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Original Article

EFFECTS OF MATURATION AS A COVARIATE OF SEX DIFFERENCE ON MOTOR COMPETENCE IN ADOLESCENTS

EFEITO DA MATURAÇÃO COMO COVARIÁVEL DA DIFERENÇA ENTRE SEXOS NA COMPETÊNCIA MOTORA EM ADOLESCENTES

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ABSTRACT
The aim of this study was to evaluate differences between sexes in motor competence (MC) by product- and process-oriented assessments, and examine the effect of maturation as a covariate influencing the MC of boys and girls. The sample comprised 50 adolescents (28 boys), aged 11-17 years (14.02 ± 2.49), from two public schools. The MC was evaluated in three skills (horizontal jump, hop and throw) by process- (developmental sequences for body components) and product-oriented assessments (distance, time and speed, respectively). Maturation was evaluated with the peak height velocity (PHV). Sex differences were evaluated using ANOVA and, subsequently, ANCOVA, considering the PHV as a covariate. Boys had better MC in all the skills for product-oriented assessment, and most of body components for process-oriented assessment. After using the PHV as a covariate, the magnitude of differences between sexes increased in most of motor skills for both types of assessments, favoring boys. Considering the effect of maturation on the difference between the sexes in the MC, we emphasize the need to observe the maturation while studying the MC during adolescence.
Key-words: Psychomotor performance. Motor development. Adolescents.

RESUMO
O objetivo do presente estudo foi verificar a diferença entre sexos na competência motora (CM) avaliada por produto e processo do movimento, e analisar o efeito da maturação como uma covariável influenciando a CM de rapazes e moças. A amostra foi composta por 50 adolescentes (28 rapazes), com idade entre 11 e 17 anos (14,02±2,49), provenientes de duas escolas públicas. A CM foi avaliada em três habilidades (salto horizontal, saltito e arremesso sobre o ombro), por meio de medidas orientadas ao processo (sequências desenvolvimentais por componentes corporais) e ao produto do movimento (distância, tempo e velocidade, respectivamente). A maturação foi avaliada com o pico de crescimento em estatura (PCE). Diferenças entre os sexos foram avaliadas com a ANOVA One-Way e, posteriormente, a ANCOVA, utilizando o PCE como covariável. Os rapazes tiveram melhor CM em todas as habilidades nas medidas de produto do movimento e na maioria dos componentes corporais, que mediram o processo do movimento. Após a utilização do PCE como covariável, a magnitude da diferença entre os sexos aumentou na maioria das habilidades motoras para ambos os tipos de medida, favorecendo os rapazes. Considerando o efeito da maturação sobre a diferença entre os sexos na CM, ressaltamos a necessidade de observar a maturação ao examinar a CM na adolescência..
Palavras-chave: Desempenho psicomotor. Desenvolvimento motor. Adolescentes.

Introduction

The term motor competence (MC) has been used to describe movements aimed at goals that involve control and coordination of the human body[1.2]. A growing body of evidence has pointed out the importance of MC for maintenance of health, since high MC is associated with a higher physical activity levels[3,4] and physical fitness[1,5], in addition to the maintenance of a healthy weight in childhood and adolescence [1,5].

The literature has suggested various correlates to the development of MC, among which stand out the age, weight status and sex[6]. In both sexes, with advancing age, accompanied by the improvement of biological functions (maturation) and the accumulation of perceptual-motor experiences, is associated with an increase in MC[7,8]. Regarding weight status, youth with healthy weight exhibit higher MC than those with overweight and obesity[1,5,9]. Nonetheless, the literature has not been conclusive when it comes to the differences between sexes in MC. Some studies have shown that boys show higher MC in object control skills[10-12]; there are also studies that show superiority for girls in locomotor skills[13,14] and others who have not found differences in MC related to sex[15-17]. Although some sociocultural influences allow to speculate possible explanations for these differences (e.g. greater encouragement to practice of physical activities and sports), such results may also be related to the type of measurement of MC[6] and/or to the phase of development investigated.

The use of both product-oriented measures as those oriented to the process of movement could provide valuable information, allowing a more comprehensive understanding of the differences between the sexes in MC. A recent study of meta-analysis confirmed the boys' superiority in object control skills, especially when the MC is assessed by means of product-oriented measures, that emphasize strength, speed or power, different from process-oriented measures, which assess the quality of motor action[6].

Since most of the studies have investigated early and middle childhood, little is known about the difference between sexes in adolescence, a phase in which the maturation may have an important role influencing the MC in both sexes. It is known that the adolescence period is marked by considerable physical, physiological and psychological changes caused by the maturation process[18]. In parallel, it is widely known that the inter-individual variation in biological maturation tends to influence the growth and the physical performance in adolescence[18,19], mainly because differences between boys and girls in timing and pubertal growth spurt time can promote biomechanical changes due to not synchronized growth from different parts of the body, as well as their respective proportions[20,21]. Thus, such alterations may affect the difference between sexes in MC. Studies that use only the chronological age, do not consider the differences in the timing of maturation and, thus, the influence of maturation on the MC of adolescents has been scarcely reported[21,22].

Antunes et al.[22] assessed motor coordination, gross motor skills, physical activity, physical fitness and skeletal maturation in children aged between 6 and 8 years old, and reassessed the motor coordination of the same subject after 6 years, i.e., in adolescence. Their results were presented separately for boys and girls, and indicated that the biological maturation in childhood was not a significant predictor of the development of motor coordination in adolescence in both sexes. Whereas the study by Freitas et al.[21] evaluated the relationship between motor coordination and skeletal maturation in adolescents aged 11 to 14 years old, and showed that, regardless of other variables, the skeletal maturation came to explain up to 8.1% of the variance of motor coordination of boys and up to 2.8% of the girls. The authors reinforce that the relationship between motor coordination and maturation status differs according to sex, which leads us to emphasize the importance of investigating the maturation in studies on the MC of adolescents.

Considering that knowing the role of maturation would be essential to evaluate the MC of adolescents and that a more comprehensive view of MC must use measures of process and product, the objective of this study was to verify the difference in MC of boys and girls, evaluated by product- and process-oriented assessments, and examine the effect of maturation as a covariate influencing the MC.

Methods

This is a comparative cross-sectional study[23], whose procedures were approved by the Ethics Committee of the University of Pernambuco (CAAE: 05712212.9.0000.5207).

Participants

A non-probabilistic sample was composed of 50 adolescents (56% boys) aged between 11 and 17 years (μ=14.02; SD=2.49) from two public schools in the city of Recife, Brazil. All teenagers had the Informed Consent Form signed by parents or guardians. To participate in the study, the adolescents should not present any physical or intellectual condition that would prevent them from performing the tests.

Instruments and Procedures

The assessment of MC was held with process-oriented measures (quality of the body components actions) and the product of the horizontal jump, hop, and tennis ball throwing. Recent studies have used these skills to evaluate the MC in children and adolescents[24,25], suggesting a good sensitivity to discriminate the MC of young people[24].

The product-oriented measurements of MC were the following: (1) horizontal jump - distance in centimeters from the line of departure to the closest proximal landing point; (2) hop - time performed in jumps with one foot over a distance of 10 meters; (3) tennis ball throwing – maximum ball speed measured with radar gun (Buschnell Model 10-1911). All children were instructed to perform 5 attempts with maximum effort to produce more advanced ballistics skills patterns of movement. For analysis, the best performance was used.

To evaluate the process of movements the analysis of developmental sequences for bodily components was used[26,27]. In the horizontal jump and in hop the body components of the arms actions were analyzed (1 to 4 points in both the skills) and the legs (1 to 4 points in the horizontal jump, and 1 to 5 points in hop). Regarding the throwing the trunk actions were analyzed (1 to 3 points), swing of the arm forward (1 to 3 points), forearm forward movement (1 to 3 points). The most elevated scores in the body components are related to the most advanced domain stages of such skills. Five attempts were recorded, but it was used for analysis only the one which reached the best score of the product of movement.

The maturation status was assessed using the calculation of age at peak height velocity (PHV)[28], also called of maturity offset, obtained from the chronological age in years and the measures of height, body mass index, trunk-head height and the lower limbs length. Height was measured with a portable stadiometer (Glicomed) with a precision of 0.1 cm, and body mass was measured using a digital scale (Glicomed) with a precision of 0.1 kg. For the verification of the sitting-height the measure between the highest point of the head (vertex) and the support plan of the hip (Ischial spines) is made with the individual sitting in a 50-cm bench and keeping the head in the Frankfurt horizontal plane; trunk-head height was obtained by subtracting the height measured with the individual being assessed from the sitting-height; the leg length was obtained by the difference between the height and the sitting-height. The age calculation in years for PHV was performed based on the following equation: (a)boys: $PHV = -9.236 + [0.0002708 \times (LL \times SH)] + [-0.001663 \times (A \times LL)] + [0.007216 (A \times SH)] + [0.02292 \times (BM/H) \times 100]$; (b) girls: $PHV = -9.376 + [0.0001882 \times (LL \times SH)] + [0.0022 \times (A \times LL)] + [0.005841 \times (A \times SH)] - [0.002658 \times (A \times BM)] + [0.07693 \times (BM/H) \times 100]$, where: LL = Leg length; H = Height; A = Age; BM = Body mass; SH = Sitting-height.

Statistical analysis

Initially, the data were analyzed for normality (Kolmogorov-Smirnov test and inspection of histograms) and presented descriptively with mean and standard deviation for numerical variables (Tables 1 and 2). To evaluate possible differences in MC of boys' and girls' analyses of variance for a factor were performed (ANOVA One-Way). Subsequently, the analysis of covariance (ANCOVA), using the age at PHV as covariate, was performed to verify the influence of maturation on the difference between the sexes. Effects sizes were calculated with eta squared (η^2) considering η^2=0.01 as low, η^2=0.06 as medium and η^2=0.14 as large effect[29]. All the analyses were performed with the software SPSS 2.1 adopting a significance level of $p<0.05$.

Results

Table 1 shows the descriptive characteristics of the individuals according to the sexes. Although boys and girls have not exhibited differences in anthropometric characteristics, the girls are maturationally more advanced that the boys, once that they had higher age at PHV (Table 1).

Table 1. Descriptive characteristics of the sample

Variables	Boys (n=28)	Girls (n=22)	F
	Mean (SD)	Mean (SD)	
Age, years	13.96 (2.74)	14.09 (2.18)	0.31
Body mass, kg	54.05 (15.83)	48.80 (11.75)	1.69
Height, cm	161.07 (13.62)	156.97 (8.29)	1.54
BMI, $kg \cdot m^{-1}$	20.63 (4.27)	19.68 (3.89)	0.65
PHV, years	-1.24 (2.10)	2.70 (2.52)	36.35*

Note: BMI, body mass index; PHV, peak height velocity; *p<0.01
Source: The authors.

When comparing the boys' and girls' performance regarding the product of movement, significant differences were found in all the skills in favor of the boys ($p\leq0.05$). After considering the adjustment through the PHV, the differences increased for horizontal jump and for hop, and they decreased at the throw. The effect size for the differences observed in all the sills was large (Table 2).

At the comparison between sexes for the measures of process, the boys had superior performance in the action of at least one body component of each skill (Table 2). In the horizontal jump no differences were found between the sexes in the ANOVA One-Way ($p>0.05$), however with the inclusion of the age at PHV as a covariate in ANCOVA, boys showed superiority in action of the arms [$F(2.47)=8.14$; $p<0.01$; $\eta2=0.15$]. In hop, ANOVA One-Way indicated that the boys showed better performance in body components of the arm [$F(1.48)=7.58$; $p<0.01$; $\eta2=0.14$] and of the leg [$F(1.48)$; $p<0.05$; $\eta2=0.11$]. After adjustment by the age at PHV, with the use of ANCOVA, there was a decrease in the magnitude of the difference between sexes in the arms action [$F(2.47)=11.79$; $p<0.01$; $\eta^2=0.20$], and an increase in the legs action [$F(2.47)=12.70$; $p<0.01$; $\eta^2=0.21$]. At the throw over their shoulder, ANOVA One-Way showed differences between sexes at the trunk action [$F(1.48)=11.46$; $p<0.01$; $\eta^2 2=0.19$] and the arm [$F(1.48)=7.17$; $p<0.05$; $\eta^2=0.13$], both in favor of boys; at the ANCOVA, after the inclusion of the \age at PHV as a covariate, there was a decrease in the magnitude of the difference at the trunk action [$F(2.47)=12.99$; $p<0.01$; $\eta^2=0.22$] and increase at the arms action [$F(2.47)=50.67$; $p<0.01$; $\eta^2=0.52$]. All the differences found in the comparison between sexes, from the measurements of process, had large effect size after considering the age at PHV as a covariate, with the exception of the action of the legs components in hop, whose effect size was medium.

Table 2. Differences between sexes in the MC by product- and process-oriented measures, without and with adjustment of the age at PHV.

Skills	Boys (n=28) Mean (SD)	Girls (n=22) Mean (SD)	F	η^2	F_{PHV}	η^2
Product-oriented measurements						
Horizontal jump, cm	195.53 (51.02)	151.86 (27.10)	13.16**	0.21	50.05**	0.52
Hop, s	1.67 (0.28)	2.00 (0.44)	10.11**	0.17	15.00**	0.39
Throw, m/s	40.46 (9.39)	30.63 (5.12)	19.49**	0.29	23.19**	0.33
Process-oriented measurements						
Horizontal jump						
Arm	3.57 (1.14)	3.27 (0.98)	0.96	0.02	8.14**	0.15
Leg	3.96 (0.79)	3.82 (0.50)	0.57	0.01	1.87	0.04
Hop						
Arm	3.93 (0.98)	3.04 (1.29)	7.58**	0.14	11.79**	0.20
Leg	3.71 (0.60)	3.22 (0.81)	5.95*	0.11	12.70**	0.21
Throw						
Trunk	2.29 (0.53)	1.77 (0.53)	11.46**	0.19	12.99**	0.22
Arm	2.82 (0.77)	2.13 (1.04)	7.17*	0.13	50.67**	0.52
Forearm	2.21 (0.63)	2.05 (0.58)	0.95	0.02	2.77	0.06

Note: *p<0.05; **p<0.01
Source: The authors

Discussion

The objective of this study was to examine the difference between sexes in MC evaluated by means of product- and process-oriented measurements, and the maturation effect as a covariate influencing the MC in adolescent boys and girls. In general terms, the results show that boys had better performance in all the measurements oriented to the product of the movement and in the majority of the body components for the process-oriented measurements. After using the age at PHV as a covariant of MC, the magnitude of the difference between the sexes increased in most of motor skills for both types of measurements.

Differences between the sexes in MC are widely documented in the literature [6,8,], although the superiority of one over the other is not consensual[6]. A recent meta-analysis study presents strong evidence for the superiority of boys in object control skills, which was not confirmed to the skills of locomotor or stability[6]. Ratifying the results of Barnet et al.[6,] other studies with adolescents have shown that boys have higher MC in object control skills (e.g. throw, kick, strike)[11,12,25] or on tasks of motor coordination (e.g. hopping for height on one foot and moving sideways)[21,22]. Locomotor skills (e.g. jumps and gallop) and stability (e.g. walking backwards) did not seem to differ between the sexes[12,21,22]. De Meester et al.[15], in turn, found no differences between the sexes. In line with the meta-analysis conducted by Barnet et al.[6], such findings highlight that the differences between sexes may express themselves in different forms according to the type the motor skill investigated.

In this study, the MC assessment counted on process- and product-oriented measurements, in locomotor and object control skills. The use of both types of measurements has been suggested in recent studies on the evaluation of motor skills[24,30], because it is a more comprehensive and reliable form to represent the MC, especially when examining the quality of the movement pattern and the product resulting from such motor action. As to the measurement of product movement, our results initially showed that boys were significantly higher in all the skills assessed. As to the process of movement, boys were also superior in at least one body component of developmental sequences of movement. These findings differ from other studies with adolescents who have not found differences between the sexes in locomotor skills[12,15,21,22]. These differences may be related to socio-cultural influences, i.e., boys may be more encouraged to practice physical and/or sportive activities, which, in turn, may provide opportunity for the development of MC[6,11,12]. Additionally, the literature has suggested that the boys can benefit from advantages due to their anthropometric measurements and their physical capacities[6,18], which underpin the implementation of motor skills, especially when the MC measurement evaluates the environmental outcome of the movement, i.e., in product-oriented measurements[31,32].

It is widely recognized that the adolescence period is marked by biological constant changes greatly influenced by the maturation process[18,19]. As expected, our results confirm that the boys reach the age at PHV later than girls (see Table 1). Therefore, the present study used the maturity offset as a covariate to examine the difference between the sexes in MC, in order to balance potential benefits resulting from the maturation *timing*, particularly due to the girls to be more advanced in maturational terms.

The superiority of the boys demonstrated before the use of age at PHV as a covariate suggests that the girls seemed not to take advantage of the maturation benefit to achieve a higher MC. After the use of age at PHV as covariate, the magnitude of the differences between the sexes increased in most skills (see Table 2), and in both measures. However, the skills used in the present study, also called ballistics[32], require high levels of power and inter- and intramuscular coordination[1], which are essential for participation in a wide variety of sports throughout life[33,34] and enjoy together the development of MC and multiple aspects of physical fitness, especially the neuromuscular development[1,25,35]. Considering that during the adolescence boys are also often more involved in the practice of sports[36,37], it is possible that such participation may also have stimulated the increase of the differences between the sexes, although longitudinal or experimental studies are necessary. In addition, it is plausible to assume that, among the girls, some physical and physiological changes inherent in the puberty process, such as changes in body composition (increase in the quantity of fat), proportions (increase in the width of the hips), as well as discomfort with the establishment of the menstrual cycle may be associated with the decrease in the practice of physical and sports activities, disfavoring the development of MC[18,37].

The present study has some limitations that should be reported. First, the cross-sectional design used preclude the causal attribution for the differences, so as not it does not make it possible to know whether the differences tend to increase across time. Another limitation is regarding the use of an indirect measure for the maturation assessment. Although there are different methods to assess the maturity (e.g. skeletal age, menarche age, puberty stage, a percentage of the father's height, among others)[18], the maturity offset has been widely used as a noninvasive method to evaluate the biological maturation, besides being an important covariate of motor performance, physical activity and physical fitness in adolescence[18,38,39]. The sample size of this study may have affected the distribution of subjects in the different stages of maturation, even though our study was able to detect differences between the sexes in all the skills assessed, and thus studies with larger samples would be desirable to confirm our results. Data on the practice of physical activities and sports for adolescents could also provide important information to interpret the differences found. However, some strengths of the present study need to be highlighted: (i) our study is one of the few to examine the difference between genders in the adolescents' MC , especially in Brazil; (ii) the MC assessment regarding the process and the product of movements has been suggested in recent studies of motor development[24,30], particularly due to revealing different aspects of MC; (iii) the use of age at PHV as a covariable of the comparison between the sexes permitted to assess the influence of maturation on the adolescents' MC.

Differences between the sexes can be minimized if there are efforts to ensure that girls have well-successful motor experiences and receive adequate instructions in physical and sports activities, in order to develop fully different aspects of MC. Parents, teachers and physical education professionals can benefit from these pieces of information to consider the role of maturation during adolescence in order to attenuate sex differences and promote important health aspects related to MC throughout life.

Conclusions

Based on the results it can be concluded that, in this sample, the boys had higher MC than the girls, regardless of the type of measurement of MC, i.e., not only for measurements that emphasize the quality of moviment patterns but also to evaluate the movement outcome. In addition, the use of covariate maturity offset tends to exacerbate the difference between sexes in MC, especially favoring the boys. Considering the effect of maturation on the difference between the sexes in the MC, we emphasize the need to observe the maturation while studying the MC during adolescence.

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