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ORIGINAL SCIENTIFIC ARTICLE

MATURITY STATUS AND FAT-FREE MASSES AS DETERMINANTS OF PHYSICAL FITNESS AMONG MACEDONIAN SCHOOLCHILDREN AGED 6 TO 14

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Abstract

Study purpose. The research goal was to establish if the fat-free mass, chronological age and maturity status are determinants of physical fitness, and to analyze the development changes of fat-free mass and physical fitness in concordance with chronological age and maturity status in schoolchildren aged 6 to 14.

Materials and methods. The research was conducted on a sample of 9106 students aged 6 to 14 years. In order to reach the research goals, the following variables were measured: height, weight, sitting height, fat mass, fat-free mass and various components of the physical fitness (lower limbs explosive strength, handgrip strength, abdominal muscle repetitive strength, speed and agility). The values of body mass and biological maturation indexes (APHV) were obtained by using formulas.

Results. The boys' age at peak height velocity was estimated at 13.00±0.82, and the girls' one at 11.57± 0.68. The relationships between chronological age and age at peak height velocity with fat-free mass was r=0.82 to 0.94 in the boys and r=0.83 to 0.92 in the girls. The relationships between fat-free mass and physical fitness tests in the boys were: standing long jump (r=0.55), 30 sec sit-ups (r=0.37), handgrip strength (r=0.75) and shuttle run 4 × 10 meters (r=-0.40); and in the girls – standing long jump (r= 0.45), 30 sec sit-ups (r= 0.36), handgrip strength (r= 0.74) and shuttle run 4 x 10 meters (r= -0.43). The differences in fat-free mass and physical fitness tests were more prominent when the comparison was done with relation to the biological maturation (APHV) and chronologic age.

Conclusions. On the basis of the obtained results, it can be concluded that maturity status and fat-free mass determinate the physical fitness performances in the schoolchildren of both genders. Also, the age at peak height velocity should be used in Physical Education as a tool of monitoring, ranging and classification of physical performances in children and adolescents.

Keywords: physical fitness, fat-free mass, maturity status, children, adolescents.

Introduction

The analysis of the body mass components are necessary for understanding what impact the physical growth, diet effects, diseases and physical activity, among other environmental factors, have on human's organism (Valtueña Martínez et al., 1996). The studies which deal with the body composition most often investigate absolute and relative body mass components, since they change during the period of growing and biological maturation, so it is necessary to pay attention when selecting the assessment methods of the same children and adolescents (Malina & Geithner, 2011).

The body composition components can be determined by methods on the field or in laboratory. The monitoring of body composition components in children and adolescents is of a particular significance in assessing different phases of growth and maturation (Sherar et al., 2005).

From the perspective of anthropometry, body composition is normally considered as a two-component model consisting of fat mass and fat-free mass. Namely, fat

mass provides information about the increase of body fat in the person, which associates with a serious risk of several diseases such as cardiovascular disease, hypertension, insulin resistance, hyperinsulinemia, total obesity, abdominal adiposity, deteriorated health skeleton condition and a great number of metabolic risk factors (Pulgaron & Delamater, 2014; Seidell et al., 1989). Whereas the fat-free component plays an important role in physical performances (Poortmans et al., 2005), body position maintenance and movements in adults, children and adolescents.

It is known that the body composition proportions (fat mass and fat-free mass) change during the period of growth and biological maturation. Therefore, the body composition components can be determiners when analyzing physical fitness performances in schoolchildren. In this direction, physical fitness is a powerful indicator of the health condition in childhood, adolescence and adulthood alike (Ortega et al., 2007). For example, the muscle strength and global muscular fitness have a specific importance in doing different daily routines and activities throughout lifetime (Thivel et al., 2016). Agility and speed are the fitness components that are related to different sports (Farrow, Young & Bruce, 2005; Uzun et al., 2020) and are necessary for the individual to perform successfully different fundamental motoric skills and movement models (Couturier, Chepko & Holt, 2014).

Within the teaching of physical education, the physical performances such as strength, speed and agility are mainly developed during the learning process depending on the gender and age. These physical qualities' development involves collaborative/ cooperative activities, such as jumping, running and throwing, which are performed every day through playing (Milanese et al., 2020). Further, physical performance is determined not only by the levels of physical activities (Sola, Brekke & Brekke, 2010), but by the levels of biological maturation of children and adolescents as well, since the intensity and duration of puberty period is individually specific and may significantly vary from one person to another (Malina, Bouchard & Bar-Or, 2004).

Taking into consideration the fact that the changes during the growth, development and biological maturation take place in childhood and adolescence, it is possible for the maturity status (MS) and the fat-free component level (FFM) to be determinants of the physical fitness performances in schoolchildren.

Therefore, the research goal was to establish if fat-free mass, chronological age and maturity status (APHV) are determinants of physical fitness performance (strength, strength endurance, speed and agility), and to analyze fat-free mass and physical fitness concor with chronological age and maturity status in Macedonian schoolchildren aged 6 to 14.

Material and Methods

Participants

The research was conducted on a sample of 9106 students aged 6 to 14 years from 19 primary schools (eight rural and eleven urban) from the East and Central Macedonia. The total sample of respondents was divided, according to the gender, into two subsamples (subsample n1 = 4573 boys and subsample n2 = 4443 girls). These two subsamples were divided into nine groups regarding their chronologic age (6, 7, 8, 9, 10, 11, 12, 13 and 14 years). The average age of the respondents of both genders was 10.05±2.41 years. Parents or legal guardians signed a document that they agreed for their child to participate in the research. The study protocol was performed following the ethical guidelines of the Declaration of Helsinki of 1961 (revision of Edinburgh 2013).

Anthropometric Measurements and Body Composition

The anthropometric measurements were carried in accordance with the methodology of International Biology Program (IBP). The weight was taken with medical decimal weighing scale. The height and sitting height were taken with a Martin's anthropometry. During measurements, the children were in underwear and barefooted. Body mass index was calculated as body weight in kilograms divided by the square of height in meters.

Components of body composition were assessed using bioelectrical impedance. The measuring was conducted with an OMRON BF511 body composition monitor, by means of which body weight, muscle mass percentage, body fat percentage, and fat-free mass were determined. In order to provide highly precise results from the body composition assessment, we ensured that the preconditions recommended by ACSM and Heyward (1992) were fulfilled prior to each measuring.

Evaluation of Physical Fitness

Four tests, which are part of the national MAKFIT battery, validated and standardized, were applied in the following order: Hand grip test, Standing broad jump test, 30 sec sit-ups and Shuttle run: 4 × 10 meters (Gontarev et al., 2018).

Maturity State

Maturity status was determined using the predictive non-invasive methods of Sherar et al. (Sherar et al., 2005). The prediction equation requires measurements of height, sitting height, and weight together with the birth-date and gender. This method uses a maturity-offset protocol, allowing for the prediction of time before or after peak height velocity from age, age at peak height velocity, and an estimation of percentage of adult stature attained.

Statistical analysis

The normal distribution of the variables was established through the Kolmogorov-Smirnov test. The basic descriptive statistical parameters were calculated for all the variables (mean and standard deviation). The gender differences were established through the t-test for independent samples. The association between the variables was established by the use of Pierson's coefficients of correlation. The differences regarding the age and APHV were established with the analysis of the variance and Turkey's test of specificity. Also, the calculation was made about the coefficients of determination r^2 and standard error of estimation. In all calculations, $p < 0.05$ was considered. All the analyses were performed using the Statistical Package SPSS, v. 22.0 for Windows.

Results

The anthropometric measures, physical fitness performances and body composition of the examined respondents' sample are presented in Table 1. The inspection of the Table shows that between the girls and boys there are not statistically significant differences to be established in the variables of years (p = 0.107) and sitting height (p = 0.642). The boys demonstrate higher values in: peak years of growth velocity, weight, height, body mass index, body fat expressed in kilograms and the fat-free component (p<0.001). Along with that, boys achieve better results in the fitness tests: standing long jump, 30 sec sit-ups, handgrip strength and 4 x 10m shuttle run (p <0.001).

The relations between the tests for physical fitness assessment with chronological age, fat-free mass and age at peak years of growth velocity are presented in Table 2. All the tests for assessing physical fitness were statistically significantly related to chronological age, fat-free mass and peak years of growth velocity. With the boys, the determination coefficients (r2) ranged as follows: in the test of "standing long jump" from 30 to 48%; for the test of "30 sec sit-ups" – from 14 to 27%; for the test of "handgrip strength" – from 52 to 58%; and for the test of "4 x10 meters shuttle run" – from 16 to 31%. With the girls, the determination coefficients were relatively lower. As for the test of "standing long jump", the coefficients ranged from 20 to 32%; for the

Table 1. Anthropometric profile, body composition and physical performance of the sample studied

	Boys (n=4573)		Girls (n=4443)		t	p
	Mean	SD	Mean	SD		
Age (years)	10.09	2.39	10.01	2.44	1.61	0.107
MS (APHV)	13.00	0.82	11.57	0.68	90.38	0.000
Anthropometry						
Height (cm)	144.58	15.67	143.27	14.68	4.08	0.000
Sitting height (cm)	76.00	7.31	75.93	7.37	0.47	0.642
Weight (kg)	42.41	15.48	40.88	14.04	4.93	0.000
BMI (kg/m^2)	19.65	4.00	19.38	3.95	3.16	0.002
Body composition						
Fat mass (kg)	9.77	6.24	10.38	6.61	-4.48	0.000
FFM (kg)	32.64	11.12	30.50	8.41	10.33	0.000
Physical fitness						
Standing long jump (cm)	140.87	32.03	120.09	24.33	34.60	0.000
30 sec sit-ups (n)	15.33	5.74	12.78	5.36	21.74	0.000
Handgrip strength (kg)	24.71	16.43	20.14	12.05	14.54	0.000
4×10 m shuttle run test (sec)	13.95	2.00	15.12	2.04	-27.46	0.000

t, Student's t-value, MS, maturity stage, APHV, peak growth velocity years, BMI, body mass index, FFM, fat-free mass.

Table 2. Relationship between physical fitness tests with fat-free mass and maturity status in schoolchildren of both sexes

Physical fitness	Independent variable	Boys				Girls			
		r	r^2	SEE	p	r	r^2	SEE	p
Standing long jump (cm)	Age (years)	0.70	0.48	23.02	0.000	0.57	0.32	0.32	0.000
	MS (APHV)	0.66	0.43	24.11	0.000	0.54	0.30	20.42	0.000
	FFM (kg)	0.55	0.30	26.80	0.000	0.45	0.20	21.76	0.000
30 sec sit-ups (n)	Age (years)	0.52	0.27	4.90	0.000	0.45	0.20	4.79	0.000
	MS (APHV)	0.47	0.22	5.07	0.000	0.43	0.18	4.85	0.000
	FFM (kg)	0.37	0.14	5.34	0.000	0.36	0.13	5.01	0.000
Handgrip strength (kg)	Age (years)	0.72	0.52	11.39	0.000	0.72	0.51	8.42	0.000
	MS (APHV)	0.76	0.58	10.65	0.000	0.76	0.57	7.89	0.000
	FFM (kg)	0.75	0.57	10.83	0.000	0.74	0.55	8.10	0.000
4 ×10 m shuttle run test (sec)	Age (years)	-0.56	0.31	1.66	0.000	-0.52	0.27	1.74	0.000
	MS (APHV)	-0.50	0.25	1.73	0.000	-0.50	0.25	1.76	0.000
	FFM (kg)	-0.40	0.16	1.83	0.000	-0.43	0.18	1.84	0.000

MS, maturity stage, APHV, peak years of growth velocity, SEE, standard error of estimation, r, correlation, r2, coefficient of determination

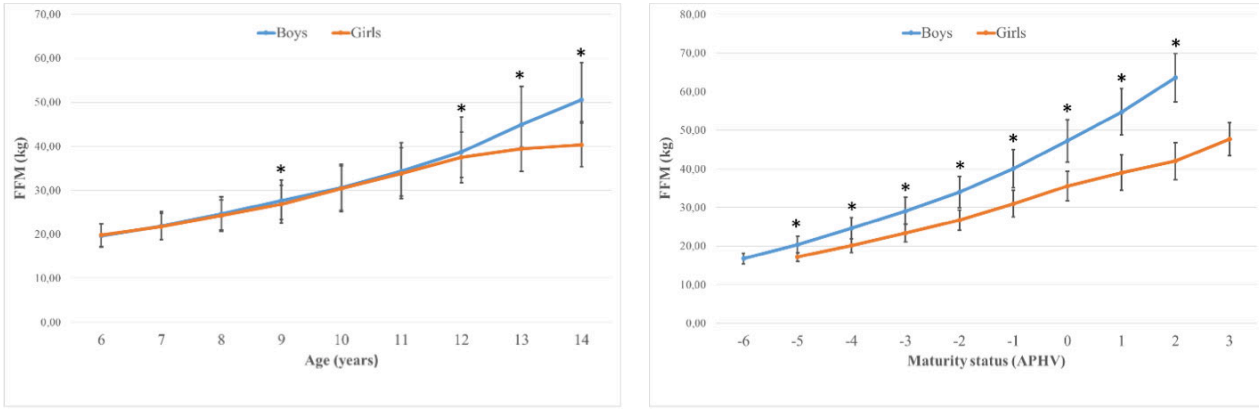

Fig. 1. Mean FFM values of children and adolescents by chronological age and maturity status.*, significant difference in relation to girls

test "30 sec sit-ups" – from 13 to 20%; the test "handgrip strength" – from 51 to 57%; and the test "4 x 10 meters shuttle run" – from 18 to 27%. The relationships between chronological age, age at peak height velocity and fat-free mass were r=0.82 to 0.94 in boys and r=0.83 to 0.92 in girls.

Chart 1 represents the comparisons of fat-free mass with reference to the chronologic age and peak years of growth velocity in both genders. In the comparisons by chronological age, differences are observed from 12 to 14 years ($p < 0.05$), however, when compared by maturity status, the differences are significant in all peak years of growth velocity (from -5APHV to +2APHV) ($p < 0.001$).

The comparisons of physical fitness performances to chronologic age and peak years of growth velocity are represented in Chart 2. Inspecting the chart, it is obvious that statistically significant differences ($p > 0.05$) were established in all of the physical fitness tests between the boys and girls of all age categories. Also, statistically significant differences were established on all APHV levels between the boys and girls in all physical fitness tests. In general, the use of the peak years of growth velocity allows a better categorization of the performance of the children and adolescents studied.

Discussion

The first research goal was to establish if fat-free mass, maturity status and chronological age are determinants of physical fitness performance (explosive power of lower limbs, handgrip strength, abdominal muscle repetitive strength, speed and agility) in Macedonian schoolchildren aged 6 to 14. The results showed a moderate relationship between fat-free mass, maturity status and chronological age with the physical fitness tests for assessing the explosive power of the lower limbs, absolute handgrip strength, abdominal muscle repetitive strength, speed and agility in both genders.

The obtained study results are in accordance with previous study works, where it is established that the physical fitness of children and adolescents is under the influence of of different factors, such as gender, age, body composition, biological maturation phase, physical activity level, apart from other factors (Malina, 2005; Malina, Bouchard, & Bar-Or, 2004).

Generally speaking, these relationships are explained due to the fact that the maximal power, explosive power, muscle strength, speed and agility are presented in a series of motor actions that must be developed efficiently. Therefore, the result of these tests is reflected in the performance and depends on the acquired muscle strength levels. Consequently, the muscle strength is defined as an ability of manifesting maximum strength in the shortes period of time, which is of crucial importance for a wide range of activities, such as running, jumping, exeleration and throwing, whereby all the tests in the present research depend on the fat-free mass (Beaudart et al., 2019; Avcin et al., 2023).

The research results indicate that chronological age, age at peak height velocity and fat-free mass during childhood and adolescence have a positive effect on physical fitness performances. A large number of research studies indicate that the proper muscle mass maintenance has important implications in everyday life and is of essential importance in performing activities of daily living (Thivel et al., 2016) and provides great benefits related to health (Smith et al., 2014).

A considerable number of previous research works point that the high level of fat-free mass can increase the insulin sensitivity (Nam et al., 2001; Berman et al., 2012), and the low level of the muscle mass is associated with a great number of metabolic risk factors and insulin resistance (McCarthy et al., 2014; Cohen et al., 2014). In this connection, the preservation and increase of skeleton muscle mass in childhood and adolescence shod be a constant care on the part of Physical Education teachers and parents. It is because maintaining the optimal skeleton muscle mass in childhood and adolescence can improve peak muscle mass and bone strength (Liu et al., 2019), and it has a positive effect on the physical performances.

The second research goal was to analyze fat-free mass and physical fitness performances in relation to chronological age and maturity status. The results showed coherence between the two indicators because the analysis based on both chronologic age and maturity status (through APHV) showed significant differences between the two genders, but the gender differences were more prominent when the analysis was done based on the maturity status (through APHV). Also, as the chronologic age and maturity status were increasing, the level of all fitness components increased too. Data from cross-sectional studies confirm our findings

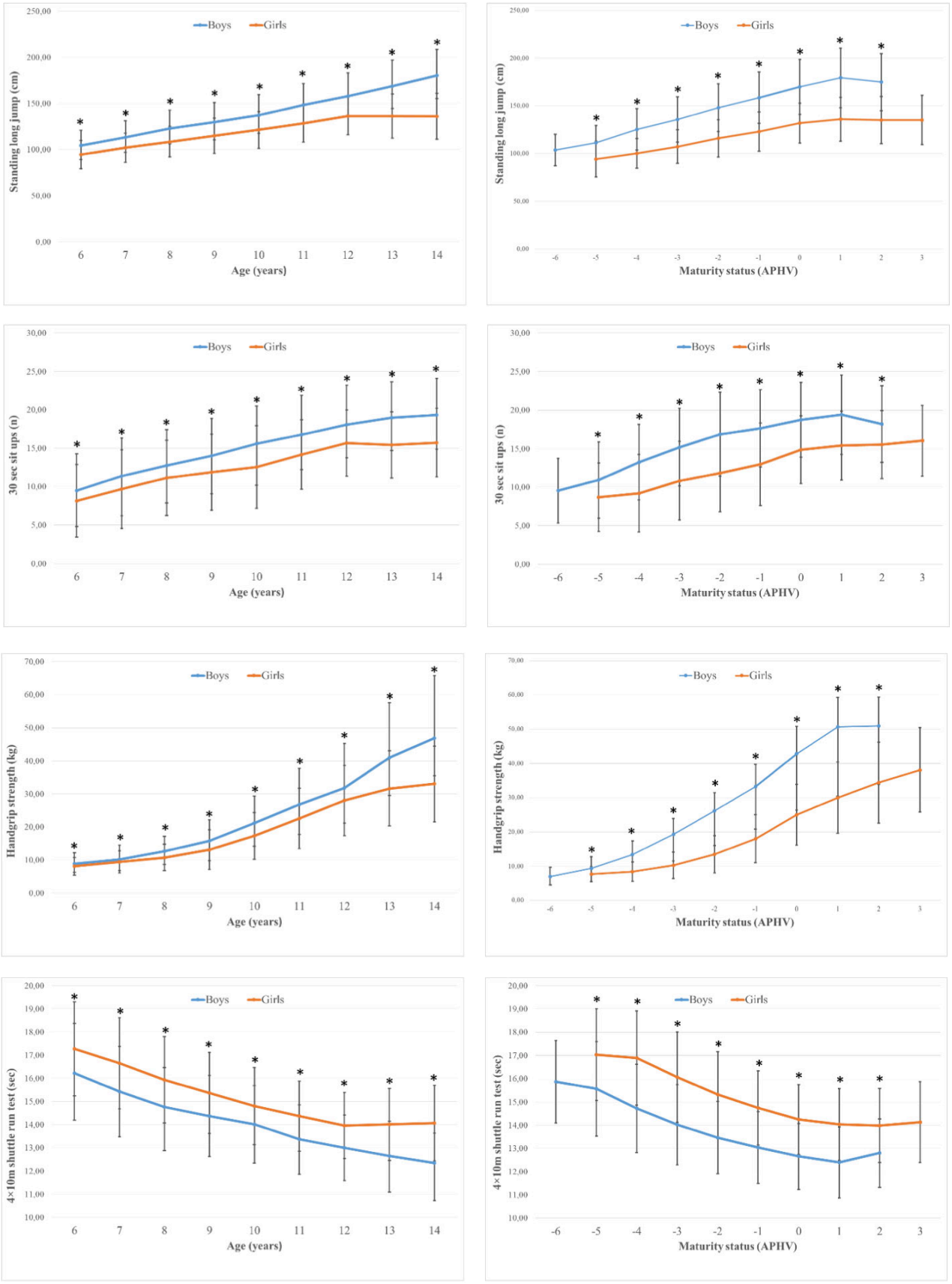

Fig. 2. Mean physical performance values of children and adolescents by chronological age and maturity status.*, significant difference in relation to girls

in as much as physical fitness enhancements were reported in groups of increasing age (Santos et al., 2014; Catley & Tomkinson 2013; Woll et al., 2011).

The research results suggest that the assessment and monitoring of fat-free mass and physical fitness performances of children and adolescents should be carried out with control of maturity status since this type of somatic maturation's indicator is often determined with regression equations that are specific for the age and gender (Moore et al., 2015), which aim to classify the state of maturation by APHV.

In general, it is considered that school children can have advantages or disadvantages in physical fitness testing by being more or less mature than their chronologically age matched counterparts. Thus, the control of time and rate of growth is of a significant importance, having in mind that the maturation is highly individual and asynchronous with the decimal age during the adolescence (Malina, Bouchard & Bar-Or, 2004). Therefore, it is of a crucial significance to classify schoolchildren according to their maturity status, especially if we wish to analyze the relation between fat-free mass and physical fitness.

In this respect, the schoolchildren of same chronological age differ considerably in their maturity status, so that there are differences in the height, weight, fat mass and fat-free mass between the adolescents of earlier maturation compared to those of average and late maturation. Actually, the adolescents who reach later maturation have in general lower functional and physical characteristics (i.e. more linear physique, lower values of the absolute and relative fat component) than their average and accelerated maturing counterparts.

In fact, as it is noted in Graphs 1 and 2, the greatest changes are observed after the APHV level forward, especially in fat-free mass, lower limbs explosive power, handgrip absolute strength, and speed and agility. Consecutively, the girls show poorer performances, whereas the boys keep improving their performances as they mature further.

It is known that often during the classes of Physical education and sport the motor actions of deceleration, acceleration, change of direction, jumping and bouncing require the ability of speedy absorbing and manifesting both unilateral and bilateral strength, and it is during these activities that many boys and girls may show different physical performance results due to children's different rhythm of maturation.

That is why it is necessary to introduce control of maturity status in classes of Physical Education and sports practice, since this indicator can contribute for adequate classification of schoolchildren. The mentioned is also considered to be a powerful indicator in classification of working groups, especially it comes about variables that refer to strength physical capacity, speed, agility and strength endurance, respectively (Malina, Bouchard & Bar-Or, 2004).

The present study has certain advantages, having in mind that it is one of the first studies conducted in the R. N. Macedonia which was held on a great sample of respondents (from 6 to 14 years of age), where, apart from the chronological age, the maturity status was also taken into consideration. Along with that, the sample selection and reliability of fitness tests and anthropometric measurements allow generalizing the results to contexts with similar characteristics. On the other hand, the transversal character of the research is noticed as a main limitation, since longitudinal research works enable the investigators to establish the cause-and-effect relationships, and even to check the changes in course of time. The maturity status control by the use of non-invasive method (the anthropometric one) can cause small prejudices in the results, yet, in the absence of other methods, the authors think that the application of this method is compatible. Along with that, this method has been applied in a greater number of previous research studies and it has appeared to be valid and reliable (Mirwald et al., 2002; Marinho et al., 2020; Cossio-Bolaños et al., 2021; Avcin et al., 2023).

Conclusions

On grounds of the obtained results, it can be concluded that fat-free mass, chronological age and maturity status are determinants of physical fitness performance (lower limbs explosive power, absolute handgrip strength, abdominal muscles' repetitive strength, speed and agility). Perhaps maturity status should be introduced in Physical education and sport as a tool for classification of physical fitness performances, especially with schoolchildren before and during the adolescence phase, since it ostensibly reduces physical and anthropometric differences in relation to chronological age.

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СТАН ЗРІЛОСТІ ТА МАСА ТІЛА БЕЗ ЖИРУ ЯК ВИЗНАЧАЛЬНІ ЧИННИКИ ФІЗИЧНОЇ ПІДГОТОВЛЕНОСТІ СЕРЕД МАКЕДОНСЬКИХ ШКОЛЯРІВ ВІКОМ ВІД 6 ДО 14 РОКІВ

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Авторський вклад: A – дизайн дослідження; B – збір даних; C – статаналіз; D – підготовка рукопису; E – збір коштів

Реферат. Стаття: 8 с., 2 табл., 2 рис., 32 джерела.

Мета дослідження. Мета дослідження полягала в тому, щоб установити, чи є маса тіла без жиру, хронологічний вік і стан зрілості визначальними чинниками фізичної підготовленості, а також проаналізувати зміни розвитку маси тіла без жиру та фізичної підготовленості у відповідності з хронологічним віком і станом зрілості у школярів віком від 6 до 14 років.

Матеріали та методи. Дослідження проведене на вибірці з 9106 учнів віком від 6 до 14 років. Для досягнення цілей дослідження вимірювали такі змінні: зріст, вага, висота в положенні сидячи, маса жиру, маса тіла без жиру та різні компоненти фізичної підготовленості (вибухова сила нижніх кінцівок, сила хвату, сила багатократного напруження м'язів живота, швидкість і спритність). Значення індексів маси тіла та біологічного дозрівання (APHV – вік на момент пікової швидкості зростання) отримували за допомогою формул.

Результати. Вік на момент пікової швидкості зростання у хлопчиків оцінювали в 13,00±0,82 року, у дівчат – в 11,57±0,68 року. Співвідношення між хронологічним віком і віком на момент пікової швидкості зростання та масою тіла без жиру становило r=0,82-0,94 у хлопчиків та r=0,83-0,92 у дівчат. Співвідношення між масою тіла без жиру та показниками фізичної підготовленості у хлопців становили: стрибок у довжину з місця (r=0,55), присідання протягом 30 с (r=0,37), сила хвату (r= 0,75) та човниковий біг 4 × 10 метрів (r= -0,40); у дівчат – стрибок у довжину з місця (r=0,45), присідання протягом 30 с (r=0,36), сила хвату (r=0,74) та човниковий біг 4 × 10 метрів (r=-0,43). Відмінності в тестах маси тіла без жиру та фізичної підготовленості були помітнішими, коли порівнювали біологічне дозрівання (APHV) і хронологічний вік.

Висновки. На підставі одержаних результатів можна зробити висновок, що стан зрілості та маса тіла без жиру визначають показники фізичної підготовленості школярів обох статей. Крім того, вік на момент пікової швидкості зростання слід використовувати у фізичному вихованні як засіб моніторингу, ранжування та класифікації фізичних показників дітей і підлітків.

Ключові слова: фізична підготовленість, маса тіла без жиру, стан зрілості, діти, підлітки.

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