać liczbę dni w ciągu ostatnich 7, w których uprawiał Pan/i intensywną aktywność fizyczną, np. aerobik, biegi, szybka jazda rowerem, szybkie pływanie w czasie wolnym.

1. Dni w tygodniu .....
2. Nie wykonywałam/em takiej czynności. → **przejsć do pytania 24**

23. Proszę podać, ile czasu zwykle poświęca Pan/i w jednym z takich (przeciętnych) dni na intensywną aktywność fizyczną w czasie wolnym.

1. Godzin dziennie .....
- Minut dziennie .....

**24. Proszę podać liczbę dni w ciągu ostatnich 7, w których wykonywał Pan/i umiarkowaną aktywność fizyczną w czasie wolnym, np. jazda rowerem w regularnym tempie, pływanie w regularnym tempie, gra w siatkówkę.**

1. Dni w tygodniu .....
2. Nie wykonywałam/em takiej czynności. → *przejsć do części 5*

**25. Proszę podać, ile czasu zwykle spędza Pan/i w jednym z takich (przeciętnych) dni na umiarkowaną aktywność fizyczną w czasie wolnym.**

1. Godzin dziennie .....  
Minut dziennie .....

## **CZĘŚĆ 5: CZAS SPĘDZONY SIEDZĄC**

*Pytania w tej części dotyczą czasu, który spędza Pan/i siedząc zarówno w pracy, w domu, podczas nauki i w czasie wolnym. Może to obejmować czas spędzony siedząc przy biurku, z wizytą u przyjaciół, podczas czytania, oglądania telewizji leżąc lub siedząc (nie wliczając w to czasu poświęconego na sen). Proszę nie brać pod uwagę czasu spędzonego siedząc w pojeździe mechanicznym, bo o tym już była mowa.*

**26. Biorąc pod uwagę ostatnie 7 dni proszę podać, ile przeciętnie czasu spędził Pan/i siedząc w dniu powszednim.**

1. Godzin dziennie .....  
Minut dziennie .....

**27. Biorąc pod uwagę ostatnie 7 dni proszę podać, ile przeciętnie czasu spędził Pan/i siedząc w dniu wolnym od pracy.**

1. Godzin dziennie .....  
Minut dziennie .....

## Kwestionariusz częstości spożycia żywności - Food Frequency Questionnaire (FFQ)

### CZĘSTOŚĆ SPOŻYCIA ŻYWNOSTCI

Uprzejmie proszę o określenie zwyczajowej częstości spożywania podanych produktów poprzez zaznaczenie **X** w odpowiedniej kolumnie. Bardzo proszę o szczerze i rzetelne wypełnienie ankiety, pamiętając, że nie ma odpowiedzi ani dobrych ani złych. Odpowiadając na pytania proszę zwrócić uwagę na wielkość porcji zaznaczoną przy produkcie w nawiasie, a w razie konieczności zsumować porcje (1 porcja - 1 raz). Proszę uwzględnić żywność spożywaną podczas posiłków i między posiłkami, w domu i poza domem, w ciągu ostatnich 12 miesięcy. Serdecznie dziękuję za wypełnienie kwestionariusza.

| Produkty spożywcze i ilości / wielkości porcji                                           | Częstość spożycia    |                      |                 |                                |                                  |                        |                                          |
|------------------------------------------------------------------------------------------|----------------------|----------------------|-----------------|--------------------------------|----------------------------------|------------------------|------------------------------------------|
|                                                                                          | 4-5 razy<br>dziennie | 2-3 razy<br>dziennie | Raz<br>dziennie | Kilka<br>razy<br>w<br>tygodniu | Raz/dwa<br>razy<br>w<br>tygodniu | 1-3 razy<br>w miesiącu | Nigdy/<br>rzadziej niż raz w<br>miesiącu |
| <b>PIECZYWO JASNE (PSZENNE, ŻYTNIE, MIESZANE PSZENNO-ŻYTNIE, TOSTOWE, BUŁKI, ROGALE)</b> |                      |                      |                 |                                |                                  |                        |                                          |
| Pieczyno żytne na zakwasie                                                               |                      |                      |                 |                                |                                  |                        |                                          |
| <b>PIECZYWO RAZOWE</b>                                                                   |                      |                      |                 |                                |                                  |                        |                                          |
| <b>RYŻ BIAŁY, MAKARON ZWYKŁY, DROBNE KASZE (KASZA MANNA, KUSKUS)</b>                     |                      |                      |                 |                                |                                  |                        |                                          |
| <b>KASZA GRZCZANA, INNE KASZE PEŁNOZIARNISTE, PŁATKI ZBOŻOWE, MAKARON PEŁNOZIARNISTY</b> |                      |                      |                 |                                |                                  |                        |                                          |
| Kasza gryczana (średnia porcja)                                                          |                      |                      |                 |                                |                                  |                        |                                          |
| Kasza jaglana (średnia porcja)                                                           |                      |                      |                 |                                |                                  |                        |                                          |
| Płatki jaglane (miseczka)                                                                |                      |                      |                 |                                |                                  |                        |                                          |
| Płatki żytnie (miseczka)                                                                 |                      |                      |                 |                                |                                  |                        |                                          |
| Płatki owsiane (miseczka)                                                                |                      |                      |                 |                                |                                  |                        |                                          |

|                                                                                                            |  |  |  |  |  |  |  |
|------------------------------------------------------------------------------------------------------------|--|--|--|--|--|--|--|
| Płatki śniadaniowe typu Musli, Granola (miseczka)                                                          |  |  |  |  |  |  |  |
| Płatki śniadaniowe typu Chocapic (miseczka)                                                                |  |  |  |  |  |  |  |
| Makaron pełnoziarnisty (średnia porcja)                                                                    |  |  |  |  |  |  |  |
| Kielki pszenne / owsiane (łyżka)                                                                           |  |  |  |  |  |  |  |
| Zarodki pszenne (łyżka)                                                                                    |  |  |  |  |  |  |  |
| <b>ŻYWNOŚĆ TYPU FAST FOOD (FRYTKI, HAMBURGERY, PIZZA, ZAPIEKANKI, CHIPSY)</b>                              |  |  |  |  |  |  |  |
| <b>POTRAWY SMAŻONE (MIĘSNE LUB MĄCZNE)</b>                                                                 |  |  |  |  |  |  |  |
| <b>SMALEC/OLEJ KOKOSOWY JAKO DODATEK DO PIECZYWA LUB POTRAW, DO SMAŻENIA, PIECZENIA</b>                    |  |  |  |  |  |  |  |
| Smalec (łyżeczka)                                                                                          |  |  |  |  |  |  |  |
| Olej kokosowy (łyżeczka)                                                                                   |  |  |  |  |  |  |  |
| Masło (łyżeczka)                                                                                           |  |  |  |  |  |  |  |
| <b>OLIWA I OLEJ RZEPAKOWY JAKO DODATEK DO PIECZYWA LUB POTRAW, DO SMAŻENIA, PIECZENIA</b>                  |  |  |  |  |  |  |  |
| Olej lniany (łyżka)                                                                                        |  |  |  |  |  |  |  |
| Olej rzepakowy (łyżka)                                                                                     |  |  |  |  |  |  |  |
| Oliwa z oliwek (łyżka)                                                                                     |  |  |  |  |  |  |  |
| Olej sojowy (łyżka)                                                                                        |  |  |  |  |  |  |  |
| Olej z wątroby dorsza (łyżka)                                                                              |  |  |  |  |  |  |  |
| Olej z nasion bawełny (łyżka)                                                                              |  |  |  |  |  |  |  |
| Olej palmowy (łyżka)                                                                                       |  |  |  |  |  |  |  |
| <b>MARGARYNY LUB MIKSY Z MASŁA Z MARGARYNĄ JAKO DODATEK DO PIECZYWA LUB POTRAW, DO SMAŻENIA, PIECZENIA</b> |  |  |  |  |  |  |  |
| <b>ORZECHY, PESTKI DYN, NASIONA SŁONECZNIKA I INNE NASIONA ROŚLIN OLEISTYCH</b>                            |  |  |  |  |  |  |  |
| Orzechy włoskie (garść)                                                                                    |  |  |  |  |  |  |  |
| Migdały (garść)                                                                                            |  |  |  |  |  |  |  |
| Orzechy ziemne (garść)                                                                                     |  |  |  |  |  |  |  |



|                                                                      |  |  |  |  |  |  |  |
|----------------------------------------------------------------------|--|--|--|--|--|--|--|
| Mak (łyżka)                                                          |  |  |  |  |  |  |  |
| Orzechy brazylijskie (garść)                                         |  |  |  |  |  |  |  |
| Pestki dyni (łyżka)                                                  |  |  |  |  |  |  |  |
| Siemię lniane (łyżka)                                                |  |  |  |  |  |  |  |
| Nasiona chia (łyżka)                                                 |  |  |  |  |  |  |  |
| Nasiona słonecznika (łyżka)                                          |  |  |  |  |  |  |  |
| Sezam (łyżka)                                                        |  |  |  |  |  |  |  |
| Orzechy laskowe (garść)                                              |  |  |  |  |  |  |  |
| <b>MLEKO (W TYM MLEKO SMAKOWE, KAKAO, KAWA NA MLEKU)</b>             |  |  |  |  |  |  |  |
| Mleko (szklanka)                                                     |  |  |  |  |  |  |  |
| Kakao (szklanka)                                                     |  |  |  |  |  |  |  |
| Mleko smakowe (szklanka)                                             |  |  |  |  |  |  |  |
| Kawa na mleku (szklanka)                                             |  |  |  |  |  |  |  |
| <b>FERMENTOWANE NAPOJE MLECZNE (JOGURTY, KEFIRY)</b>                 |  |  |  |  |  |  |  |
| Jogurty naturalne (kubek 150 g)                                      |  |  |  |  |  |  |  |
| Jogurty greckie (kubek 150g)                                         |  |  |  |  |  |  |  |
| Jogurty owocowe / pitne (kubek 150 g)                                |  |  |  |  |  |  |  |
| Kefir (szklanka)                                                     |  |  |  |  |  |  |  |
| Maślanka (szklanka)                                                  |  |  |  |  |  |  |  |
| <b>Jogurt Activia</b>                                                |  |  |  |  |  |  |  |
| <b>Jogurt Actimel</b>                                                |  |  |  |  |  |  |  |
| <b>SERY TWAROGOWE (W TYM SERKI HOMOGENIZOWANE, DESERY TWAROGOWE)</b> |  |  |  |  |  |  |  |
| Sery twarogowe (średnia porcja)                                      |  |  |  |  |  |  |  |
| <b>SERY ŻÓLTE (W TYM SERKI TOPIONE, SERY PLEŚNIOWE)</b>              |  |  |  |  |  |  |  |
| Sery żółte / topione / pleśniowe (średnia porcja)                    |  |  |  |  |  |  |  |
| <b>WĘDLINY, KIELBASY, PARÓWKI WIEPRZOWE</b>                          |  |  |  |  |  |  |  |
| Wędliny wieprzowe (plasterek)                                        |  |  |  |  |  |  |  |

|                                                                                                       |  |  |  |  |  |  |  |
|-------------------------------------------------------------------------------------------------------|--|--|--|--|--|--|--|
| Kiełbasy wieprzowe (sztuka)                                                                           |  |  |  |  |  |  |  |
| Parówki wieprzowe (sztuka)                                                                            |  |  |  |  |  |  |  |
| <b>WĘDLINY, KIEŁBASY, PARÓWKI DROBIOWE, CIEŁĘCE</b>                                                   |  |  |  |  |  |  |  |
| Wędliny drobiowe, cięte (plasterek)                                                                   |  |  |  |  |  |  |  |
| Kiełbasy drobiowe, cięte (sztuka)                                                                     |  |  |  |  |  |  |  |
| Parówki drobiowe, cięte (sztuka)                                                                      |  |  |  |  |  |  |  |
| Wątroba drobiowa / wołowa / jagnięca (porcja 100 g)                                                   |  |  |  |  |  |  |  |
| <b>POTRAWY Z MIĘSA CZERWONEGO (WIEPRZOWINY, WOŁOWINY, CIEŁĘCINY, BARANINY, JAGNIĘCINY, DZICZYŻNY)</b> |  |  |  |  |  |  |  |
| <b>POTRAWY Z MIĘSA BIAŁEGO (KURCZAKA, INDYKA, KRÓLIKA)</b>                                            |  |  |  |  |  |  |  |
| <b>RYBY</b>                                                                                           |  |  |  |  |  |  |  |
| Łosoś (porcja 100 g)                                                                                  |  |  |  |  |  |  |  |
| Makrela (porcja 100 g)                                                                                |  |  |  |  |  |  |  |
| Śledź (porcja 100 g)                                                                                  |  |  |  |  |  |  |  |
| Sardynki (porcja 100 g)                                                                               |  |  |  |  |  |  |  |
| Ostrygi (porcja 100 g)                                                                                |  |  |  |  |  |  |  |
| Tuńczyk (porcja 100 g)                                                                                |  |  |  |  |  |  |  |
| Dorsz (porcja 100 g)                                                                                  |  |  |  |  |  |  |  |
| Pstrąg (porcja 100 g)                                                                                 |  |  |  |  |  |  |  |
| Mintaj (porcja 100 g)                                                                                 |  |  |  |  |  |  |  |
| Owoce morza (porcja 100 g)                                                                            |  |  |  |  |  |  |  |
| Wątroba rybna (porcja 100 g)                                                                          |  |  |  |  |  |  |  |
| <b>JAJA</b>                                                                                           |  |  |  |  |  |  |  |
| <b>WARZYWA STRĄCZKOWE LUB POTRAWY Z NASION ROŚLIN STRĄCZKOWYCH (FASOLI, GROCHU, SOCZEWICY, SOI)</b>   |  |  |  |  |  |  |  |
| Fasola czerwona (średnia porcja)                                                                      |  |  |  |  |  |  |  |
| Soczewica (średnia porcja)                                                                            |  |  |  |  |  |  |  |
| Ciecierzycy (średnia porcja)                                                                          |  |  |  |  |  |  |  |

|                                                   |  |  |  |  |  |  |  |
|---------------------------------------------------|--|--|--|--|--|--|--|
| Groch (średnia porcja)                            |  |  |  |  |  |  |  |
| Soja (średnia porcja)                             |  |  |  |  |  |  |  |
| Tofu (średnia porcja)                             |  |  |  |  |  |  |  |
| Mleko sojowe (szklanka)                           |  |  |  |  |  |  |  |
| <b>ZIEMNIAKI (NIE WLICZAJĄC FRYTEK I CHIPSÓW)</b> |  |  |  |  |  |  |  |
| <b>OWOCE</b>                                      |  |  |  |  |  |  |  |
| Czarna porzeczka (garść)                          |  |  |  |  |  |  |  |
| Kiwi (sztuka)                                     |  |  |  |  |  |  |  |
| Pomarańcza (sztuka)                               |  |  |  |  |  |  |  |
| Mandarynka (sztuka)                               |  |  |  |  |  |  |  |
| Grejpfrut (połowa sztuki)                         |  |  |  |  |  |  |  |
| Banan (sztuka)                                    |  |  |  |  |  |  |  |
| Śliwki (sztuka)                                   |  |  |  |  |  |  |  |
| Brzoskwinia (sztuka)                              |  |  |  |  |  |  |  |
| Melon (plaster)                                   |  |  |  |  |  |  |  |
| Borówki (garść)                                   |  |  |  |  |  |  |  |
| Maliny (garść)                                    |  |  |  |  |  |  |  |
| Truskawki (5 sztuk)                               |  |  |  |  |  |  |  |
| Wiśnie (garść)                                    |  |  |  |  |  |  |  |
| Jagody goji (łyżka)                               |  |  |  |  |  |  |  |
| Figi suszone (sztuka)                             |  |  |  |  |  |  |  |
| Morele suszone (sztuka)                           |  |  |  |  |  |  |  |
| <b>WARZYWA</b>                                    |  |  |  |  |  |  |  |
| Marchew (średnia porcja)                          |  |  |  |  |  |  |  |
| Jarmuż (garść)                                    |  |  |  |  |  |  |  |
| Szpinak (garść)                                   |  |  |  |  |  |  |  |
| Natka pietruszki (łyżka)                          |  |  |  |  |  |  |  |
| Dynia (średnia porcja)                            |  |  |  |  |  |  |  |
| Cykorja (średnia porcja)                          |  |  |  |  |  |  |  |

|                                                                                                               |  |  |  |  |  |  |  |
|---------------------------------------------------------------------------------------------------------------|--|--|--|--|--|--|--|
| Brokuły (średnia porcja)                                                                                      |  |  |  |  |  |  |  |
| Bruselka (średnia porcja)                                                                                     |  |  |  |  |  |  |  |
| Kalarepa (średnia porcja)                                                                                     |  |  |  |  |  |  |  |
| Papryka czerwona (średnia porcja)                                                                             |  |  |  |  |  |  |  |
| Papryka żółta (średnia porcja)                                                                                |  |  |  |  |  |  |  |
| Szparagi (średnia porcja)                                                                                     |  |  |  |  |  |  |  |
| Awokado (średnia porcja)                                                                                      |  |  |  |  |  |  |  |
| Oliwki konserwowe (średnia porcja)                                                                            |  |  |  |  |  |  |  |
| Kiełki rzodkiewki / brokuła (łyżka)                                                                           |  |  |  |  |  |  |  |
| Salata / rukola (garść)                                                                                       |  |  |  |  |  |  |  |
| Cebula (średnia porcja)                                                                                       |  |  |  |  |  |  |  |
| Czosnek (średnia porcja)                                                                                      |  |  |  |  |  |  |  |
| Grzyby (średnia porcja)                                                                                       |  |  |  |  |  |  |  |
| Topinambur (średnia porcja)                                                                                   |  |  |  |  |  |  |  |
| Cykoria (średnia porcja)                                                                                      |  |  |  |  |  |  |  |
| <b>SŁODYCZE (CUKIERKI, CIASTKA, CIASTA, BATONY CZEKOLADOWE, BATONY TYPU „MUSLI” I IN. WYROBY CUKIERNICZE)</b> |  |  |  |  |  |  |  |
| Gorzka czekolada (3 kostki)                                                                                   |  |  |  |  |  |  |  |
| <b>ZUPY W PROSZKU LUB GOTOWE ZUPY (Z PUSZKI, SŁOIK, ZAGĘSZCZONE) NIE WLICZAJĄC ZUP MROŻONYCH</b>              |  |  |  |  |  |  |  |
| <b>KONSERWY MIĘSNE</b>                                                                                        |  |  |  |  |  |  |  |
| <b>KONSERWY WARZYWNE, WARZYWA MARYNOWANE LUB KISZONE</b>                                                      |  |  |  |  |  |  |  |
| <b>Kiszona kapusta</b>                                                                                        |  |  |  |  |  |  |  |
| <b>Kiszone ogórki</b>                                                                                         |  |  |  |  |  |  |  |
| <b>SOKI OWOCOWE</b>                                                                                           |  |  |  |  |  |  |  |
| <b>SOKI WARZYWNE LUB WARZYWNO- OWOCOWE</b>                                                                    |  |  |  |  |  |  |  |
| <b>Kwas chlebowy</b>                                                                                          |  |  |  |  |  |  |  |
| <b>GORĄCE NAPOJE (HERBATA, KAWA, NAPARY Z ZIOŁ LUB OWOCÓW)</b>                                                |  |  |  |  |  |  |  |



|                                                                                                         |  |  |  |  |  |  |  |
|---------------------------------------------------------------------------------------------------------|--|--|--|--|--|--|--|
| Napary ziołowe (szklanka)                                                                               |  |  |  |  |  |  |  |
| Kawa (filiżanka)                                                                                        |  |  |  |  |  |  |  |
| Herbata czarna (szklanka)                                                                               |  |  |  |  |  |  |  |
| Herbata zielona (szklanka)                                                                              |  |  |  |  |  |  |  |
| <b>SŁODZONE NAPOJE GAZOWANE LUB<br/>NIEGAZOWANE TYPU COCA-COLA, PEPSI,<br/>SPRITE, FANTA, LEMONIADA</b> |  |  |  |  |  |  |  |
| <b>NAPOJE ENERGETYZUJĄCE (RED BULL, SHOT,<br/>BLACK HORSE I IN.)</b>                                    |  |  |  |  |  |  |  |
| <b>WODA MINERALNĄ</b>                                                                                   |  |  |  |  |  |  |  |
| <b>WODA STOŁOWA, ŹRÓDLANA</b>                                                                           |  |  |  |  |  |  |  |
| <b>NAPOJE ALKOHOLOWE</b>                                                                                |  |  |  |  |  |  |  |
| Wino czerwone (lampka)                                                                                  |  |  |  |  |  |  |  |
| Wino białe (lampka)                                                                                     |  |  |  |  |  |  |  |
| Piwo (puszka/butelka)                                                                                   |  |  |  |  |  |  |  |
| Alkohol ciężki: wódka/brandy/whisky (kieliszek)                                                         |  |  |  |  |  |  |  |
| <b>Przyprawy / dodatki</b>                                                                              |  |  |  |  |  |  |  |
| Sól jodowana (Szczypta)                                                                                 |  |  |  |  |  |  |  |
| Pieprz czarny (Szczypta)                                                                                |  |  |  |  |  |  |  |
| Kurkumina (Szczypta)                                                                                    |  |  |  |  |  |  |  |
| Zioła inne (Szczypta)                                                                                   |  |  |  |  |  |  |  |
| Miód (łyżka)                                                                                            |  |  |  |  |  |  |  |

## Kwestionariusz do badania poglądów i zwyczajów żywieniowych oraz procedura opracowania danych (Część A. Zwyczaje żywieniowe)

Chcemy zapytać o Pana/Pani zwyczaje żywieniowe w ciągu ostatniego roku.

7. Ile posiłków spożywa Pan/Pani zazwyczaj w ciągu dnia?

Proszę wskazać jedną odpowiedź.

Posiłek – produkty żywnościowe lub ich zestawy spożywane zwyczajowo w określonych porach dnia, np. rano, w południe, wieczorem.

- (1) \_\_ 1 posiłek
- (2) \_\_ 2 posiłki
- (3) \_\_ 3 posiłki
- (4) \_\_ 4 posiłki
- (5) \_\_ 5 posiłków lub więcej

8. Czy spożywa Pan/Pani posiłki o stałych porach dnia?

Proszę wskazać jedną odpowiedź.

- (1) \_\_ Nie
- (2) \_\_ Tak, ale tylko niektóre
- (3) \_\_ Tak, wszystkie

9. Jak często spożywa Pan/Pani żywność (pojada) między posiłkami?

Proszę wskazać jedną odpowiedź.

Pojadanie (dojadanie) – okazjonalne spożywanie produktów lub zestawów produktów między posiłkami, przeważnie w niewielkich ilościach.

- (1) \_\_ Nigdy
- (2) \_\_ 1-3 razy w miesiącu
- (3) \_\_ Raz w tygodniu
- (4) \_\_ Kilka razy w tygodniu
- (5) \_\_ Raz dziennie
- (6) \_\_ Kilka razy w ciągu dni

*Pytanie skierowane do osób pojadających między posiłkami*

10. Jaką żywność spożywa Pan/Pani zazwyczaj między posiłkami w dni powszednie?

Można wskazać dowolną liczbę odpowiedzi.

- (10/1) \_\_ Owoce
- (10/2) \_\_ Warzywa
- (10/3) \_\_ Niesłodzone napoje i desery mleczne, np. jogurty, serki twarogowe, mleko
- (10/4) \_\_ Słodzone napoje i desery mleczne, np. serki homogenizowane, napoje mleczne słodzone, mleko smakowe
- (10/5) \_\_ Słodkie przekąski, np. cukierki, ciastka, ciasta, batony czekoladowe, batony typu 'musli', wafle
- (10/6) \_\_ Słone przekąski, np. krakersy, paluszki, chipsy, frytki
- (10/7) \_\_ Orzechy, migdały, nasiona, pestki
- (10/8) \_\_ Inne produkty, proszę wymienić jakie? .....

11. Jakie mleko i napoje mleczne spożywa Pan/Pani najczęściej?

Proszę wskazać jedną odpowiedź.

- (1) \_\_ O standardowej zawartości tłuszczu (pełnotłuste)
- (2) \_\_ O obniżonej zawartości tłuszczu

(3) ☐ Bez tłuszczu

12. Jak przygotowane potrawy mięsne spożywa Pan/Pani zazwyczaj?

Można wskazać dowolną liczbę odpowiedzi.

- (1) ☐ Gotowane
- (2) ☐ Duszone
- (3) ☐ Grillowane
- (4) ☐ Pieczone
- (5) ☐ Smażone
- (6) ☐ Nie jadam mięsa

13. Jakiego tłuszczu do smarowania pieczywa używa Pan/Pani najczęściej?

Proszę wskazać jedną odpowiedź.

- (1) ☐ Nie używam żadnego tłuszczu do smarowania pieczywa
- (2) ☐ Stosuję różne tłuszcze
- (3) ☐ Majonez
- (4) ☐ Margaryna
- (5) ☐ Masło
- (6) ☐ Mix masła z margaryną
- (7) ☐ Smalec

14. Jakiego tłuszczu do smażenia potraw używa Pan/Pani najczęściej?

Proszę wskazać jedną odpowiedź.

- (1) ☐ Nie stosuję żadnego tłuszczu do smażenia potraw
- (2) ☐ Stosuję różne tłuszcze
- (3) ☐ Olej roślinny (w tym oliwa z oliwek)
- (4) ☐ Margaryna
- (5) ☐ Masło
- (6) ☐ Smalec

15. Czy słodzi Pan/Pani gorące napoje, np. herbatę, kakao, kawę?

Proszę wskazać jedną odpowiedź.

Jeśli ma Pan/Pani inny zwyczaj słodzenia np. kawy i herbaty, to proszę opisać słodzenie tego napoju, którego więcej Pan/Pani wypija w ciągu typowego dnia.

- (1) ☐ Nie
- (2) ☐ Tak, słodzę jedną łyżeczką cukru (lub miodu)
- (3) ☐ Tak, słodzę dwiema lub więcej łyżeczkami cukru (lub miodu)
- (4) ☐ Tak, używam słodzików (niskoenergetycznych substancji słodzących)

16. Czy dosala Pan/Pani gotowe potrawy i kanapki przy stole?

Proszę wskazać jedną odpowiedź.

- (1) ☐ Nie
- (2) ☐ Tak, ale tylko czasami
- (3) ☐ Tak, dosalam większość potraw

17. Jaką wodę pije Pan/Pani zazwyczaj?

Można wskazać dowolną liczbę odpowiedzi.

- (1) ☐ Nie piję wody
- (2) ☐ Piję wodę niegazowaną
- (3) ☐ Piję wodę gazowaną
- (4) ☐ Piję wodę z dodatkami smakowymi

*Proszę sobie przypomnieć swój typowy pod względem odżywiania dzień w ostatnim tygodniu, a następnie odpowiedzieć na kolejne pytania.*

18. Jaki to był dzień tygodnia?

Można wskazać jedną odpowiedź.

- (1) ☐ Poniedziałek
- (2) ☐ Wtorek
- (3) ☐ Środa
- (4) ☐ Czwartek
- (5) ☐ Piątek
- (6) ☐ Sobota
- (7) ☐ Niedziela

19. Ile posiłków zjadł(a) Pan/Pani w tym dniu? Proszę wpisać liczbę ..... posiłków w tym dniu  
Posiłek – produkty żywnościowe lub ich zestawy spożywane zwyczajowo w określonych porach dnia, np. rano, w południe, wieczorem.

20. Ile razy zjadł(a) Pan/Pani w tym dniu warzywa lub owoce? Proszę wpisać liczbę ..... razy w tym dniu

Proszę uwzględnić spożycie w posiłkach i między posiłkami.

21. Czy zjadł(a) Pan/Pani w tym dniu żywność typu fast food, np. frytki, hamburgery, pizzę, hot dogi, zapiekanki?

- (1) ☐ Nie
- (2) ☐ Tak. Ile razy? Proszę wpisać liczbę ..... razy w tym dniu