Akademia Wychowania Fizycznego i Sportu

im. Jędrzeja Śniadeckiego w Gdańsku

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BIOLOGICAL EVALUATION IN SPORT PERFORMANCE DURING CHILDHOOD: AN ALLOMETRIC APPROACH

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Gdańsk 2021

TABLE OF CONTENT

INTRODUCTION
WPROWADZENIE

The study of the diversity and evolution of living organisms, understood in its Darwinian sense as "descendant with modification" (Darwin, 1859), represents modern evolutionary biology's fundamental topic. Indeed, body mass alone cannot describe human body shape without accounting for stature. As a result, recognizing the mathematical formulation that accurately normalizes body mass by height has been of long-standing interest. Measurements in physiology and sport science are frequently recorded per-body mass (m) or per-surface area ratio standards, e.g. maximum oxygen uptake ($ml.kg^{-1}min^{-1}$) or peak power per cross-sectional area of muscle ($W \bullet cm^{-2}$). These simple-ratio standards have been used to facilitate the assessment of measurements recorded from individuals of different body-sizes. Isolating by an "appropriate" body size variable, it is assumed that will have removed differences in the physiological variable due to the subject's size will have been removed. Hence, the scaled physiological performance variables are supposed to be independent of the subjects' body size.

More measurements, for example, maximum oxygen uptake (in l/min) and peak and mean power (in W), are known to vary with the subject's body size. These simple ratio standards have been subject to much criticism by authors such as Tanner (1949), Katch (1973), Katch and Katch (1974) and more recently by Armstrong and Welsman (2019), Giuriato et al, (2020), Carnevale Pellino et al, (2020), Nevill et al, (1992), Nevill et al (2019). These authors' criticism is based on several observations. When simple ratio standards, e.g. maximum oxygen uptake ($ml \bullet kg^{-1} \bullet min^{-1}$), are associated with body size dimensions, e.g. body mass (kg), establishing a negative correlation. Simple ratio standards fail to produce a dimensionless physiological performance variable. In contrast, it would appear that these simple ratio-standards "over-scale" by converting the positive correlation, between the physiological performance variable and the body size variable, to a negative one. Secondly, it is assumed that the relationship between the two ratio-variables is linear and then claim that if the model that describes this relationship is a real linear proportion, then the least-squares linear regression line should pass nearly, if not through, the origin. In light of this, some authors propose using an additive adjustment, based on the regression line, to correct the numerator variable for differences in the body-size denominator variable (Katch and Katch, 1974). Furthermore, Armstrong and Welsman (2019) suggest that the evidence-based on this assumption was simplistic to describe aerobic fitness concerning a single morphological covariate (body mass).

Further, it suggested that aerobic fitness development analyses must take account of age and sex-specific, maturation-driven changes in Fat-Free Mass, governing by biological characteristics of individuals. A 10-years observational study in Italian children considers BMI as categorical variables suggesting that Italian physical fitness levels flatlined rather than actual. Performance in flexibility and strength of lower limb, endurance, and speed still maintained in this decade (Lovecchio et al, 2020). Authors suggest that BMI particularly underestimates the extent of the obesity prevalence, irrespective of what cut-off values are employed cut-off in children (McCarthy et al. 2003; Griffith et al. 2012; Nevill and Metsios, 2015). Authors suggested that BMI not replicate the changes in body composition in accord with particularly the presence of sarcopenia, weight/ height^2 does not capture any aspect of adiposity that is missed by body mass. Weight/height^2 is no more than a deterministic function of 2 measured variables. BMI is a parameter that summarising two variables and not represent a proper predictor of authentic performance (Lovecchio and Zago, 2019; Giuriato et al, 2020). Indeed, growth does not reflect parallel increases in this developmental pattern; while height increases by 3–4% per year, body mass increases by 8–10% (Cole et al, 2012). Furthermore, a commonly used ratio scaling—the power-to-body mass ratio may be a misleading index (Armstrong and Welsman, 2019). In light of this, Nevill et al (2009), suggesting that body size refers to the physical magnitude of the body and its segments (stature, mass, surface area, etc.). Body structure or shape describes the distribution of body parts expressed as ratios, such as the body mass index (BMI) or the head length-to-body length (exclusive of head) ratio. Mosimann (1970) (introduced the concept of body shape, defined it, the ratio of two body dimensions measured in the same units that would yield a "dimensionless" ratio variable reflecting body shape. The authors argued that certain body size/shapes are more suitable for specific sports and less prone to injury, contrasting, for example, the physique of a rugby player with a marathon runner and a basketball player's physique that of a gymnast. Nevill and Holder (1995) introduced an innovative approach based on allometric modeling. In light of this, Nevill et al. (2009) concluded that allometric models allow identifying the most appropriate body size and shape indices related to motor performance and providing valid inferences in the investigation of group differences.

Scaling models and statistical methods

Some authors describe the scaling model (Tanner 1949; Katch 1973; Katch and Katch 1974; Nevill et al, 1992a) were all presented without reference to the errors associated with each model. However, different scaling methods will make quite different assumptions concerning the relationship between the physiological performance variable Y_i, the appropriate body size variable $X_{i,}$ and their associated residual errors.

(i) The simple ratio standard (Y_i/X_i) implies the following mathematical relationship between the physiological performance and the body size variables (Nevill et al, 1992b),

$$Yi=a \bullet X_i + e_i \qquad (1)$$

where e_i is an additive error term. The model assumptions, given in Eq. 1, assume the groups' ratio standard parameter a is calculated using least-squares linear regression but by omitting the in-intercept constant.

(ii) The least-squares linear adjustment method of scaling assumes the following model (Nevill et al, 1992b):

$$Y_i=a + b \bullet X_i + e_i \qquad (2)$$

where e_i denotes the residual errors from the least-squares regression line of best fit. Similar to the simple ratio standard model, least-squares, linear regression assumes a constant error term throughout the range of Y_i and X_i's variables. An assumption that would appear questionable when modelling human performance variables was recorded from different body size subjects. Linear model with an additive error term, the residual errors are obtained by rearranging Eq. 1 (Nevill et al, 1992b):

$$e_i= Y_i - a - bX_i$$

The method of adjustment, outlined by Katch and Katch (1974), requires this residual error to be added to the group's arithmetic mean, i.e., Y + e_i, to represent the individual's "adjusted" or scaled score.

(iii) The power function ratio standard (Y_i/X_i^b) assumes the following model between the physiological performance variable (Y_i) and the body size variable (X_i) (Nevill et al, 1992b)

$$Y_i= a \bullet X_i^b \bullet e_i \qquad (3)$$

where e_i is a multiplicative error ratio term. This multiplicative error term is a particularly attractive feature of this model since it will accommodate a spread in the subjects' Y~and Xi values when plotted against each other, provided these scores diverge at a constant proportion to each other. The parameters *a* and *b* are obtained assuming a log-linear model, i.e. by taking logs of Eq. 3 and fitting the least-squares regression line to $\log(Y_i)$ using $\log(X_i)$ as the predictor variable (Nevill et al, 1992b),

$$\log (Y_i) = \log (a) + b \bullet \log (Xi) + \log (e_i) \tag{4}$$

The residual error ratios are obtained by re-arranging Eq. 3 to obtain (Nevill et al, 1992b)

$$e_i = Y_i / (a \bullet X_i^b) = (Y_i / X_i^b) / a \tag{5}$$

Hence, the power function of best fit suggests that the appropriate scaling method should be the power function ratio standard Y_i / X_i^b, a familiar equation to supporters of the simple ratio standard when the power function parameter equals unity (i.e. b=l).

Allometric approach and statistical analyses

It is common knowledge that larger people expend more energy than smaller people due to their higher energy cost of metabolism and movement. However, suppose energy expenditure is expressed as a simple ratio standard, per unit body mass. In that case, smaller people consume more energy per unit body mass than larger people, i.e., by dividing by body mass, the energy expenditure will have been over adjusted/ scaled. This assumption is in accord with scaling methods (Tanner, 1949). An alternative allometric or power function model, $Y= aX^{\beta}\in$, was initially proposed to describe the relationship between the physiological performance variable (Y) and body size variable (X), the simple ratio standard (when the exponent $\beta = 1$) being a particular case (Kleiber, 1950). For these models, both the variables and errors assuming to be proportional. An assumption that would appear to be appropriate, based on numerous examples that the error variation seems to increase in proportion to the response variable, contradicting the usual linear regression assumption of a constant error variance (Nevill and Holder, 1995, 2000).

Based on the power function model, $Y = aX^{\beta}\in$, Nevill et al. (1992a,b) introduced the term \power function ratio standard," defined as $(YX^{-\beta})$, to adjust a subject's physiological performance variable (Y) for body size as measured by the variable (X). The power function model can be linearized with a log-transformation (i.e., $\log_e(Y) = \log_e(a) + \beta\log_e (X) + \log_e(\in)$, where $\log_e(a)$ and β are the intercept and linear slope parameters, respectively), and standard linear regression analysis can be used to estimate the unknown parameters, provided the log of the error term, $\log_e(\in)$, is independent and has a normal distribution with constant variance. In humans, there is strong evidence to suggest that the muscle mass of both the arms and legs increases at a greater proportion to body mass than that expected by geometric similarity (Nevill et al., 2019). Under such circumstances, body-mass power functions may be unable to accurately describe physiological variables associated with muscle mass, i.e., incapable of providing unbiased parameter estimates. For these reasons, more flexible allometric models may be required. Nevill et al. (2009), to investigate the most appropriate body-size characteristics associated with a variety of physical performance variables, we adopted the following proportional, multiplicative model with allometric body size components,

$$Y = mass^{k_1} \cdot height^{k_2} \cdot \exp(a + b\ age + c\ age^2) \cdot \varepsilon \ (1)$$

This model has the advantages of having proportional body size components (most physical performance variables are known to vary proportionally with body size and shape). Flexibility of a quadratic in age within an exponential term that will ensure that Y will always remain non-negative irrespective of the subjects' age. Note that "ε," the multiplicative error ratio, also assumes the error will increase in proportion to Y's physical performance variable.

The model (Eq. 1) can be linearized with a log transformation. A linear regression analysis on log(Y) can then be used to estimate the unknown parameters of the log-transformed model:

$$\log(Y) = k_1 \cdot \log(height) + k_2 \cdot \log(mass) + a + b \cdot age + c \cdot age^2 + \log(\varepsilon) \ (2)$$

Further categorical or group differences within the population (e.g., sex and maturation) can easily be explored by allowing some of the parameters, for example, the constant parameter "a", in the log-transformed model to vary for each group (by introducing fixed indicator variables or fixed factors in an ANCOVA). Each model, reporting the coefficient of determination, R^2, to indicate the explained variance achieved by the variable height, mass, age, sex and maturation status. Proportional allometric models with multiplicative errors were shown to be superior to linear or additive polynomial models for various reasons (Nevill et al, 2005), including provide: i) biologically interpretable models that should consider interpreting carefully because human physiques are not being geometrically similar to each other. ii) Allometric models will provide sensible estimates within and beyond the range of data. iii) They also provide a superior fit, based on maximum log-likelihood criteria (i.e., a smaller error variance), that will naturally lead to iv) a more powerful ANCOVA test of significance. v) ANCOVA leads to more correct conclusions when investigating population (epidemiological) or experimental differences between groups.

MATERIAL AND METHODS

METODOLOGIA BADAŃ WŁASNYCH

1. **Problem of the study, research question and hypothesis**
1. **Problem pracy, pytania i hipotezy badawcze**

Physiological parameter

Aerobic evaluation in accord with allometric

The evaluation of the physical fitness in children and adolescent in the last decades become crucial to defining the health status of the population (Penedo and Dahn, 2005) due to the strong association between the high level of physical performance and the healthy condition of the person (Harsha, 1995). Indeed, it has been confirmed that regular physical activity leads to improvements in physiological and psychological health with essential outcomes for disease prevention (Hesketh et al, 2014). In light of this, aerobic efficiency is considered an indirect expression of the cardiorespiratory-system functions, which in turn is the most critical condition for long- term health status (Byrne et al, 2018).
Allometric scaling has confronted the 'convenient and traditional' (Bar-Or and Rowland 2004) interpretation of data and showing, in contrast with ratio scaling, that with body mass appropriately measured for, there is a progressive increase in youth peak VO with age in both sex (Welsman et al. 1996). However, it is the emergence (Aitkin et al. 1981) and regular refinement (Rasbash et al., 2018) of multilevel regression modelling which has opened up new analytical approaches to developmental exercise physiology. Multilevel modelling enables the effects of variables such as age, body mass, Fat-Free Mass, and maturity status to be partitioned concurrently within an allometric framework to provide a flexible and sensitive interpretation of exercise performance variables. In contrast to traditional methods that require a complete longitudinal data set, both the number of observations per individual and the comments' temporal spacing may vary within a multilevel model: an innovative re-analysis of previously published data of elite youth athletes. Nevill et al. (1998) introduced multiplicative, allometric modelling to paediatric sport science and w. Thent authors applied it to interpreting growth and maturation changes in peak oxygen uptake from 11–13 years (Armstrong et al. 1999).

Motor Ability Evaluation

Strength evaluation in accord with allometric

Muscle strength testing is commonly used to evaluate, assess, and compare data regarding muscle function in athletic, clinical, and rehabilitation settings. The ability to compare muscle strength between and within groups is important in research as well. Strength testing results are commonly confounded by body size, and inconsistencies can arise when strength data are non-normalised for body size or normalised using inappropriate methods (Jaric 2002, 2003). Allometric scaling is based on the theory of geometric similarity, which holds that all humans have the same shape and differ only in size (Astrand and Rodahl 1986; Jaric et al. 2005). More specifically, limb lengths are proportional to body height (L), and all areas are proportional to L^2, whereas all volumes and volume-associated indices, such as body mass, are proportional to L^3. As such, muscle Cross Sectional Area is proportional to Body $\text{Mass}^{2/3}$. Alternatively, any muscle CSA is directly proportional to the strength/force produced by that muscle. However, these assumptions may be confounded by other factors such as body composition, fibre type distribution, muscle fibre pennation angle, distances of the tendon insertion from the centre of rotation of the joint, and limitations inherent in measures of CSA compared with muscle volume. The issues identified above have been extensively reviewed by Bruce et al. (1997). Allometric scaling models use log-linear or other regression models to remove the potential confounders of differences in Body Mass, Fat-Free Mass or CSA. However, allometric scaling models must be carefully evaluated for appropriateness of fit using regression diagnostics (Batterham and George 1997; Nevill and Holder 1995, 2000). Based on limited evidence, it has been suggested that increased adiposity may impair muscle function and strength. Several studies have shown that obese individuals demonstrate significantly lower muscle strength or power even after allometric scaling of strength/power measures using BM as the scaling variable (Pescatello et al., 2007)

Agility evaluation in accord with allometric

Agility (ability to rapidly changing body direction and position in the horizontal plane) and dribbling speed (sprinting while controlling the ball) are central components in the development of talented youth soccer players (Huijgen et al, 2010). Playing position also impacts agility performance in youth soccer match play (Buchheit et al, 2010). In light of this, Coelho e Silva et al, (2010) suggested that soccer players who are 'advanced' in maturation tend to be taller, heavier, healthier, more powerful and faster than players who are 'later' in development. The influence of variation in body size and maturation on soccer-specific skills is less documented, and trends are not as consistent for functional capacities (Figueiredo et al, 2009). Multilevel modelling (Goldstein, 1995) is appropriate for the analysing of longitudinal observations, i.e., repeated measurements. It is suggested that allometric rather than additive models would provide a superior fit and more plausible interpretation of such longitudinal data (Nevill et al, 1998). In literature exist few studies about agility and allometric model. One of these suggested that based on the multilevel models with best statistical fit, the results indicate that an increase in 1kg in Fat Free Mass was associated with improved agility performance by 5%, when body size, and body composition are controlled regardless of playing position. There also appears to be an independent training effect; each one h of additional training per week over the competitive season (~40-weeks) was associated with a 3% improvement in dribbling speed performance when stature and SA are controlled.

Aim of the Thesis

Studies presented the development of methods that allowed to investigate performance changes through an allometric model. Outcomes of the proposed studies have exact scientific value and practical application. The presented research gives necessary knowledge regard following aspects:

1) Enjoyment and self-reported physical competence
2) Anthropometric characteristics and factors that influence aerobic performance
3) Anthropometric characteristics and factors that influence strength outcomes
4) Analyse growth and physical activity through allometric model

In practical application performed investigations may be useful in:

1) Training and planning
2) Designing training regimes for athletes and school children
3) Evaluation of the real progression in performance
4) Research of talent

Further, the allometric model provides special attention to growth fluctuations, which become important to avoid bad judgment in case children will be poorly assesed: the cause could be due to the natural growth path and not for lack of physical activity, in accord with literature (Armstrong et al, 1999; Beunen et al, 2002; Nevill and Holder, 1995). Furthermore, find cut-off to intercept right athletic perspective. The findings about Japanese, North African, and even in Greek children

(Tanaka and Matsuura, 1982; Chaouachi et al, 2005; Nevill et al, 2009) suggesting that an allometric model is an excellent approach to scaling aerobic performance outcomes. The allometric model offers the optimal shape associated with anthropometric characteristics and other factors, such as physical activity, sport, and performance outcomes.

Further, suggest some practical applications during the early stage of life, i.e. the trainer/ PE teacher during childhood should be aware of the absence/presence of differences between sex during childhood. Coaches should adopt a test and sample-specific scaling model based on anthropometric characteristics rather than theoretical models based on the assumption of body dimension similarity. This method is useful for first analyses, but the growth does not respect linear trend. Then a robust approach is necessary, such as the only age cluster-imposed thoughts about homogeneous CNS maturation.

Research tried to provide information on strength status in adolescents to perform better in speed-agility and explosive strength.

2. **Test procedure**
2. **Procedura badań**

STUDY 1. Enjoyment and self-reported physical competence according to Body Mass Index: international study in European primary school children.

Giuriato M, Lovecchio N, Fugiel J, Lopez Sanchez GF, Pihu M, Emeljanovas A. J Sports Med Phys Fitness. 2020;60(7):1049-1055. doi:10.23736/S0022-4707.20.10550-4

Material and Methods

A total sample of 1999 children aged 8–11 years (girls = 998; boys = 1001) attending primary school in five different countries (Italy, Spain, Poland, Lithuania, Estonia) were involved in a cross-sectional study at the begin of the second month of the next scholastic years (September or October according to the different local inter-province plane). All family gave their informed consent and volunteered to take part in the protocol during school hour. Children provided written assents after a specification that the agreement in this survey was free and no extra academic credits were awarded for participation, according to the Declaration of Helsinki. All subjects completed anthropometric measure to determine BMI according to the standard procedures described by the International Society for the Advancement of Kinanthropometry (Marfell-Jones et al., 2006). Further, all subjects have compiled two questionnaires:
Physical Activity Enjoyment Scale (PACES) revised by Motl et al. (2001). As reported in this children version questionnaire (Moore et al., 2009) the responses were indicated on a Likert-scale ranging from strongly disagree (1) to agree (5) strongly. The questionnaire (16 items) provided an overall rating of enjoyment (EN) of the Physical Education (PE) lesson. Indeed, after reverse scoring, the seven negatively worded item, a unidimensional measure of EN for physical activity is determined by summing the things (Motl et al., 2001), with a range of 16–80 being possible. Thus, higher PACES scores reflect more significant levels of EN.

International Fitness Scale (IFIS): It is a self-reported fitness scale validated initially in nine European countries and languages (Ortega et al., 2013). The IFIS comprises 5 Likert-scale questions (very poor, poor, average, good, and very good) focused on five fitness areas: general fitness, cardiorespiratory, strength, speed-agility and flexibility. The IFIS had high validity and moderate-to-good reliability (average weighted Kappa: 0.70 and 0.59) respectively, for children

(Sánchez-López et al., 2015) and university students (Ortega et al., 2013). In particular, the questionnaire was administrated, in the classroom, ten minutes before the transfer into changing room.

Procedure

The researchers collected the data at the end of 55-minute PE lessons, typically held in the school gym under the baton of the curricular PE teacher.

The participants were to told ask for help if confused concerning the clarity of particular items. To minimize students' tendency to give socially desirable responses, students were encouraged to answer honestly and were assured that their scores would be kept confidential.

	BMI%	8 years	9 years	10 years	11years
F	**UW**	8	7	12	16
	NW	79	72	69	74
	OW	10	16	18	9
	OB	4	4	1	1
M	**UW**	12	9	7	17
	NW	74	66	73	68
	OW	10	16	16	14
	OB	4	8	4	0

Table 1 Percentage of children belonged to the four BMI categories

Results

Enjoyment and Body Mass Index

PACES questionnaire revealed a general score of 50.96 with 0.1 points of difference between boys and girls. Considering the age stage he mean score of PACES waswas65, 50.77, 50.09 and 50.92, respectively from 8 to 11 years old. On average, the s 1 (enjoy) showed the highest mean value for males and female ANCOVA showed significant differences for age ($p = .011$) with enjoyment (PACES) as dependent variable but not between sex ($p = .956$) and BMI categories ($p = .161$; ES very close to 0.1; figure 1). Enjoyment level obtained by the different BMI groups (no differences found by Prochaska et al., 2003) indicates that the positive experience during physical education goes beyond/overcame the personal characteristics (sex and anthropometry). This is a good point for physical education teacher and trainer to plan the activity without restriction criteria due to sex and status, at least in childhood. Indeed, as previously demonstrated by Lovecchio and Zago (2019) the adoption of strategies avoidant the endurance the physical level become very similar in students (pre-adolescent) of different BMI categories. This trend is worth of a circular rationale: enjoyment decrease in same time of BMI increase (Table 1). The variation of BMI status in turn leads to a decrement for enjoyment and then a returning to a scantly adherence to physical activity (Hashim et al., 2008; Ntoumanis et al, 2004).

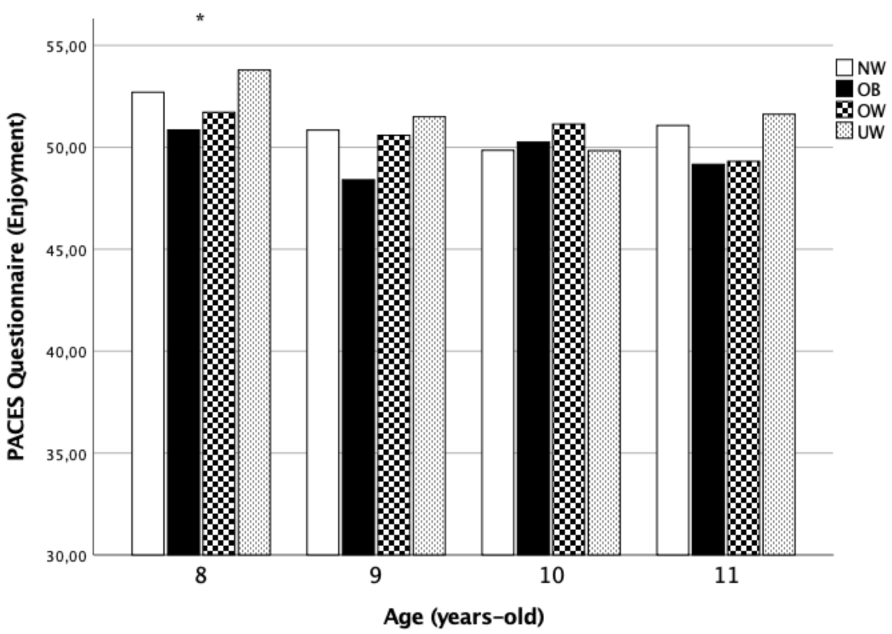

Figure 1 Enjoyment questionnaire (PACES) per age and BMI categories

** 8 years old group was significantly higher than the other group; p<0.05*

Fitness competence and Body Mass Index

IFIS revealed a different trend between boys and girls. Boys in general expressed value equal to zero while 1.20% of girls reported a value of 1 in the items n. 1 (general fitness). Only, 71 boys and 68 girls reported a full value of fitness competence (value of 5). The perceived fitness competence decreased from 8 to 11 years: boys reported a mean value of 4.10 at 8 years while 3.92 at 11. Girls, instead, varied their own reports from 4.07 to 4.01. From an anthropometric point of view the percentage of NW, OW, UW and OB are reported in Table 1 stratified for to age and sex: the NW category represented the biggest.

Within the IFIS as dependent variable the covariate analysis of the variance showed significant differences for BMI categories (p< .001; Figure 2) while no differences were found within sex (p= .995) and age (p= .531; figure 2). In particular, post-hoc test showed significative difference between NW versus OW (p< .001; ES=0.27) and OB (p= .013; ES = 0.36); and between UW versus OW (p= .021) and OB (p= .005; figure 2).

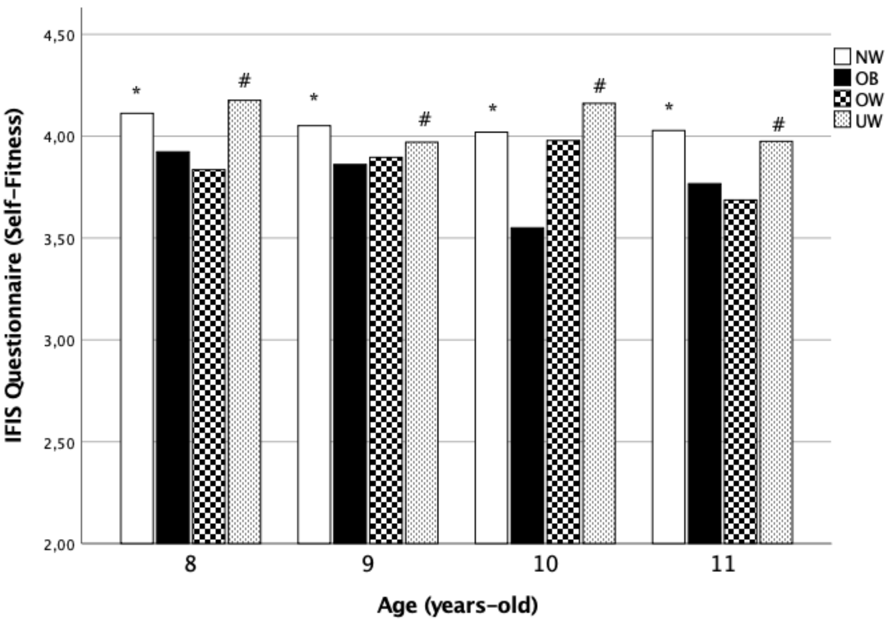

Figure 2 Self Efficacy questionnaire (IFIS) per age and BMI categories

** Normal-Weight group expressed significantly higher values than Overweight and Obese children (p<0.005) following the age stages group.*
 # Underweight groups were higher than Overweight and Obese children (p<0.005)

The variation of BMI status in turn leads to a decrement in the perceived personal competence (IFIS, fig. 2) that is, as declared by Wallhead and Ntoumanis (2004) and Teques et al. (2017), a crucial source (intrinsic motivations). Physical activity, in school or during free time, could be magic if collected the unreserved adherence of all children to enjoyment derived from become a responsibility of the teachers/trainers. In primary, schools the enhanced enjoyment lead to improvements in the intrinsic motivation that constitute the most self-determined behavioural regulations as individuals engage in exercise (Wilson and Rodgers, 2007) and self-perceived competence (Carissimi et al., 2017; Craft et al., 2003).

STUDY 2. Identifying the optimal body shape and composition associated with strength outcomes in children and adolescent according to place of residence: An allometric approach.

Lovecchio N, **Giuriato M**, Zago M, Nevill A.
J Sports Sci. 2019;37(12):1434-1441. doi:10.1080/02640414.2018.1562615

Material and Methods

A total of 7102 junior high school children (3058 boys; 4044 girls) aged 11–14 years living in an urban or rural area of norther Italy volunteered to participate in the study. Inclusion criteria were: no history of illness potentially affecting growth; no neurological, orthopedic or cardiovascular diseases; active participation in physical education (PE) classes. Children found in good general health were deemed eligible. The parents (or legal guardians) gave written, informed consent after having received a detailed explanation of the study procedure and possible risks in accordance with the Declaration of Helsinki (as revised in 1983) and after approval of the regional office of Ministry of Education (drlo-09–1516; Prot. EF-230). Anthropometric characteristics of the children by sex and place of residence (urban or rural) are given in Table 2.

Anthropometric characteristics

Anthropometric measurements of height and body mass were taken according to standard procedures described by the International Society for the Advancement of Kinanthropometry (Clarys et al., 2006) BMI was then calculated. The percentage of FM (FM%) was estimated using skinfolds (known to be associated with body fatness in young people; Boeke et al., 1993; Duren et al., 2008). Skinfold thickness were measured in triplicate to the nearest 0.1 cm at the triceps and subscapular crest (Heymsfield et al, 2005) with Harpenden calipers (HSK-BI, British Indicators, Weybridge, UK). The percentage of FM (FM%) was then determined using the formula proposed by Blaha and Vignerova (2002) and Carter (2002):

Boys FM= 0.735 · (triceps skinfold + subscapularis skinfold) +1

Girls FM= 0.61 · (triceps skinfold + subscapularis skinfold) + 1

Place of residence

The classification of urban and rural was based on the criteria suggested by Pokos (2002) and Tsimeas et al. (2005) as indicated by the United Nation (2002): towns with a population of 10.000 or more were classified as urban, towns with less than 10.000 was classified as rural.

Physical fitness tests

Three tests were selected from a reliable and valid battery of physical fitness tests (Council of Europe, 1998; Kemper and Van Mechelen, 1996; Ruiz et al., 2011; Tomkinson et al, 2007): *Standing Broad Jump* (SBJ), *Sit-Ups* (SUP) and *Sit and Reach* (SAR) were performed to define explosive strength, the endurance strength and flexibility of the hamstring and the spine muscles; respectively.

Statistical analyses

The multiplicative model (Equation 1) with allometric body-size components was used to identify the most appropriate body size and shape characteristics associated with, as well as detect any categorical differences (e.g., sex, age, place of residence urban vs. rural) in, two physical performance variables (SBJ and the number of sit-ups performed in 30 s (SUP30). The model is similar to that used to predict the physical performance vari- ables of Greek children (Nevill et al., 2009).

$$Y= a \cdot mass^{k1} \cdot height^{k2} \cdot \varepsilon \qquad (1)$$

The model has the advantage of having proportional body- size components and a multiplicative error that assumes, ε, will increase proportionally with the physical performance variable Y.

The model (Equation 1) can be expanded to incorporate FM % and SAR as follows;

$$Y= a \cdot mass^{k1} \cdot height^{k2} \cdot FM\%^{k3} \cdot \exp(b \cdot FM + c \cdot SAR) \cdot \varepsilon \qquad (2)$$

Results

Standing broad jump in accord with allometric approach

The estimated allometric parameters from the two multiplicative models relating the SBJ distance to the body-size components in Equation 1, and the model Equation 2 incorporating FM% and SAR, are given in Table 2. The multiplicative model (Equation 1) relating the SBJ distance to the body-size components for SBJ was:

$$\text{SBJ distance(cm)} = a \cdot \text{mass}^{-0.357} \cdot \text{height}^{1.302}$$

With a positive height and a negative mass exponent, the model suggested the optimal body-size height-to-mass ratio associated with SBJ is approximately the reciprocal ponderal index (RPI) = height $\cdot$mass$^{-0.333}$.

Fitting Model (Equation 1) revealed significant differences in the constant "a" parameter due to sex ($P < 0.001$), age ($P < 0.001$) and by place of residence (urban vs. rural) ($P < 0.05$), together with two interactions between the categorical variables age and sex ($P < 0.001$; Figure 3 and age and place of residence ($P < 0.01$; Figure 4).

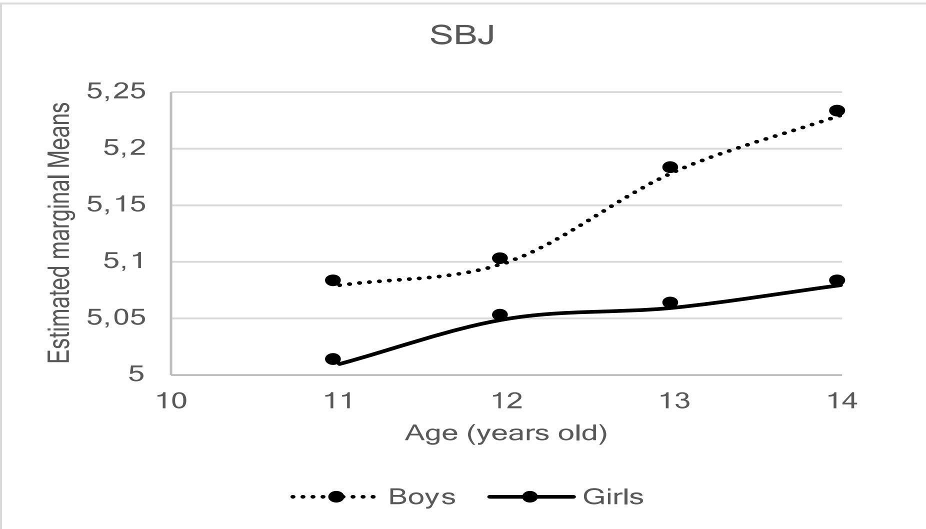

Figure 3 Interaction between sex and age on lower limb strength (SBJ test). Covariates appearing in the model are evaluated at following values: lnMass= 3.9674, lnHt= 5.0781

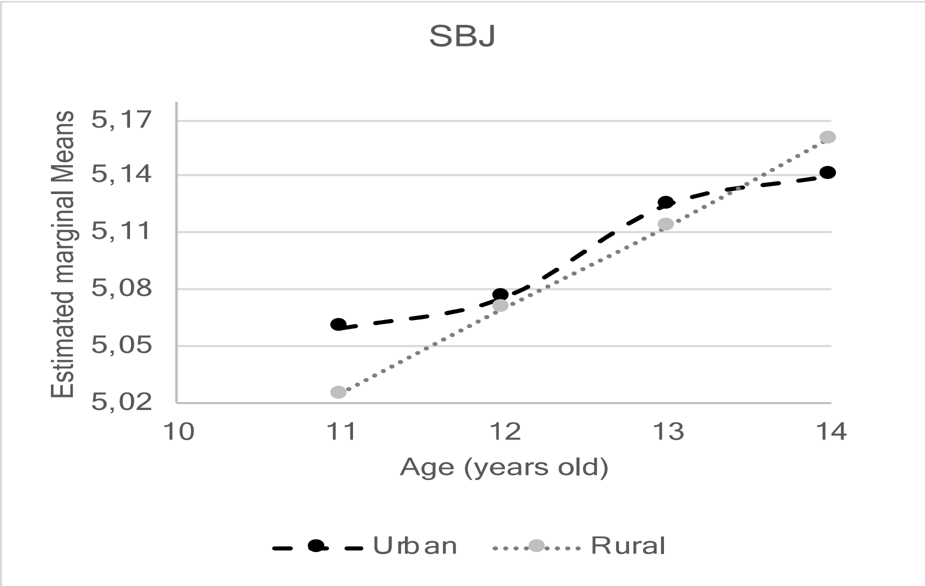

Figure 4 Interaction between place of residence (urban, rural) and age on lower limb strength (SBJ test). Covariates appearing in the model are evaluated at following values: lnMass= 3.9674, lnHt= 5.0781

As soon as the terms FM% and SAR terms were incorporated into Model (Equation 2) to predict SBJ distance, the dominance of the negative body-mass term was replaced by the more sensitive fat-mass (%) terms, entered as a gamma function. The model predicts a small initial rise, but then an overall decline in SBJ with greater FM%. Differential calculus reveals that peak SBJ occurs at FM % = -(0.158–0.072)/(−0.015) = 5.7% in boys and FM% = −0.158/ (−0.015) = 10.7% in girls based on the estimated gamma function terms (See T-score in Table 2).

Model	Parameters	B	SE	Lower Bound	Upper Bound	T-score
Eq.1	**lnMass**	-.357	.010	-.378	-.337	-34.4
	lnHt	1.302	.045	1.213	1.390	28.9
	R Squared = .316 (Adjusted R Squared = .314)					
Eq.2	**lnMass**	.051	.019	.013	.089	2.6
	lnHt	.398	.056	.289	.508	7.1
	LnFAT%	.158	.015	.128	.188	10.2
	Male * LnFAT%	-.072	.008	-.088	-.056	-8.9
	FAT%	-.015	.001	-.016	-.013	-18.9
	SAR	.0030	.0002	.0026	.0034	15.5
	R Squared = .397 (Adjusted R Squared = .395)					

Table 2 Estimated allometric parameters from the multiplicative models relating SBJ distance to body-size components in Eq1, and model that incorporating the additional terms FM% and SAR in Eq2

Allometric model including height, body mass, and performance test

Note that the sit-and-reach (SAR) test results are positively associated with log-transformed SBJ performance, see Table 2. The effect of incorporating FM% and SAR into the Model (Equation 2) to predict SBJ distance revealed significant differences in the constant "a" parameter due to age (P < 0.001) and place of residence (urban vs. rural) (P < 0.05) BUT not sex (P > 0.05). The two interactions remained as before but the gap between boys' and girls' Ln(SBJ) performances in the sex-by-age interaction was greatly reduced. The interaction between place of residence (urban vs. rural) and age on jump distance (log transformed) remained largely unchanged.

Sit-up test in accord with allometric approach

The estimated allometric parameters from the two models relating the number of SUP to the body-size components in Equation 1, and the model Equation 2 incorporating FM% and SAR, are given in Table 3.

Model	Parameters	B	SE	Lower Bound	Upper Bound	T-score
Eq.1	**lnMass**	-.307	.019	-.343	-.271	-16.5
	lnHt	.958	.081	.800	1.116	11.9
	R Squared = .153 (Adjusted R Squared = .151)					
Eq.2	**lnMass**	.097	.022	.054	.140	4.4
	lnHt	NS				
	LnFAT%	.262	.028	.207	.317	9.3
	Male * LnFAT%	-.139	.015	-.168	-.109	-9.3
	FAT%	-0.018	.0013	-0.0208	-0.0156	-13.8
	SAR	.0046	.0004	.0039	.0053	12.9
	R Squared = .196 (Adjusted R Squared = .195)					

Table 3 Estimated allometric parameters from the multiplicative models relating SUP distance to body-size components in Eq1, and model that incorporating the additional terms FM% and SAR in Eq2

The multiplicative model relating the number of sit-ups performed in 30 s (SUP30) to the body-size components iden- tified the mass and height exponents as $k_1 = -0.307$ (SEE = 0.019) and $k_2 = 0.958$ (SEE = 0.081) respectively. The body-mass and height components associated with the model (Equation 1) for the number of sit-ups in 30 s can be rear- ranged and expressed as a height-to-mass ratio within a curvilinear power function as follows:

$\text{Mass}^{-0.307} \cdot \text{Height}^{0.958} = (\text{Height} \cdot \text{Mass}^{-0.320})^{0.958}$

Since $\text{Mass}^{-0.307} = (\text{Mass}^{-0.320})^{0.958}$. the 95% confidence interval (CI) for the rearranged/rescaled mass exponent −0.320 is (−0.358 to −0.282). Note that this height-to-body mass ratio is very similar to the reciprocal ponderal index (RPI) = height $\cdot \text{mass}^{-0.333}$, since the 95% CI encompasses −0.333.

When we fitted Model (Equation 1) to the log-transformed SUP, the constant "a" parameter varied by sex ($P < 0.001$), age ($P < 0.001$) and by place of residence (urban vs. rural) ($P < 0.001$) together with two interactions between the categorical variables age and sex ($P < 0.001$; Figure 5) and age and place of residence ($P < 0.05$; Figure 6). As soon as the terms FM% and SAR terms were incorporated into Model (Equation 2) to predict the number of SUP (see Table 3), once again the dominance of the negative body- mass term was replaced by the more sensitive fat-mass (%) terms, entered as a gamma function. As with the LnSBJ model, the model for LnSUP predicts a small initial rise, but then an overall decline in SUP with greater FM%. Differential calculus reveals that peak in SUP occurs at FM% = -(0.263–0.139)/(−0.018) = 6.8% in boys and FM% = -(0.263)/(−0.018) = 14.4% in girls based on the estimated gamma function terms from Table 3.

Figure 5 Interaction between sex and age per number of Sit-Up. Covariates appearing in the model are evaluated at following values: lnMass= 3.9667, lnHt= 5.0780

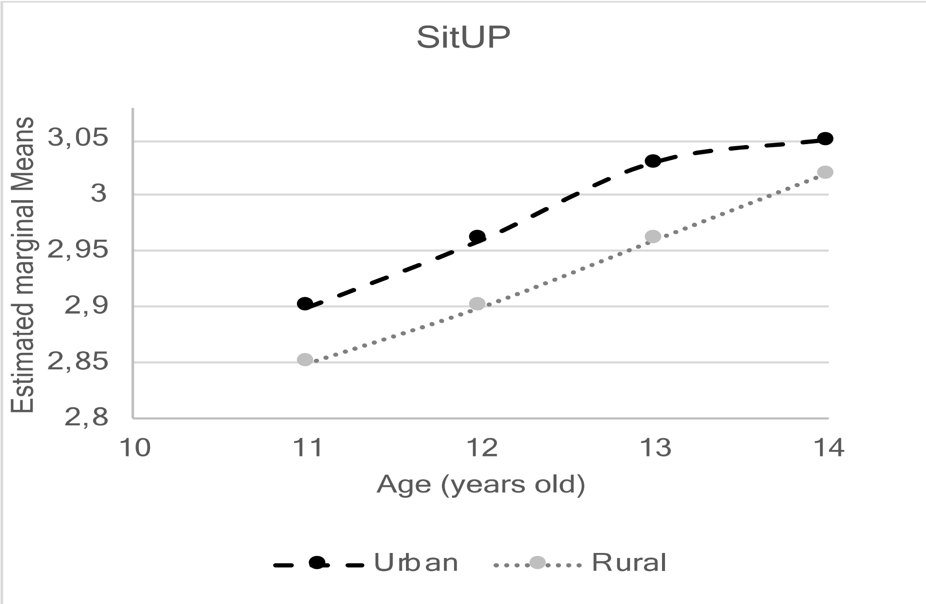

Figure 6 Interaction between place of residence (urban, rural) and age per number of Sit-Up. Covariates appearing in the model are evaluated at following values: lnMass= 3.9667, lnHt= 5.0780

The sit-and-reach (SAR) results were again positively associated with log-transformed SUP performances, see Table 3

The effect of incorporating FM% and SAR into the Model (Equation 2) to predict the number of SUP revealed significant differences in the constant "a" parameter due to age ($P < 0.001$), sex ($P < 0.001$) and place of residence (urban vs. rural) ($P < 0.05$). Only the sex-by-age interactions remained but, as with the sex- by-age interaction with SBJ, the gap between the boys and girls was significantly reduced.

The allometric model (Equation 1) identified the optimal height-to-body mass ratios associated with the standing broad jump and sit-ups in 30s to be $(\text{height}\cdot\text{mass}^{-0.357})^{1.302}$ and $(\text{height}\cdot\text{mass}^{-0.320})^{0.958}$ respectively. With a positive height and a negative mass exponent (being approximately −1/3), these models indicate the optimal body- size or height-to-mass ratio associated with SBJ and SUP is approximately the reciprocal ponderal index (RPI) = height $\cdot\text{mass}^{-0.333}$. The RPI suggests that taller, more linear or ectomorphic children (W. H. Sheldon's classification of body types that measures the body's degree of slenderness and angularity) will perform better at such physical fitness tests. he negative effect of body mass in the RPI when predicting both SBJ and SUP is obvious (i.e., the power-weight ratio), but the positive relationship between height and performance is not so clear, although an increase in height in children and adolescent is often accompanied by an increase in muscle strength (Lieber, 2010) and therefore in power output.

Allometric model including height, body mass, fat mass, flexibility and performance test

The dominant (negative) body- mass term used in model (Equation 1) was replaced by the more sensitive fat-mass (FM%) terms, entered as a gamma function (for the relative importance, see the T-test scores in Tables 3 and 4). The model predicts a small initial rise, but then an overall decline in both SBJ and SUP with increasing FM%. The peak in SBJ occurs at FM% = 5.7% in boys and FM % = 10.7% in girls, whilst the peak in SUP occurs at FM % = 6.8% in boys and FM% = 14.4% in girls (based on the estimated gamma function terms from Tables 2 and 3 respectively). Being flexible also appears to benefit children's SBJ and SUP performances. The finding that flexibility is positively associated with physical performance tests it was confirmed by García-Pinillos, Ruiz-Ariza, Moreno Del Castillo, and Latorre-Román (2015), that suggesting that greater hamstring flexibility benefitted a number of physical performance tests including vertical jump performance in semi-professional academy footballers.

Allometric model in accord to place of residence

Urban children outperformed their rural counterparts in both Ln(SBJ) (Table 2) and Ln(SUP) (Table 3), having controlled for differences in body size (Equation 1). These results are supported by Zheng and An (2015) who reported that, compared to their matched urban counterparts, rural residents are 8.1% ($P < 0.0001$) more likely to be physically inactive in their leisure time and 5.8% ($P = 0.005$) less likely to live within 30-min walking distance to the nearest exercise facility. There is also some evidence that young people living in rural communities are more likely to be sedentary (Plotnikoff et al, 2004).

STUDY 3. Body size and shape characteristics for Cooper's 12 minutes run test in 11-13 years old Caucasian children: an allometric approach.

Giuriato M, Nevill A, Kawczynski A, Lovecchio N. J Sports Med Phys Fitness. 2020;60(3):417-421. doi:10.23736/S0022-4707.19.10282-4

Material and Methods

556 children aged 11- 13 years from north Italy were freely enrolled in this study. In particular, at the begin of the school year 2017- 18, 282 boys (body mass (kg)= 46.51±10.33; height (cm)= 155.57±10.06) and 274 girls (mass (kg)= 45.48±9.47; height (cm)= 154.50±8.87) were involved in the protocol whereas the main criteria of inclusion were defined as: i) no history of illness

considered likely to affect growth; ii) no neurological/orthopedic or cardiovascular diseases; iii) active participation in physical education per classes; and iv) self-declared "sedentary". Children found in good general health and not under medication at the time of the study were deemed eligible. During a common appointment in the first week of October 2017 all children, supervised by their physical education teacher, participated in the stages of the study. The endurance performance was evaluated through the endurance Cooper Test (known also like 12 min run test) since is safe, easy, short and administrable with the minimal and cheap amount of equipment (Heywood, 1997) in particular, this test is largely used in field session of training for middle/ long-distance race (Cooper, 1968) during valid and reliable estimation of cardio-vascular fitness and aerobic power (VO_{2max}) (Schumann et al., 2017) and often adopted as competition during inter-school challenges (Iqbal and Ghosh, 1995). The parents (or legal guardians) and all children gave written informed consent after having received a detailed explanation of the study procedure and possible risks. The study protocol was conducted following the cur- rent national and international laws and regulations governing the use of human subjects (declaration of Helsinki ii). in particular, all procedures were not invasive and did not involve risks different from those undertaken during common physical education classes.

Results

Cooper test in accord with allometric modeling

The multiplicative model relating to the 12 min run test test and to the body-size components was:

$$\text{Cooper test} = a \cdot \text{mass}^{-0.325} \cdot \text{height}^{0.878}$$

with the mass and height exponents being k1=-0.325 (See=0.40) and k2= 0.878 (See=0.141), respectively. The adjusted coefficient of determination (adj R^2) was 32.3%, with a log-transformed error ratio of 0.136 or 14.5% having taken antilogs. Significant differences in the constant 'a' parameter were identified by sex ($P<0.001$) and age ($P<0.001$) while the interaction of sex per age was not significant ($P=0.761$). These age and sex main effects and the non-significant interaction (log-transformed) are shown in Figure 6. The scaling method identified the optimal height-to-body mass ratios associated with cooper endurance test to be $(\text{height}•\text{mass}^{-0.37})^{0.878}$ (note that the 95% ci of the scaled mass exponent -0.370 was -0.459 to -0.281, that encompasses -0.333): corresponding to a slim subject (ectomorph) (Table 4).

Parameter	B	Error st.	t	sign.	Confidence interval 95%	
					Inferior limit	Superior limit
Intercept	4.512	0.629	7.176	0.000	3.277	5.747
Female	-0.154	0.012	-13.372	0.000	-0.176	-0.131
Male	0					
Age (11)	-0.075	0.017	-4.48	0.000	-0.107	-0.042
Age (12)	-0.018	0.015	-1.215	0.225	-0.046	0.011
Age (13)	0					
LnMass	-0.326	0.04	-8.24	0.000	-0.404	-0.249
LnHT	0.885	0.141	6.293	0.000	0.608	1.161

Table 4 Estimated parameter B in 12 min run test. Male and age (13) are redundant because it was consider baseline

Figure 7 Interaction between sex and age in 12 min run test (Cooper test)

EXTRA FINDINGS:

Allometric association between physical fitness test results, body size/shape, biological maturity, and time spent playing sports in adolescents.

Giuriato M, Kawczynski A, Mroczek D, Lovecchio N, Nevill A.
PLoS One. 2021 Apr 6;16(4):e0249626. doi: 10.1371/journal.pone.0249626. PMID: 33822815.

Material and Methods

771 adolescents (401 boys and 331 girls, age range, 14 – 19 years) attending a high school in northern Italy. Inclusion criteria were: physical fitness certificate; regular physical education (PE) class attendance; no physical impairments or illnesses.

Anthropometric measures

Anthropometric measurements were taken by trained operators (quality-control coefficient for inter- and intra-observer reliability, 95% confidence interval). Standing height was measured to the nearest 0.5 cm (Seca Stadiometer 208) without shoes, feet together, and head in the Frankfort plane. Body mass was measured to the nearest 0.5 kg (Seca Beam Balance 710), with participants wearing minimal clothing. Waist circumference (WC) was measured over the naked skin with flexible bands (Seca) to the nearest 0.1 cm, half-way between the lower rib and the top of the iliac crest at the end of gentle expiration, according to Fredrik's guidelines (Clarys et al., 2006; Fredriks et al., 2005)

Measures of Physical Fitness

Three physical fitness components were evaluated using field tests from the Eurofit test battery (Council of Europe, 1988), as administered in a similar previous study (Lovecchio et al, 2019). All three tests are reliable, valid instruments to measure physical fitness (Lovecchio and Zago, 2019) and are considered independent of each other. A brief explanation is given below.

Standing Broad Jump (Ortega et al., 2008) (SBJ, lower limb explosive strength, systematic error near zero; cm): from a standing position immediately behind a line with feet approximately shoulder-width apart, the participants jumped as far as possible with feet together. The rearmost foot is taken as the measure (centimetres). Swinging the upper limbs during the jump is permitted.

Sit-Ups (Artero et al., 2011) (SUP, trunk strength-endurance, ICC ranged from 0.85 to 0.98; n): The efficiency of abdominal musculature is measured by the maximum number of sit-ups (crunch) achieved within 30 s. The starting arrangement involves the subject taking a lying position, fingers interlocked behind the nape, knees bent at a 90° angle, and heels/feet flat on the floor. The subject rises from the lying to the sitting position with the elbows extended so that they touched the knees. The total number of sit-ups performed correctly within 30 s is recorded.

Shuttle Run Test 10 x 5 m (Altmann et al, 2019) (SHR, speed-agility, 0.8 to 4.0% of CV; s): Two parallel lines (2 meters long) are drawn on the floor 5 m apart. The subject runs as fast as possible from the starting line to the other and returns to the starting line, crossing each with both feet each time for a total of 10 times. The stopwatch is stopped when the subject crosses the finishing line with one foot. The test is recorded to the nearest 0.1 s.

Sports participation

Extra hour sport (EHS) after school

Data on physical activity and sports participation were collected via a self-reported questionnaire (Telama et al., 2005) administered to each participant 1 week before the physical fitness assessment. As described in Telama et al. (2005), the questionnaire contained items on the weekly frequency of sports after school hours and whether in team or individual sports.

Open and closed skills (OCS)

Sports can be divided into two categories according to the effects of the environment on motor skills: open and closed sports (Artero et al., 2011). Open sports are characterized by skills performed in a dynamic and changing environment (e.g., soccer or basketball), while closed sports take place in a predictable and static environment (e.g., sprint or gymnastics) (Artero et al., 2011).

Individual and team sport (ITS)

Sports can also be divided into two categories according to competitions: individual and team sports. Individual sports are characterized by individual performance against another single participant, while team sports involve two or more members who compete against the opposite team (Altmann et al, 2019)

Results

	Sex		**Type of sport**		**Type of activity**	
Performance	**Boys (n=401)**	**Girls (n=370)**	**Open Skill (n=346)**	**Closed Skill (n=257)**	**Individual (n=317)**	**Team (n=286)**
SBJ (cm)	205.80	168.27	198.32	182.71	183.62	199.91
	24.51	22.71	25.42	31.02	30.51	24.77
SUP (n)	23.48	20.35	23.10	21.83	21.90	23.23
	4.04	4.00	3.94	4.50	4.56	3.75

SHR (s)	19.34	21.34	19.59	20.66	20.67	19.40
	1.60	1.71	1.72	1.84	1.84	1.61

Table 5 Physical fitness outcomes (Mean ± SD) by sex, type of sport, and type of activity.

Standing Broad Jump test

Table 6 presents the estimated parameters from the multiplicative model relating the SBJ distance to the body-size components in Eq.1, incorporating EHS and MO.

Parameter	B	SE	t	p-value	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Intercept Ln(a)	2.697	.793	3.400	.001	1.140	4.255
Male ΔLn(a)	.135	.021	6.529	.001	.095	.176
Ln(M) (k_1)	-.125	.057	-2.198	.028	-.236	-.013
Ln(H) (k_2)	.700	.150	4.664	<.001	.405	.995
Ln(WC) (k_3)	-.166	.084	-1.978	.048	-.330	-.001
EHS (b)	.010	.002	5.865	<.001	.006	.013
MO (c)	.019	.006	3.230	.001	.007	.030

Table 6 SBJ performance: parameter of Equation 1 based on females. Parameters for girls are not given because considered as offset.

The multiplicative model (Eq.1) relating the SBJ distance to the body-size components was:

SBJ distance (cm) = $a \cdot M^{-0.125} \cdot H^{0.700} \cdot WC^{-0.166}$

With positive height (H) and negative mass (M), and waist (WC) exponents, the model suggests that being taller but lighter (less body mass) with a smaller waist circumference is the optimal body shape associated with SBJ.

Fitting Model (Eq.1) revealed significant differences in the constant “a” parameter due to sex (P <0.001), together with two interactions between the categorical variables “sex” and “type of sport” (Team vs Individual) (P <0.001; Fig. 8) and “Open vs Closed Skill” and “type of sport” (Team vs Individual) (P <0.05; Fig. 9).

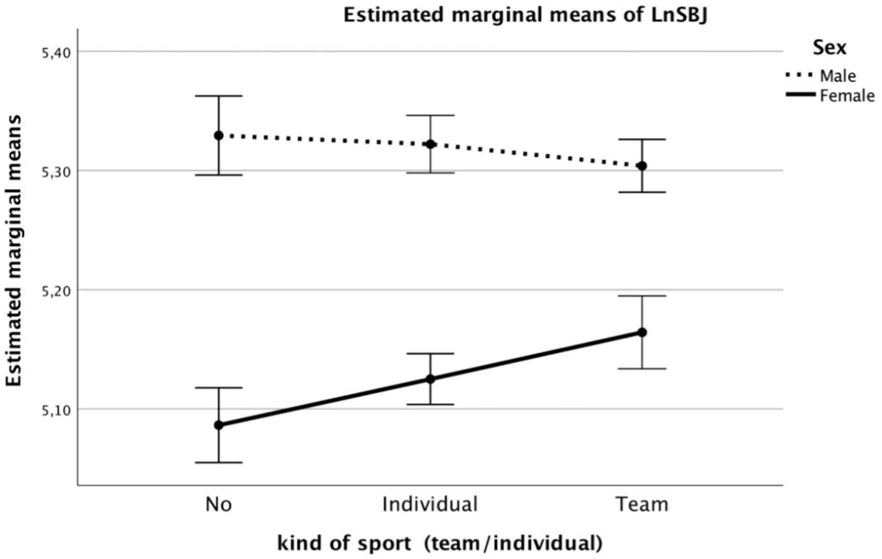

Figure 8 Estimated marginal means of SBJ test by type of sport (team/individual) and sex (boys/girls). Covariates appearing in the model are evaluated as: LnWC = 4.2640, LnHT = 5.1327, LnMass = 4.1025, Extra school hours of sports = 4.311, Maturity offset = 2.96

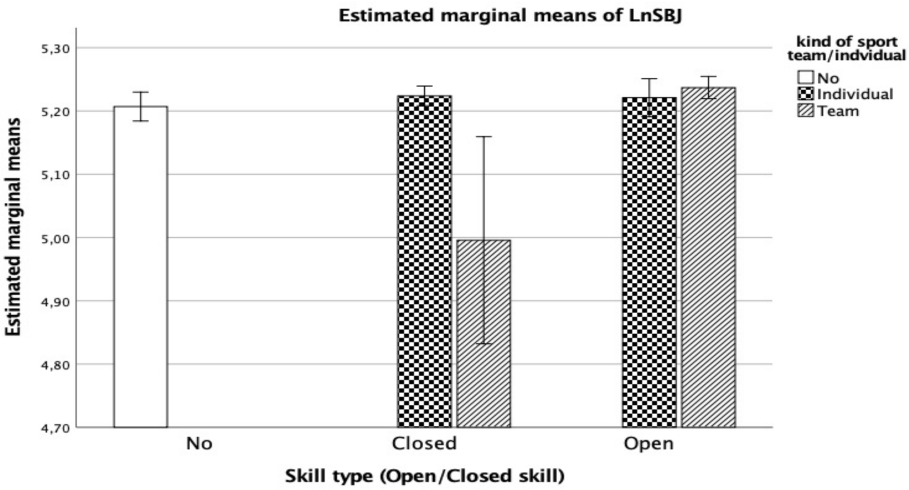

Figure 9 Estimated marginal means of SBJ by type of skill (open/closed) and sport (team/individual). Covariates appearing in the model are evaluated as: LnWC = 4.2640, LnHT = 5.1327, LnMass = 4.1025, Extra school hours of sports = 4.311, Maturity offset = 2.9637

A significant positive contribution to predict log-transformed SBJ distance was noted for extra hours of sports (EHS) and maturity offset (MO) (both $P < 0.001$).

Sit-Up test

Table 7 presents the estimated allometric parameters from the model relating the number of SUP to the body-size components in Eq.1, incorporating EHS and MO.

Parameters	B	SE	t	P-value	95% Confidence Interval	
					Lower Bound	Upper Bound
Intercept Ln (a)	3.696	.309	11.958	<.001	3.090	4.303
Male ΔLn (a)	.142	.029	4.912	<.001	.086	.199
Ln (WC) (k_3)	-.161	.075	-2.149	.032	-.308	-.014
EHS (b)	.015	.002	6.070	<.001	.010	.019
MO (c)	-.030	.007	-4.338	<.001	-.043	-.016

Table 7 SUP performance: parameter of Equation 1 based on females. Parameters for girls are not given because considered as offset.

The multiplicative model relating the number of sit-ups performed in 30 s (SUP) to the body-size components using Eq. 1 identified waist circumference as the only significant body-size component k3= -0.161 (SEE=0.075).

The model (Eq.1) fitted to the log-transformed SUP also revealed that the constant "a" parameter varied by sex (P <0.001), together with an interaction between the categorical variables "sex" and "kind of sport" (Individual vs. Team) (P <0.001; Fig 10).

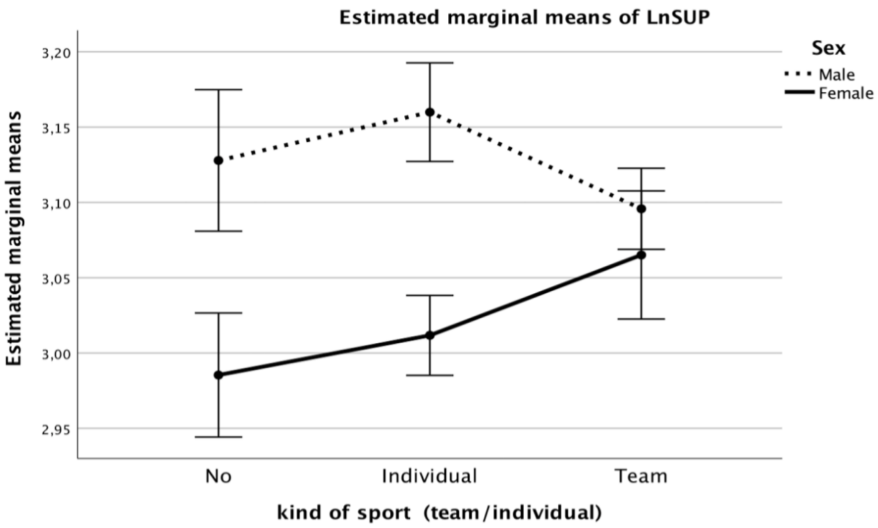

Figure 10 Estimated marginal means of SUP test by type of sport (team/individual) and sex (boys/girls). Covariates appearing in the model are evaluated as: LnWC = 4.2640, Extra school hours of sports = 4.311, Maturity offset = 2.9637.

A significant contribution to predict log-transformed SUP distance was noted for extra hours of sports (EHS) and maturity offset (MO) (both P <0.001; Fig 11). As expected, EHS was positively related, whereas MO was negatively related to the number of sit-ups in 30 s.

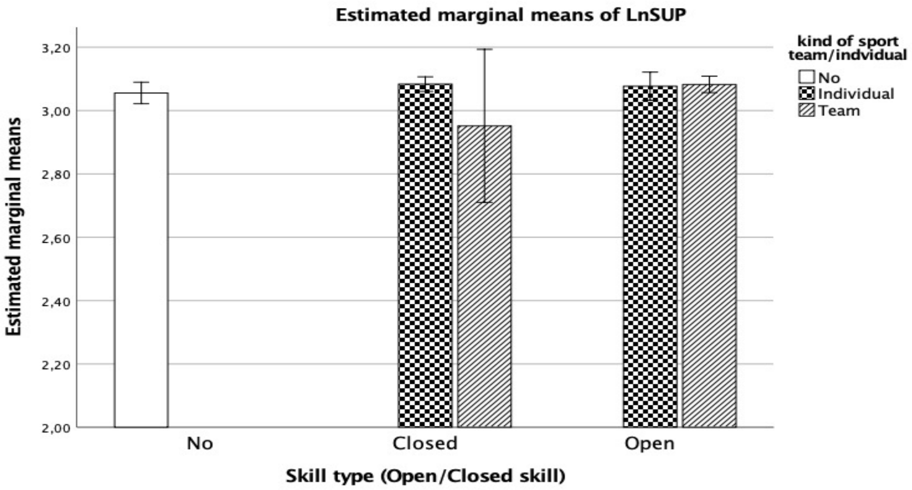

Figure 11 Estimated marginal means of SUP test by type of skill (open/closed) and sport (team/individual). Covariates appearing in the model are evaluated as: LnWC = 4.2640, Extra school hours of sports = 4.311, Maturity offset = 2.9637.

Shuttle Run Test 10x 5m (SHR)

Parameter	**B**	**SE**	**t**	**P-value**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Intercept Ln (a)	-1.247	.084	-13.7	<.001	-1.412	-1.083
Male ΔLn (a)	.100	.008	-12.6	<.001	-.116	-.085
Ln (M) (k_1)	-.059	.021	-2.8	.006	-.100	-.017
EHS (b)	.006	.001	6.0	<.001	.004	.008
MO (c)	.009	.003	2.8	.050	.003	.016

Table 8 SHR performance: parameter of equation 1 based on females. Parameters for girls are not given because considered as offset.

The model relating the shuttle-run-test performance (using mean speed, in m.s-1) to the body-size components using Eq. 1 identified body mass as the only significant body-size component k3= -0.059 (SEE=0.021). The model (Eq.1) fitted to the Ln-transformed SHR also revealed that the constant "a" parameter varied by "sex" (P <0.001) and "type of sport" (individual vs team) (P <0.001; Fig. 12,13).

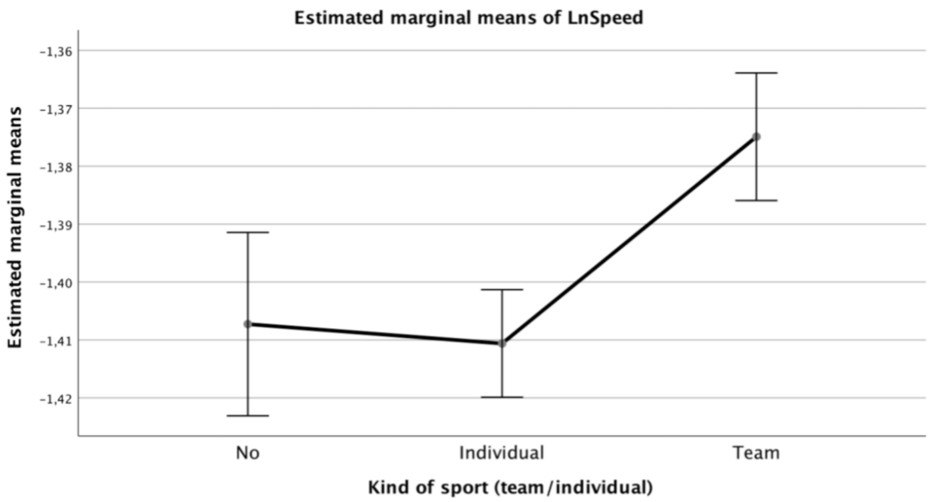

Figure 12 Estimated marginal means of SHR test by type of sport (team/individual). Covariates appearing in the model are evaluated as: LnMass = 4.1025, Extra school hours of sports = 4.311, Maturity offset = 2.9637.

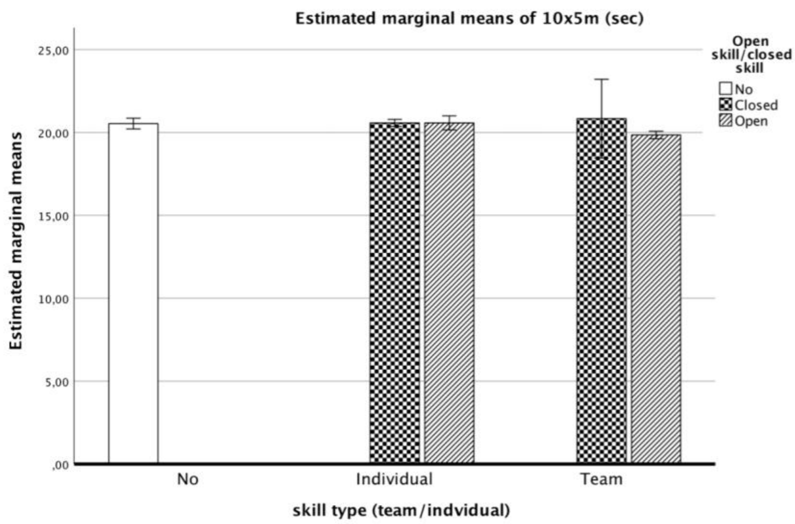

Figure 13 Estimated marginal means of SHR test by type of skill (open/closed) and sport (team/individual). Covariates appearing in the model are evaluated as: LnMass = 4.1025, Extra school hours of sports = 4.311, Maturity offset = 2.9637.

A significant contribution to predict log-transformed SHR speed was noted for extra hours of sports (EHS) and maturity offset (MO) (both P <0.001). As expected, EHS and MO were positively related to the shuttle run speed.

CONCLUSIONS
GŁÓWNE WYNIKI I WYPŁYWAJĄCE Z NICH WNIOSKI

Physical activity it is needed not only to prevent disease during all whole life, but also for build new athletes, from bottom to top level. In light of this, it is necessary consider and plan physical activity in all of its form. Negative spiral could become a positive escalation: more EN (a strongest predictors of PA participation) lead to significant positive perceptions of physical competence (Biddle et al., 2003; Ferrer-Caja and Weiss, 2000) and then a new reinforcement for EN (Wallhead and Ntoumanis, 2004; Prochaska et al., 2003) that in turn improve the positive attitude for physical education and out-of-school physical activity participation (Prochaska et al., 2003). In this the regard, form of deliberate play and variety of activities (Pesce et al., 2016) should be an essential part of PE lessons with particular attention since the first years of primary school. Moreover, first study suggested that it is necessary more insight, about physical activity and BMI. Indeed, BMI don't reflect real trend of fat in children, and don't explain if negative fat mass affected enjoyment and self-reported physical fitness, in this way allometric modeling could be mor effective to investigate the real trend of fitness from children to adolescence (Nevill et al, 2009).

In fact, the results of second study, based on allometric statistical, suggested that optimal shape associated with two mass-dependent physical activities (SBJ, SUP) is an ectomorph body shape (linear physique). However, incorporating BF% and flexibility (SAR terms) into the allometric model (Equation 2 of Study 2), new insights we obtained. Although having an ectomorph body shape (linear physique) appears advantageous overall, being too thin can be detrimental to these strength outcomes. Furthermore, when incorporated the flexibility test into the allometric model (Equation 2 of Study 2) appears that children aged 11 to 14, benefit their strength outcomes. Whether being flexible leads to better strength outcomes or whether superior strength results in greater flexibility is unclear, however this intriguing finding provides a valuable opportunity for future research. Furthermore, urban children aged 11 to 14 have superior strength outcomes compared with rural children, having controlled for differences in body size/shape, a finding that may be associated with rural environments having fewer exercise facilities compared with urban conurbations.

The multiplicative model relating the distance in 12 min run test, to the body-size components suggested that distance covered by running decreases with the increase of body mass, explaining that the body mass affects negatively the endurance performance (mass$^{-0.325}$) while the height affects it in a positive way (height$^{0.878}$). The model of performances (aerobic endurance – 12 min run test), identified as height-to-weight ratios in study 3, is similar to the reciprocal ponderal index (height^3/weight or height/weight$^{0.333}$) found by Nevill et al. (2009) in Greek school-children. This could be explained with the suggestion that the endurance performance in the range 11-13 years (both male and female) showed a direct relation with the changes in body surface area: boys increased their body surface more than girls and then the VO2peak significantly increased (Armstrong and Welsman, 2019). VO2 has been clouded by expressing and analyzing youth peak in 1:1 ratio with body mass. Indeed, Tanner (1962) suggested that the VO2peak increases with sex-specific, concurrent changes in a range of age- and maturity status-driven morphological and physiological covariates with the timing and time of changes specific to individuals. Furthermore, trends of boys and girls showed similar qualitative tendencies considering the stage 11-12 and 12-13-year-old (Figure 7). The attention to growth fluctuations become important to avoid bad judgment in case children will be poorly evaluated. The cause could be due to the natural growth path and not for lack of physical activity, in accord with literature (Armstrong and Welsman, 2019). Conversely, the stage 11-12 years-old rep- resent a significant cut-off to intercept right athletic perspective.

The study 4 (extra findings) add at the research the influence of extra hour of sport (EHS), specifically strength type, open closed skills, and team-, and individual- sport. Investigated the relationships between biological maturation/body shape characteristics (height, mass, WC) and physical fitness using field tests (SBJ, SUP, SHR 10x5m) in a cohort of adolescents, including the influence of EHS. The allometric modeling approach to determine the influence of sports involvement outside school hours takes into account different types of skill sets (open, closed) and sports (team or individual) (Nevill et al, 1998). Findings suggest that fat body mass negatively affects physical fitness in adolescents. This results it is in line with the previous study this thesis. Furthermore, EHS were the first predictor of performance on the three tests (SBJ, SUP, SHR 10x5m) (Figs. 8 – 13). EHS are important for the development of adequate strength in both team and individual sports. Suggesting, that trainer and sport scientists should take into account strength/resistance training already in preadolescence. Further studies on EHS and strength training in youths may provide additional evidence for fitness improvement (i.e., progression in skills and strength conditioning) and associated health-related benefits (Stricker et al., 2020). In light of this, even the amount of hour spent in physical activity could be insert into allometric modeling to describe the guideline to promoting physical activity and excellence from children. Furthermore, this information further help trainer that could insert or improve hour of physical activity, inserting extra hour focusing on strength and resistance training.

REFERENCE

BIBLIOGRAFIA

1. Aitkin M, Anderson D, Hinde J Statistical modelling of data on teaching styles. J Roy Stat Soc A, 1981 144:148–161
2. Altmann S, Ringhofl S, Neumann R, Woll A, Rumpf MC. Validity and reliability of speed tests used in soccer: A systematic review. PLoS One. 2019; 14(8): e0220982.
3. Armstrong N, Welsman JR, Nevill AM, Kirby BJ. Modeling growth and maturation changes in peak oxygen uptake in 11–13 yr olds. J Appl Physiol. 1999;87:2230–6.
4. Armstrong N, Welsman J. Sex-Specific Longitudinal Modeling of Short-Term Power in 11- to 18-Year-Olds. Med. Sci. Sports Exerc. 2019, 51, 1055–1063. [CrossRef]
5. Artero AG, España-Romero V, Castro-Piñero J, Ortega FB, Suni J, Castillo-Garzon MJ, et al. Reliability of field-based fitness tests in youth. Int J Sports Med 2011; 32:159–69.
6. Astrand PO, Rodahl K. Textbook of work physiology. McGraw-Hill; New York: 1986.
7. Bar-Or O, Rowland TW. Pediatric exercise medicine. Human Kinetics, Champaign, 2004, pp 5–7
8. Batterham AM, George KP. Allometric modeling does not determine a dimensionless power function ratio for maximal muscular function. J Appl Physiol. 1997; 83:2158–2166. [PubMed: 9390994]
9. Beunen G, Baxter-Jones A, Mirwald RL, et al. Intraindividual allometric development of aerobic power in 8-to 16-year-old boys. Med Sci Sports Exerc. 2002; 34:503-510.
10. Biddle S, Wang C, Chatzisarantis N, Spray C. Motivation for physical activity in young people: Entity and incremental beliefs about athletic ability. Journal of Sport Sciences. 2003; 21, 973- 989
11. Boeke CE, Oken E, Kleinman KP, Rifas-Shiman SL, Taveras EM, Gillman MW. Correlations among adiposity measures in school-aged children. BMC Pediatrics 1993, 13, 99
12. Bruce SA, Phillips SK, Woledge RC. Interpreting the relation between force and cross-sectional area in human muscle. Med Sci Sports Exerc. 1997; 29:677–683.10.1097/00005768-199705000-00014
13. Buchheit M, Mendez-Villanueva A, Quod MJ, Poulos N, Bourdon P. Determinants of the variability of heart rate measures during a competitive period in young soccer players. Eur J Appl Physiol 2010; 109: 869–878
14. Byrne H, Caulfield B, de Vito G. Self-directed exercise programmes in sedentary middle-aged individuals in good overall health; a systematic review. prev Med 2018; 114:156–63.
15. Carissimi A, Adan A, Tonetti L, Fabbri M, Hidalgo MP, Levandovski R, Natale V, Martoni M. Physical self-efficacy is associated to body mass index in schoolchildren. J Pediatr (Rio J). 2017; 93(1):64-69
16. Carnevale Pellino V, Giuriato M, Ceccarelli G, et al. Explosive Strength Modeling in Children: Trends According to Growth and Prediction Equation. Appl. Sci. 2020, 10, 6430.
17. Chaouachi M, Chaouachi A, Chamari K, et al. Effects of dominant somatotype on aerobic capacity trainability. Br J Sports Med 2005; 39:954–9.

18. Clarys JP, Provyn S, Marfell-Jones M, Van Roy P. Morphological and constitutional comparison of age-matched in-vivo and post-mortem populations. 2006; Morphologie. 90 (291):189-96
19. Coelho e Silva MJ, Figueiredo AJ, Simoes F, Seabra A, Natal A, Vaeyens R, Philippaerts R, Cumming SP, Malina RM. Discrimination of u-14 soccer players by level and position. Int J Sports Med 2010; 31: 790–796
20. Cole TJ, Lobstein, T. Extended international (IOTF) body mass index cut-offs for thinness, overwcut-offsd obesity. Pediatric Obes. 2012, 7, 284–294. [CrossRef]
21. Cooper KH. A means of assessing maximal oxygen intake. correlation between field and treadmill testing. JAMA 1968; 203:201–4.
22. Council of Europe. Eurofit: Handbook for the Eurofit Tests of Physical Fitness. Rome (IT): Council of Europe; 1988
23. Darwin C. Origin of species, Murray edition, 1859
24. Ferrer-Caja E, Weiss MR. Predictors of intrinsic motivation among adolescent students in physical education. Research Quarterly for Exercise and Sport. 2000; 71, 267-279
25. Figueiredo AJ, Goncalves CE, Coelho-e-Silva MJ, Malina RM. Youth soccer players, 11-14 years: maturity, size, function, skill and goal orienta- tion. Ann Hum Biol 2009; 36: 60–73
26. Fredriks AM, van Buuren S, van Heel WJM, et al. Nation wide age references for sitting height, leg length, and sitting height/height ratio, and their diagnostic value for disproportionate growth disorders. Archives of Disease in Childhood. 2005; 90, 807–812.
27. Giuriato M, Nevill A, Kawczynski A, Lovecchio N. Body size and shape characteristics for Cooper's 12 minutes run test in 11–13 years old Caucasian children: An allometric approach. J. Sports Med. Phys. Fit. 2020, 60, 417–421.
28. Goldstein H. Multilevel Statistical Models. 2nd ed. London: Arnold, 1995
29. Harsha DW. The benefits of physical activity in childhood. am J Med Sci 1995;310(Suppl 1):S109–13.
30. Hashim H, Grove JR, Whipp P. Validating the youth sport enjoyment construct in high school physical education. Research Quarterly for Exercise and Sport, 2008 79, 183-195.
31. Hesketh KR, Goodfellow L, Ekelund U, McMinn AM, Godfrey KM, Inskip HM, et al. activity levels in mothers and their preschool children. pediatrics 2014;133:e973–80.
32. Heywood V. The Physical Fitness Specialist Certification Manual, The cooper institute for aerobics research, dallas TX, revised 1997. in: heywood V, editor. advance fitness assessment & exercise prescription. Third edition. leeds: human Kinetics; 1998. p. 48
33. Huijgen BC, Elferink-Gemser MT, Post W, Visscher C. Development of dribbling in talented youth soccer players aged 12-19 years: a longitudinal study. J Sports Sci 2010; 28: 689–698
34. Iqbal R, Ghosh AK. Validation of cooper's 12 Minute run Test for estimation of aerobic capacity (Vo2 max). indian J physiol pharmacol 1995;53:164–7.
35. Jaric S, Mirkov D, Markovic G. Normalizing physical performance tests for body size: a proposal for standardisation. J Strength Cond Res. 2005; 19:467–474.10.1519/R-1

36. Jaric S. Muscle strength testing use of normalisation for body size. Sports Med. 2002; 32:615– 631.10.2165/00007256-200232100-00002 [PubMed: 12141882]

37. Jaric S. Role of body size in the relation between muscle strength and movement performance. Exerc Sport Sci Rev. 2003; 31:8–12.

38. Katch VL, Katch F. Use of weight-adjusted oxygen uptake scores that avoid spurious correlations. Res Q 1974, 4:447-451

39. Katch VL. Use of the oxygen/body weight ratio in correla- tional analyses: spurious correlations and statistical considerations. Med Sci Sports Exerc, 1973, 5:253-257

40. Lovecchio N, Giuriato M, Carnevale Pellino V, Valarani F, Codella R, Vandoni M. Italian Physical Fitness Decline: A True Fact or a Mindset? A 10-Year Observational Perspective Study. International journal of environmental research and public health, 2020, 17(21), 8008. https://doi.org/10.3390/ijerph17218008

41. Lovecchio N, Giuriato M, Zago M, Nevill A. Identifying the optimal body shape and composition associated with strength outcomes in children and adolescent according to place of residence: An allometric approach. J Sports Sci. 2019; 37(12):1434-1441

42. Lovecchio N, Zago M. Fitness differences according to BMI categories: a new point of view. J Sports Med Phys Fitness; 2019; 59(2):298-303

43. Marfell-Jones M, Olds T, Stewart A, Carter L. International Standards for anthropometric assessment. Potchefstroom, South africa: International Society for the Advancement of Kinanthropometry; 2006

44. McCarthy H, Ellis S, Cole T. Central overweight and obesity in British youth aged 11-16 years: cross sectional surveys of waist circumference. BMJ. 2003; 326:624–627.

45. Moore J, Yin Z, Hanes J, Duda J, Gutin B, Barbeau P. Measuring enjoyment of physical activity in children: validation of the Physical Activity Enjoyment Scale. Journal of Applied Sport Psychology 2009, 21:116-129.

46. Mosimann JE. Size allometry - Size and shape variables with characterisations of lognormal and generalised gamma distributions. J. Am. Stat. Assoc. 65:930–945, 1970.

47. Motl R, Dishman R, Saunders R, Dowda M, Felton G, Pate R. Measuring enjoyment of physical activity in adolescent girls. American Journal of Preventive Medicine 2001, 21:110-117.

48. Nevill AM, Cooke CB, Holder RL, Ramsbottom R, Williams C. Modelling bivariate relationships when repeated measurements are recorded on more than one subject. Eur J Appl Physiol Occup Physiol. 1992a; 64(5):419-25.

49. Nevill AM, Holder R. Modelling health-related performance indices. Ann Hum Biol. 2000; 27:543-559.

50. Nevill AM, Holder RL, Baxter-Jones A, Round JM, Jones DA. Modelling developmental changes in strength and aerobic power in children. J Appl Physiol, 1998, 84:963–970

51. Nevill AM, Holder RL. Scaling, normalising, and per ratio standards: an allometric modeling approach. J Appl Physiol. 1995; 79:1027–1031.

52. Nevill AM, Okojie DI, Smith J, O'Donoghue PG, Webb T. Are professional footballers becoming lighter and more ectomorphic? Implications for talent identification and development. Int J Sports Sci Coach. 2019; 14(3), 329–335

53. Nevill AM, Ramsbottom R, Williams C. Scaling physiological measurements for individuals of different body size. Eur J Appl Physiol Occup Physiol. 1992b;65(2):110-7. doi: 10.1007/BF00705066. PMID: 1396632.

54. Nevill AM, Tsiotra G, Tsimeas P, Koutedakis Y. Allometric associations between body size, shape, and physical performance of Greek children. Pediatr Exerc Sci. 2009;21:220-232.

55. Nevill AM, Bate S, Holder RL. Modeling physiological and anthropometric variables known to vary with body size and other confounding variables. American journal of physical anthropology, 2005, Suppl 41, 141–153. https://doi.org/10.1002/ajpa.20356

56. Nevill, AM, Metsios GS. The need to redefine age- and gender-specific overweight and obese body mass index cut-off points. Nutrition & dcut-offs, 2015, 5(11), e186. https://doi.org/10.1038/nutd.2015.36

57. Ntoumanis N, Pensgaard AM, Martin C, Pipe K. An idiographic analysis of amotivation in compulsory school physical education' Journal of sport & exercise psychology, 2004, vol. 26, no. 2, pp. 197-214.

58. Ortega FB, Artero EG, Ruiz JR, Vicente-Rodriguez G, Bergman P, et al. Reliability of health-related physical fitness tests in European adolescents. The HELENA Study. Int J Obes; 2008; 32:S49–57

59. Ortega FB, Sánchez-López M, Solera-Martínez M, Fernández-Sánchez A, Sjöström M, Martínez- Vizcaino V Self-reported and measured cardiorespiratory fitness similarly predict cardiovascular disease risk in young adults. Scand J Med Sci Sports. 2013; 23(6):749-57.

60. Penedo FJ, Dahn JR. Exercise and well-being: a review of mental and physical health benefits associated with physical activity. curr opin psychiatry 2005;18:189–93.

61. Pescatello LS, Kelsey BK, Price TB, Seip RL, Angelopoulos TJ, Clarkson PM, et al. The muscle strength and size response to upper arm, unilateral resistance training among adults who are overweight and obese. J Strength Cond Res. 2007; 21:307–313.

62. Pesce C, Masci I, Marchetti R, Vazou S, Sääkslahti A, Tomporowski PD. Deliberate Play and Preparation Jointly Benefit Motor and Cognitive Development: Mediated and Moderated Effects. Front Psychol. 2016, 11;7:349.

63. Prochaska JJ, Sallis JF, Slymen DJ, McKenzie TL. A longitudinal study of children's enjoyment of physical education. Pediatric Exercise Science. 2003; 15, 170-178.

64. Rasbash J, Steele F, Browne WJ, Goldstein H. A user's guide to MLwiN Version 3.02. University of Bristol Centre for Multilevel Modelling, Bristol, 2018

65. Schumann M, Botella J, Karavirta l, häkkinen K. Training-load- Guided vs Standardised endurance Training in recreational runners. int J Sports physiol perform 2017; 12:295–303.

66. Stricker PR, Faigenbaum AD, McCambridge TM, COUNCIL ON SPORTS MEDICINE AND FITNESS. Resistance Training for Children and Adolescents. Pediatrics, 2020, 145(6), e20201011. https://doi.org/10.1542/peds.2020-1011

67. Tanaka K, Matsuura Y. a multivariate analysis of the role of certain anthropometric and physiological attributes in distance running. ann hum Biol 1982;9:473–82.

68. Tanner JM. Fallacy of per-weight and per-surface area standards, and their relation to spurious correlation. J Appl Physiol, 1949, 2:1–15.

69. Tanner JM. Growth at adolescent. Oxford: BlackwellScientific; 1962

70. Telama R, Yang X, Viikari J, Välimäki I, Wanne O, Raitakari O. Physical activity from childhood to adulthood: a 21-year tracking study. Am J Prev Med. 2005;28(3):267-273. doi:10.1016/j.amepre.2004.12.003

71. Teques P, Calmeiro L, Silva C, Borrego C. Validation and adaptation of the Physical Activity Enjoyment Scale (PACES) in fitness group exercisers. Journal of Sport and Health Science. 2017, 09.010

72. Wallhead TL, Ntoumanis N. Effects of a sport education intervention on students' motivational responses in physical education. Journal of Teaching in Physical Education, 2004, 23, 4-18.

73. Wilson PM, Rodgers WM. Self-determination theory, exercise, and well-being. In: Hagger MS, Chatzisarantis NLD, editors. Intrinsic motivation and self-determination in exercise and sport. Champaign, IL: Human Kinetics; 2007.p.101–12

STRESZCZENIE W JĘZYKU POLSKIM

WSTĘP: Body Mass Index (BMI) nie jest optymalnym narzędziem do oceny zmian składu ciała. Wskaźnik ten opiera się tylko na dwóch zmiennych i przez to nie może służyć do skutecznej oceny sprawności fizycznej. W związku z tym w pracy została podjęta próba przedstawienia bardziej komplementarnej metody, a mianowicie modelu allometrycznego. Umożliwia on precyzyjniejszą analizę parametrów ciała ze szczególnym uwzględnieniem sprawności fizycznej.

METODA: Dla przedstawienia metody allometrii wykorzystano cztery artykuły. W pracach tych oceniano sprawność fizyczną na podstawie wydolności aerobowej, siły oraz zwinności. W badaniach brały udział dzieci obu płci w wieku od 8 do 14 lat. Wszyscy uczestnicy badań wykonali test sprawnościowy, a w pomiarach antropometrycznych określono ich wysokość i masę ciała oraz grubość fałdu skórno-tłuszczowego. Badani wypełnili również kwestionariusze dotyczące aktywności fizycznej. Wszystkie te dane zostały wykorzystane w zastosowanym modelu allometrycznym.

WYNIKI: Wyniki potwierdziły użyteczność metody allometrycznej i wykazały, że ektomorficzny typ budowy ciała jest optymalny dla uzyskiwania dobrych wyników w zakresie zwinności, siły oraz wydolności tlenowej w okresie wzrostu w badanej grupie dzieci.

WNIOSKI: Wskaźnik BMI nie jest optymalny dla wykazania naturalnego trendu zmian poziomu tkanki tłuszczowej u dzieci. Model allometryczny jest bardziej miarodajny w badaniu zależności między składem ciała a sprawnością fizyczną u dzieci w wieku 8-14 lat. Model allometryczny wykazał, że podwyższona masa ciała i zawartość tkanki tłuszczowej mają negatywny wpływ na siłę, zwinność oraz wydolność aerobową. Natomiast wysokość ciała jest czynnikiem pozytywnie wpływającym na wymienione parametry. Dodatkowo zaobserwowano również, że pozaszkolna aktywność fizyczna pozytywnie wpływa na umiejętności w grach zespołowych i sportach indywidualnych.

ABSTRACT

INTRODUCTION. Body Mass Index (BMI) does not replicate the changes in body composition. Further, BMI is a parameter that summarising two variables and not represent an appropriate predictor of authentic performance. In light of this, a more flexible approach was scaling methods. In particular, allometric models may be required to be more accurate.

METHODS. Four papers were considered the importance of using the allometric approach in physical fitness evaluation (aerobic, strength, agility). The thesis it was based on different sample (8 – 14 yo) of both sexes. Subjects have completed field test (see in the thesis), anthropometric characteristics (height, body mass, skinfold) questionnaire (enjoyment, physical activity questionnaire) to promote applied setting in school.

RESULTS. Results firstly confirm the importance of using allometric modeling. Allometric modeling suggests that ectomorph body shape (see the formula in the thesis), according to the B parameter, was the best body shape per agility, strength and aerobic performance during growth.

CONCLUSION. BMI doesn't explain the natural trend of body fat in children, like this allometric modeling could be more efficient to investigate the natural tendency of fitness from childhood to adolescence. Moreover, based on allometric statistical modeling, strength, agility, and aerobic test negatively affect body mass or fat body mass. At the same time, the height affects it positively (see equation in the thesis). Finally, an extra school physical activity (resistance training) affected positively open closed skills, and team-, and individual- sport.

SZKOŁA DOKTORSKA

OŚWIADCZENIE WSPÓŁAUTORÓW PUBLIKACJI

Enjoyment and self-reported physical competence according to Body Mass Index: international study in European primary school children.

Matteo Giuriato, Nicola Lovecchio, Jaroslaw Fugiel, Guillermo Lopez Sanchez, Maret Pihu, Arunas Emeljanovas

J Sports Med Phys Fitness. 2020;60(7):1049-1055. doi:10.23736/S0022-4707.20.10550-4

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Identifying the optimal body shape and composition associated with strength outcomes in children and adolescent according to place of residence: An allometric approach.

Nicola Lovecchio, Matteo Giuriato, Matteo Zago, Alan Nevill

J Sports Sci. 2019;37(12):1434-1441. doi:10.1080/02640414.2018.1562615

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OŚWIADCZENIE WSPÓŁAUTORÓW PUBLIKACJI

Body size and shape characteristics for Cooper's 12 minutes run test in 11-13 years old Caucasian children: an allometric approach.

Giuriato Matteo, Nevill Alan, Kawczynski Adam, Lovecchio Nicola

J Sports Med Phys Fitness. 2020;60(3):417-421. doi:10.23736/S0022-4707.19.10282-4

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OŚWIADCZENIE WSPÓŁAUTORÓW PUBLIKACJI

Allometric association between physical fitness test results, body size/shape, biological maturity,and time spent playing sports in adolescents.

Matteo Giuriato, Adam Kawczynski, Dariusz Mroczek, Nicola Lovecchio, Alan Nevill
PLoS One. 2021 Apr 6;16(4):e0249626. doi: 10.1371/journal.pone.0249626. PMID: 33822815.

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