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Differences between handgrip strength and anthropometric measurements with respect to the index of biological maturation in schoolchildren

Diferencias entre la fuerza de prensión manual y mediciones antropométricas con respecto al índice de maduración biológica en escolares

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Abstract

The aim of this study was to identify the differences in handgrip strength values and anthropometric measurements with respect to the index of biological maturation (IBM) in schoolchildren. A descriptive study was conducted with a total of 256 schoolchildren (78 boys and 178 girls) aged 10 to 14 years. Body weight, height and sitting height (trunk and leg length) were measured using the ISAK protocol; also, manual grip strength was evaluated with a digital dynamometer and a formula of Mirwald et al. (2002) was used to determine the peak growth velocity (PGV) through the IMB. Subsequently, the sample was categorized into 7 groups according to their BMI (-1.5, -1.0, -0.5, 0, 0.5, 0.5, 1.0 and 1.5 years). Significant differences were found in schoolchildren in the 0.5, 1.0- and 1.5-years group with respect to the -0.5, -1.0- and -1.5-years groups in body weight, height, trunk and leg length, and grip strength ($p \leq 0.05$). We conclude that the higher the biological maturation index there is a tendency for the anthropometry and grip strength values in schoolchildren to be higher with respect to those with a lower IMB.

Biological maturation index, Anthropometry, Strength

Resumen

El objetivo de este estudio fue identificar las diferencias de los valores de fuerza de prensión manual y mediciones antropométricas con respecto al índice de maduración biológica (IMB) en escolares. Se realizó un estudio descriptivo con un total de 256 escolares (78 niños y 178 niñas) de 10 a 14 años. Se les midió peso corporal, estatura y talla sentado (longitud de tronco y pierna) empleando el protocolo de ISAK, también, se evaluó la fuerza de prensión manual con un dinamómetro digital y se utilizó una fórmula de Mirwald et al. (2002), para determinar el pico de velocidad de crecimiento (PVC) a través del IMB. Posteriormente, la muestra se categorizó en 7 grupos de acuerdo con su IMB (-1.5, -1.0, -0.5, 0, 0.5, 1.0 y 1.5 años). Se encontraron diferencias significativas en los escolares del grupo de 0.5, 1.0 y1.5 años respecto a los grupos de -0.5, -1.0 y -1.5 años en peso corporal, estatura, longitud de tronco y piernas, y fuerza de prensión ($p \leq 0.05$). Concluimos que entre mayor sea el índice de maduración biológica existe la tendencia a que los valores en la antropometría y la fuerza de prensión en los escolares sean mayores respecto a aquellos que presentan un IMB más bajo.

Índice de maduración biológica, Antropometría, Fuerza

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Introduction

Biological maturation is defined as the set of phenomena of cellular growth and differentiation that contribute to the appearance of certain functions in the organism, which involves genetically programmed changes, which occur naturally over time, where each individual is born with its own biological clock that regulates its progression towards the state of maturity (Machado & Barbanti, 2007), highlighting that this process generates as a result an increase in the functional performance of various organs and systems of the human body, producing an increase in motor indicators in the sense of a potential increase in the development of physical abilities in children and adolescents (Malina et al. , 2003; Tanner & Tanner, 1990). In addition, maturation is a useful tool, which prevents the development of chronic degenerative diseases such as osteoporosis and cardiovascular diseases (Gotthelf & Fonseca, 2012; Izquierdo & Ibañez, 2017). Assessing morphological status at the age of puberty is of utmost importance, due to the significant changes that occur during the passage of biological maturation (Lidor et al., 2005; Matthys et al., 2012; Ziv & Lidor, 2009), in which the increase in body weight due to muscle development can become a transcendent factor that affects physical aptitudes and therefore physical performance.

There are now recent studies that show that, following the guidelines, children and adolescents can increase their muscle strength without impairing their growth and development (Gómez-Campos et al., 2013), which is why many scientific organisations such as the American College of Sports Medicine (ACSM), the American Academy of Pediatrics (AAP) and the National Strength and Conditioning Association (NSCA) have advanced strength training in this age group. Therefore, it is essential that the coach who works with children and youth categories knows the processes of maturation and growth of children and adolescents (Izquierdo & Ibañez, 2017), as there are coaches who choose their athletes from an early age, demanding high levels of professionalism, increasing training loads in time and intensity, which can often cause negative effects, affecting their development in sport in future stages (Lloyd & Oliver, 2019; Verdugo, 2015).

Otherwise, defining the limits of a healthy physical exercise range could improve the permanence of the child in sport up to an international level (García Vega, 2023; McKeag, 1991).

It has been concluded, that by selecting children with accelerated biological development they later lose the advantage and drop out, therefore, more success tends to be achieved by children with normal or delayed development (Catley & Tomkinson, 2013; Manonelles Marqueta et al., 2003; Stratton et al., 2004). Young people aged 16 and 17 years show a sharp increase in physical abilities, where they reach international sport mastery, but only 20% have accelerated development, with athletes with delayed development often being the highest achievers (Villamarin Menza et al., 2021).

In recent decades, attempts have been made to study and obtain evidence on the important role of the assessment of biological maturation in children and adolescents with physical skills, and some studies have analysed anthropometric variables and physical performance such as power and muscle strength with biological maturity (Chancolla Mamani, 2023; Enriquez-del-Castillo et al., 2022; Luna-Villouta et al., 2021). Other studies expose the importance of biological maturation with respect to their physical sport performance in order to identify the importance of biological maturation and experience in performance in order to observe possible differences with respect to anthropometry (body weight and height), years of practice and performance (Barnett et al., 2013; Itoh & Hirose 2020), studies have also been conducted to estimate maturation and implement training load around the PVC in physical development and thus avoid the risk of injury (Toselli et al., 2021; Towlson et al., 2021).

Having literature that exposes the importance of the assessment of biological maturation in physical fitness and sport (Fernandes et al., 2021), and noting that in our community this is not considered as a starting point to initiate a physical activity, health and training model in schools and sports clubs (Caiza, 2023). The aim of this study was to identify the differences in handgrip strength values and anthropometric measurements with respect to the biological maturation index in schoolchildren.

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Methodology

The present study was observational, descriptive and cross-sectional. A total of 256 schoolchildren (78 boys and 178 girls) aged between 10 and 14 years participated in the study. The schoolchildren belonged to public primary and secondary schools. The exclusion criterion for the study was the presence of chronic diseases or the inability to engage in physical activity. The directors, parents and participants were informed of the objective of the research, in which the parents signed the informed consent form and the schoolchildren signed their informed consent to participate in the study, in accordance with the deontological standards recognised by the Declaration of Helsinki.

Biological maturation

Biological maturation was determined by the anthropometric equation proposed by Mirwald (Mirwald et al, 2002) allowing the calculation of Peak Growth Velocity (PVC). This procedure involved the interaction of the anthropometric variables in which they were determined by personnel certified by the International Society for the Advancement of Kineanthropometry (ISAK), following the established protocol (Esparza Ros et al., 2019). The anthropometric measurements assessed were body weight in kilograms (kg) with the Tanita TBF-410 electronic floor scale (0 - 200 kg ± 0.01 kg), height in centimetres (cm) with the Seca 225 stadiometer (20 - 205 cm ± 5 mm), and sitting height (cm) with an anthropometric bench, the latter giving the length of the trunk and legs.

Subsequently, the Mirwald formula (Mirwald et al, 2002) was used to capture body weight, height, sitting height, date of assessment and date of birth (chronological age), and sex. Then categorised into 7 groups according to the BMI (-1.5, -1.0, -0.5, 0, 0.5, 0.5, 1.0 and 1.5). Negative values mean the years that the subject is missing in giving the PVC (-1.5, -1.0 and -0.5), positive values are the years that have passed when they gave the PVC (0.5, 1.0, 1.5), and the value zero (0) means the moment in which the PVC is presented.

Strength fitness

Grip strength was determined with a GRIP-D (Grip Strength Dynamometer T.K.K.5401 Texas Scientific Instruments, Nigata, Japan) digital hand-held adaptive grip dynamometer with an accuracy of 0.5 kg, which determines the isometric strength of the upper body. The protocol indicated to evaluate both limbs (right and left) following the instructions recommended by (Cruz-Jentoft et al., 2010). Three attempts were recorded for each arm (right and left), then the best result obtained was selected in order to interpret the muscle strength.

Statistical analysis

The statistical package SPSS (version 25) was used, analysing the normality of the data distribution with the Shapiro-Wilk test. The mean and standard deviation of the biological maturation index (BMI), anthropometric variables (body weight, height, trunk and leg length) and strength were calculated. Analysis of variance (ANOVA) was used to compare by BMI group, followed by Tukey's post hoc test. The significance level was considered to be $p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$ for all statistical analyses.

Results

In the data obtained, we observed that schoolchildren who have not reached their PVC (BMI: -1.5, -1.0 and -0.5) tend to have an age in years between 11.75 and 13.30 in boys and 10.20 and 11.08 in girls, while those who have passed their PVC (BMI: 0.5, 1.0 and 1.5) tend to have an age in years between 13.70 and 14.64 in boys and 11.51 and 13.64 in girls (Table 1 and 2).

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In the anthropometric measurements (Table 1 and 2), schoolchildren with a higher BMI (0, 0.5, 1.0 and 1.5) had higher values than those with a lower BMI (-1.5, -1.0 and -0.5), with significant differences ($p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$) in body weight measurements in girls ([-0.5 > -1.5], [0 > -1.5], [0.5 > -1.5, -1.0 and -0.5], [1 > -1.5] and [1.5 > -1.5, -1.0, -0. 5 and 0]), in height in boys ([-0.5 > -1.5], [0 > -1.5], [0 > -1.5 and -1.0], [1.0 > -1.5 and -1.0] and [1.5 > -1.5 and -1.0]) and girls ([-1.0 > -1.5], [-0. 5 > -1.5], [0 > -1.5, -1.0 and -0.5], [0.5 > -1.5, -1.0 and -0.5], [1.0 > -1.5 and -1.0] and [1.5 > -1.5, -1.0 and -0.5]), in trunk length in boys ([-0. 5 > -1.5 and -1.0], [0 > -1.5 and -1.0], [0.5 > -1.5 and -1.0], [1> -1.5 and -1.0] and [1.5 > -1.5 and -1.0]) and girls ([-1.0 > -1. 5], [-0.5 > -1.5 and -1.0], [0 > -1.5, -1.0 and -0.5], [0.5 > -1.5, -1.0 and -0.5], [1.0 > -1.5, -1.0 and -0.5] and [1.5 > -1.5, -1.0 and -0. 5]), in leg length in boys ([-0.5 > -1.5], [0.5 > -1.5] and [1.0 > -1.5]), and girls ([0 > -1.5], [0.5 > -1.5 and -1.0] and [1.5 > -1.5]).

In the physical fitness of manual grip strength (Table 1 and 2), those with a higher BMI showed greater strength than those with a lower BMI, with significant differences ($p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$) found in both boys (0.5 > -1.5 and -1.0) and girls (0.5 > -1.5 and -1.0) ([0 > -1.5], [0.5 > -1.5], [1.0 > -1.5] y [1.5 > -1.5, -1.0 y -0.5]).

	Biological maturation index						
	- 1.5 (*n* = 26)	- 1.0 (*n* = 21)	- 0.5 (*n* = 14)	0 (*n* = 5)	0.5 (*n* = 8)	1.0 (*n* = 2)	1.5 (*n* = 2)
Age (years)	11.75 ± 0.82	12.11 ± 1.18	13.30 ± 0.64	13.70 ± 0.76	14.30 ± 0.41	14.64 ± 0.01	14.41 ± 0.46
PVC (years)	13.17 ± 0.68	13.11 ± 1.07	13.64 ± 0.67	13.65 ± 0.80	13.84 ± 0.33	13.79 ± 0.06	12.84 ± 0.55
IMC (kg/m²)	23.58 ± 5.62	22.67 ± 5.52	21.78 ± 4.38	22.46 ± 3.80	21.92 ± 3.48	19.36 ± 0.49	23.28 ± 4.51
Anthropometry							
Weight (kg)	54.72 ± 13.6	55.14 ± 14.6	56.84 ± 13.22	58.52 ± 10.66	59.16 ± 9.96	56.60 ± .014	68.15 ± 17.7
Height (cm)	152.2 ± 5.32	155.7 ± 7.44	161.1 ± 5.86 a***	161.2 ± 2.40 a*	164.2 ± 3.40 a*** b**	171.0 ± 1.97 a*** b**	169.2 ± 7.63 a*** b*
Trunk length (cm)	79.94 ± 2.88	81.00 ± 2.94	83.85 ± 2.99 a*** b*	85.38 ± 2.65 a*** b*	86.26 ± 1.14 a*** b***	88.55 ± 0.35 a*** b**	89.15 ± 2.61 a*** b***
Leg length (cm)	72.31 ± 3.30	74.73 ± 5.00	77.27 ± 3.32 a**	75.90 ± 1.55	77.95 ± 3.80 a*	82.45 ± 2.33 a*	78.55 ± 7.14
Physical fitness Strength (kg)	20.36 ±7.46	20.82 ± 6.22	24.62 ± 6.87	26.44 ± 6.52	30.82 ± 6.61 a*** b***	28.50 ± 1.27	30.05 ± 2.33

Note. n: number; PVC: peak growth velocity; BMI: body mass index; kg/m2: kilograms over metres squared; cm: centimetres; kg: kilograms; a: significantly greater than (-1.5); b: significantly greater than (-1.0); c: significantly greater than (-0.5); d: significantly greater than (0); e: significantly greater than (0.5); f: significantly greater than (1.0); g: significantly greater than (1.5). Significance value: $p \leq 0.05$ (∗), $p \leq 0.01$ (∗∗) y $p \leq 0.001$ (∗∗∗)

Table 1 Differences in anthropometric characteristics and hand pressure strength with respect to the biological maturation index of male schoolchildren

	Biological maturation index						
	- 1.5 (n = 38)	- 1.0 (n = 45)	- 0.5 (n = 39)	0 (n = 28)	0.5 (n = 17)	1.0 (n = 5)	1.5 (n = 6)
Age (years)	10.28 ± 0.65	10.57 ± 0.52	11.08 ± 0.50	11.51 ± 0.63	12.01 ± 0.44	13.32 ± 0.69	13.64 ± 0.64
PVC (years)	11.74 ± 0.59	11.52 ± 0.55	11.56 ± 0.48	11.51 ± 0.60	11.51 ± 0.39	12.19 ± 0.64	12.11 ± 0.63
IMC (kg/m²)	18.57 ± 3.16	20.23 ± 4.59	20.85 ± 4.55	21.06 ± 4.76	22.91 ± 4.21	22.95 ± 3.42	25.24 ± 4.50
Anthropometry							
Weight (kg)	38.35 ± 6.89	42.81 ± 10.0	46.03± 8.71 a**	49.51±10.94 a***	55.70 ± 9.83 a*** b*** c**	55.40 ± 9.50 a**	63.53±13.14 a*** b*** c*** d*
Height (cm)	142.8 ± 4.55	146.8 ± 5.77 a**	149.4 ± 3.75 a***	153.4 ± 3.45 a*** b*** c*	156.0 ± 3.17 a*** b*** c***	155.3 ± 5.58 a*** b**	158.2 ± 2.98 a*** b*** c***
Trunk length (cm)	74.78 ± 2.76	77.13± 3.50 a**	79.04 ± 2.07 a*** b*	81.35 ± 2.25 a*** b*** c*	83.10 ± 1.76 a*** b*** c***	83.28 ± 1.64 a*** b*** c*	84.45 ± 2.37 a*** b*** c***
Leg length (cm)	68.27 ± 3.08	69.48 ± 4.88	70.55 ± 3.21	72.12 ± 2.53 a***	72.92 ± 3.24 a*** b*	72.02 ± 4.31	73.80 ± 1.04 a*
Physical fitness Strength (kg)	13.93 ± 2.68	16.10 ±3.32	16.18 ±3.13	18.24 ±3.76 a***	18.81 ±3.79 a**	19.74 ±4.63 a***	21.35 ±3.97 a*** b** c**

Note. n: number; PVC: peak growth velocity; BMI: body mass index; kg/m2: kilograms over metres squared; cm: centimetres; kg: kilograms; a: significantly greater than (-1.5); b: significantly greater than (-1.0); c: significantly greater than (-0.5); d: significantly greater than (0); e: significantly greater than (0.5); f: significantly greater than (1.0); g: significantly greater than (1.5). Significance value: $p \leq 0.05$ (∗), $p \leq 0.01$ (∗∗) y $p \leq 0.001$ (∗∗∗).

Table 2 Differences in anthropometric characteristics and hand pressure strength with respect to the biological maturation index of female schoolchildren

Discussion

Body growth such as proportionality or muscle mass, and physical skills such as some conditional abilities during puberty take a very drastic change (Malina et al., 2004), remembering that after this stage minimal growth and developmental changes are usually shown. That is why the present study had the general purpose of identifying the differences in handgrip strength values and anthropometric measurements with respect to the biological maturation index in schoolchildren. From the results obtained, we were able to observe significant differences between the biological maturation indices in anthropometric and strength measurements ($p \leq 0.05$, $p \leq 0.01$ and $p \leq 0.001$). In which schoolchildren with a higher BMI showed higher body weight, height and trunk and leg length than schoolchildren with a BMI of -1.5, -1.0 and -0.5.

During the PVC, a number of changes in body composition usually occur, the main change being muscle mass, which is an indicator of body weight (Barnett et al., 2013), if we look at our schoolchildren, only girls showed significant results of body weight of those of a high IMB than those of a low IMB, this may be because women usually give increase in body weight (muscle and fat) at early ages such as 12 and 13 years, while and boys a little later which are at 14 and 15 years of age, although at the end of growth, boys are almost 30% increase muscle mass and therefore body weight (Malina et al., 2004).

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In relation to bone length such as height, trunk and legs, we found significant results in men and women, since at the time of giving the PVC consisting of IMB of -0.5 to 0.5, a height increase of 20 to 25 cm is usually achieved (Malina et al., 2004), which also involves the longitudinal growth of the trunk and legs. Subsequently after passing the PVC, the increase in height, leg and trunk length is not very significant, as shown by the work of Hammami et al. (2019) and Matthys et al. (2013) with youth handball players.

In terms of handgrip strength, our schoolchildren with a higher IMB showed better performance than those with a lower IMB, these findings are in agreement with the work of Enriquez-del-Castillo et al. (2022), where higher results in dominant handgrip strength were observed in girls and a positive correlation between PVC and dominant handgrip strength in all children. According to other studies, biological maturation increases physical abilities in schoolchildren, as well as biological maturation levels have been shown to influence anaerobic and athletic performance (Almeida-Neto et al., 2022).

Likewise, other studies such as Hammami et al. (2019), Matthys et al. (2013), Navarro (2008) and Romero-García et al. (2022), where with children and young athletes, observed that strength is affected by development and biological maturation, recommending its inclusion in biomedical assessments for the planning and dosage of training. Although the number of years of training has been shown to contribute to the overall physical and technical performance levels of players, in these findings, individuals who reached full maturity at a younger age were larger, weighed more and possessed higher levels of strength and other physical abilities (Guimarães et al., 2019).

The sex difference in strength increases by 10% to 40% after puberty (Catley & Tomkinson, 2013; Stratton et al., 2004). Some studies in boys and girls have determined differences in physical tests such as strength (Catley & Tomkinson, 2013), observing that boys achieve better results than girls, but it is chronological age that makes the increase in strength.

In our results, those with a higher IMB were found to have higher strength values than those with a lower IMB, with girls at younger ages (11 years) and boys slightly later (14 years) where these findings were found. These data are similar to the work of Albaladejo-Saura et al. (2021) where they examined the impact of chronological age and biological maturation on variations in anthropometric and fitness profiles in athletes of both genders, showing that age and biological maturity have a clear impact on the discrepancies found between both genders.

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Conclusions

The results obtained in this study indicate that the higher the BMI, the greater the tendency for the anthropometric and grip strength values of schoolchildren to be higher than those with a lower BMI. These findings suggest that biological maturation is a starting point for establishing physical work groups in schools and in sports, and thus generate training guidelines on the degree of maturation and the peak growth rate, which could serve as a talent detection process, to reach the physical enhancement to reach the highest levels of sporting competition.

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