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ORIGINAL ARTICLE

Influence of age, sex and somatic variables on the motor performance of pre-school children

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Abstract

Background: Biological factors can affect the motor development process of children. However, the magnitude of these effects throughout the developmental process remains fairly unknown.
Aim: To determine the influence of age, sex and selected somatic measures on the motor performance of pre-school children.
Subjects and methods: Three hundred and sixty-seven pre-schoolers (172 boys and 195 girls), aged from 3–5 years old, were recruited from 10 public pre-schools located in the district of Viana do Castelo, Portugal. The children's motor performance was assessed by five motor sub-tests of Peabody Developmental Motor Scales-2: grasping, visuo-motor integration, stationary, locomotion and object manipulation sub-tests. Age, sex, height, weight and BMI were considered as hypothetical predictors of motor performance. Pearson's correlation test and multiple linear regression analysis were used to explore the magnitude of the relationship between motor sub-tests and the hypothetical predictors.
Results: Depending on the motor sub-test and age group, the models predicted motor performance from a minimum of 3.6% to a maximum of 34.4%. Age in months and sex stood out as the main predictors of motor performance.
Conclusions: The relationship between motor performance and selected biological factors varied with age and with the specificity of the motor test.

Keywords

Motor performance, PDMS-2, pre-school children, sex

History

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Introduction

The pre-school period is considered a critical time for the development and learning of fine and gross motor skills (Gabbard, 2011; Malina, 2004). The acquisition of a broad motor repertoire is an important prerequisite for advanced motor skills and may be related to active and healthy lifestyles (Barnett et al., 2009; Lubans et al., 2010; Okely et al., 2001; Williams et al., 2008; Wrotniak et al., 2006). This exact same idea is stated in a recent model of developmental mechanisms influencing lifestyle trajectories of children (Stodden et al., 2008), which predicts either a positive or negative spiral of engagement in physical activity throughout life. This process will depend on the early development of motor competence and its related effects on the self-perception of motor competence, physical activity behaviours and physical fitness. The relationship between physical activity and motor competence is cyclical or reciprocal. However, some studies indicate that it is not so much amount of physical activity that may explain motor competence, but mainly motor proficiency that seems to predict children's involvement in motor activities during childhood (Lopes et al., 2011a) and adolescence (Barnett et al., 2011).

Currently, it is accepted that early development of children's motor competence is dependent on the interaction between environmental and biological factors. Although the quality and the amount of movement experiences during childhood is initially strongly related to the child-selected conditions (e.g. biological status at birth), it will be shaped later to the nature of environmental variables and to the equilibrium of maturational processes.

Research indicates that certain characteristics of the child can affect the developmental process at different ages. For example, lower birth weight and lower gestational age are strongly related to poorer motor outcomes in the first years of life (e.g. de Kieviet et al., 2009; Goyen & Lui, 2009; Kuklina et al., 2006; Sommerfelt et al., 2002). Also, a sex effect on children's motor performance can be observed at early ages (Ikeda & Aoyagi, 2008; Lung et al., 2011; Spessato et al., 2012; Thomas & French, 1985). This different motor competence of boys and girls has been attributed to environmental and educational influences but also to biological factors such as advanced neurological development favouring girls and to some morphological characteristics favouring

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boys (Gabbard, 2011; Ikeda & Aoyagi, 2008). Despite this well-known relationship between motor performance and sex, the magnitude of its effect throughout the developmental process remains fairly unknown, particularly at pre-school age.

Regarding the relationship between children's somatic characteristics (e.g. stature, weight and body mass index) and motor performance, correlations are generally low (Bonvin et al., 2012; Logan et al., 2012; Nervik et al., 2011; Oja & Jürimäe, 1997) and vary strongly with the specificity of the motor skill (Castetbon & Andreyeva, 2012; Malina & Bouchard, 1991; Roberts et al., 2012). For instance, overweight and obese children tend to have poorer performance than their non-overweight peers, however these differences appear to be more apparent for locomotor skills than object manipulation skills (Cliff et al., 2012; Okely et al., 2004). This is a topic of great interest but the information relative to pre-school children is rather limited.

The aim of the present study was to analyse the influence of age, sex and selected somatic measures on pre-school children's motor performance. Furthermore, we sought to determine the magnitude of the relationship between motor performance and selected biological factors throughout the pre-school period.

Methods

Sample

A convenience sample was recruited from 10 public pre-schools from Viana do Castelo (Northern Portugal, 91 238 inhabitants). The parents or legal guardians of the pre-school children were informed about testing procedures and corresponding written consent was obtained. A total of 367 children (172 boys and 195 girls) between 3–5 years of age ($M = 53.0$ months, $SD = 9.6$) participated in this study. Children included in the study met the following criteria: age between 36–71 months and absence of any known intellectual, physical or emotional disabilities, as well as without special educational needs, according to an evaluation by special education professionals. Children lived in regions with different population densities: urban (44%), suburban (31%) and rural (25%).

The sample was divided in three age groups: 3-year-olds (36–47 months, $n = 122$), 4-year-olds (48–59 months, $n = 130$) and 5-year-olds (60–71 months, $n = 115$). The child's age was expressed in months at the moment of motor testing and physical assessment. The sample exhibited a balanced ratio of participants according to sex (47% boys and 53% girls) and age (3 years: 33%; 4 years: 36%; 5 years: 31%). There were no significant differences between mean age of boys and girls within each age group. Parents had different education levels: middle school (44%), high school (26%) and college (30%) and no significant differences were found for parent's education levels among age groups.

All data was collected between September 2009 and March 2010. The procedures employed were in accordance with Helsinki's Declaration of Human Ethical guidelines (1975). The study protocol was approved by the Faculty of Human Kinetics (Technical University of Lisbon, Portugal) Ethics Committee and authorized by the Portuguese Ministry of Education.

Measurements

Measures of children's motor performance

The Peabody Developmental Motor Scales-Second Edition (PDMS-2) (Folio & Fewell, 2000) was used to assess motor performance. This instrument provides detailed information about fine and gross motor skills development in children from birth to 71 months of age. The motor sub-tests of PDMS-2 are: Stationary (ability to sustain control of the body within its centre of gravity, 30 items), Locomotion (ability to move from one place to another, 89 items), Object manipulation (ability to manipulate balls, 24 items), Grasping (ability to use hands, 24 items), Visual-motor integration (ability to use his or her visual perceptual skills to perform complex eye-hand co-ordination tasks, 72 items). The PDMS-2 was previously translated into the Portuguese language and its validity and reliability was confirmed for Portuguese pre-schoolers (Saraiva et al., 2011). All PDMS-2 sub-tests showed good internal consistency ($\alpha = 0.76$–0.95) and test–re-test reliability (ICC = 0.85–0.95).

The PDMS-2 was administered according to manual guidelines (Folio & Fewell, 2000). Each child was individually tested by one PDMS-2 trained researcher in a quiet area of the school. Depending on children's age, the duration of the assessment ranged from 45–60 minutes. Each item of the motor sub-tests was scored using a 3-point rating scale. Raw scores (the sum of the individual items within each sub-test) were calculated for Grasping, Visual-motor integration, Stationary, Locomotion and Object manipulation sub-tests.

Somatic measures

Height and weight were measured using standard procedures (Lohman et al., 1988) and the body mass index (BMI) was calculated as weight (Kg)/height (m^2). These measurements were converted to age-appropriate *z*-scores according to the WHO Child Growth Standards (WHO, 2006) and the WHO reference for school-age children and adolescents (de Onis et al., 2007) using the WHO-Anthro 2005 and the WHO-AnthroPlus 2011 software, respectively.

Statistical analysis

Descriptive statistics (mean and standard deviation) were calculated for all variables and presented by age groups and sex. The Student's *t*-test was used to analyse the differences between boys and girls in motor sub-tests and somatic variables. For each age-group, Pearson's correlations were calculated to estimate the association between age in months, somatic variables and motor sub-tests. A multiple linear regression analysis was performed for each motor sub-test to determine the combination of variables with the best predictive values for each age-group. The study was powered to detect a significant multiple regression model ($F(5, 114) = 2.29$, with a power of 0.80 at the 5% level of significance, given an expected medium effect size ($f^2 = 0.15$).

All statistical analyses were carried out using the SPSS 19.0 and the level of significance was set at $p < 0.05$.

Results

Table 1 presents the means and standard deviations for all variables, by age group and sex.

Significant differences were also found between girls' and boys' performance in object manipulation ($p \leq 0.008$), Grasping ($p = 0.001$) and Visual-motor integration ($p = 0.034$) sub-tests. Boys showed higher raw scores in the Object Manipulation ($p \leq 0.008$), but girls presented a better performance in the Grasping ($p = 0.001$) and Visual-motor integration ($p \leq 0.034$) sub-tests in the 3 and 4-year-old age groups. No sex differences were found in the Stationary and Locomotion sub-tests.

Overall results indicate that boys and girls had similar somatic characteristics (height-for-age *z*-score, weight-for-age *z*-score and BMI-for-age *z*-score). Significant sex differences were only observed in the 3-year-old age group, with girls showing a higher value for weight-for-age *z*-score ($p = 0.016$) and BMI-for-age *z*-score ($p = 0.049$).

The correlations between somatic variables and PDMS-2 sub-tests in the different age groups are presented in Table 2. The results presented in Table 2 suggest that age was moderately correlated with most sub-tests (ranging from 0.26–0.53). The strength of the correlations between somatic variables and motor performance is not identical for the three age groups. In the 3-year-old group, height-for-age *z*-score and Stationary sub-test were positively correlated ($r = 0.21$, $p = 0.02$); in the 4-year-old group the correlation between BMI-for-age *z*-score and Visual-motor integration sub-test was positive ($r = 0.22$, $p = 0.01$) as well as the correlation between weight-for-age *z*-score and object manipulation ($r = 0.21$, $p = 0.05$); finally, in the 5-year-old group the height-for-age *z*-score was positively correlated to the Grasping sub-test ($r = 0.19$, $p = 0.04$) and the BMI-for-age *z*-score was negatively correlated to the Stationary sub-test ($r = -0.25$, $p = 0.008$).

The multiple regression models for each motor sub-test and age group are presented in Table 3. Age in months, sex and the somatic variables that showed a significant correlation with the specific motor sub-tests were included in the models.

The results of Table 3 show that sex and age (in months) were the variables that more often entered the final models as predictors. Depending on the motor sub-test and respective age group, the models predicted a minimum of 3.6% and a maximum of 34.4% of the performance. When computing the actual power achieved (post-hoc) for all models, we found that all models achieved a power ≥ 0.87, with exception for the grasping model at 5 years (power = 0.61). In the Object manipulation sub-test, particularly in the 5-year-old group, the most important predictor was sex ($\beta = 0.472$, $p < 0.001$), followed by age-in-months ($\beta = 0.301$, $p < 0.001$). Together, these two variables explained 34.4% ($F(2,114) = 29.373$, $p < 0.01$) of the object manipulation variance. It is important to note that the influence of sex in the Object manipulation sub-test increased throughout the age groups ($\beta = 0.227$, $\beta = 0.353$, $\beta = 0.472$ at 3, 4 and 5 years, respectively), whereas the effect of age in months decreased ($\beta = 0.428$, $\beta = 0.371$, $\beta = 0.301$, at 3, 4 and 5 years, respectively).

The somatic characteristics played a small role in predicting the motor development outcome. Height-for-age

Table 1. Descriptive statistics for study measures, by age group and sex.

	3 years				4 years				5 years			
	Total	Boys ($n = 61$)	Girls ($n = 61$)	p Values*	Total	Boys ($n = 57$)	Girls ($n = 73$)	p Values*	Total	Boys ($n = 54$)	Girls ($n = 61$)	p Values*
Age (months), Mean (SD)	42.2 (3.4)	42.3 (3.3)	42.1 (3.5)	0.751	53.0 (3.5)	52.5 (3.4)	53.4 (3.5)	0.138	64.4 (3.2)	64.8 (3.4)	64.1 (2.9)	0.254
Children's Motor Performance, Mean (SD)												
Grasping	49.0 (2.6)	48.2 (2.8)	49.7 (2.1)	*0.001*	50.8 (1.5)	50.3 (1.8)	51.3 (1.1)	*0.001*	51.3 (1.0)	51.1 (1.2)	51.5 (0.7)	0.054
Visual-Motor Integration	123.2 (7.1)	121.9 (6.9)	124.6 (7.0)	*0.034*	135.7 (5.7)	134.4 (6.1)	136.7 (5.3)	*0.025*	140.0 (3.6)	139.7 (4.3)	140.2 (3.0)	0.471
Stationary	48.7 (3.6)	48.6 (3.8)	48.8 (3.3)	0.723	53.8 (3.5)	53.3 (3.8)	54.2 (3.8)	0.151	57.5 (2.6)	57.8 (2.8)	57.2 (2.3)	0.181
Locomotion	144.1 (8.7)	145.1 (9.6)	143.0 (7.7)	0.179	159.7 (7.5)	159.2 (8.1)	160.0 (7.0)	0.545	168.4 (5.5)	169.1 (6.0)	167.8 (4.9)	0.193
Object manipulation	27.5 (4.5)	28.6 (5.0)	26.5 (3.6)	*0.008*	32.8 (5.6)	34.8 (6.1)	31.3 (4.7)	*0.000*	36.6 (4.5)	41.8 (4.5)	36.6 (4.5)	*0.000*
Anthropometric Measures, Mean (SD)												
Weight-for-age (*z*-score)	0.462 (0.94)	0.258 (0.85)	0.667 (0.98)	*0.016*	0.355 (0.92)	0.433 (0.98)	0.294 (0.88)	0.398	0.615 (1.06)	0.662 (1.17)	0.574 (0.95)	0.656
Height-for-age (*z*-score)	0.019 (0.87)	− 0.115 (0.87)	0.154 (0.85)	0.086	−0.032 (1.11)	0.151 (1.24)	−0.175 (0.97)	0.096	0.119 (0.97)	0.057 (0.81)	0.174 (1.08)	0.518
BMI-for-age (*z*-score)	0.665 (1.02)	0.483 (0.99)	0.846 (1.01)	*0.049*	0.562 (1.12)	0.526 (1.22)	0.590 (1.05)	0.750	0.779 (1.24)	0.903 (1.38)	0.670 (1.10)	0.317

*Student's *t*-test for comparison between boys and girls; *p* values in italics are statistically significant.

Table 2. Correlations between age (in months), somatic variables and motor sub-tests for each age group.

	Grasping	Visual-Motor integration	Stationary	Locomotion	Object manipulation
3 years ($n=122$)					
Age (months)	0.31**	0.53**	0.40**	0.53**	0.43**
Weight-for-age (*z*-scores)	0.03	0.05	0.13	−0.03	0.00
Height-for-age (*z*-scores)	−0.01	0.08	0.21*	0.06	−0.03
BMI-for-age (*z*-scores)	0.06	0.01	0.01	−0.10	0.02
4 years ($n=130$)					
Age (months)	0.26**	0.50**	0.32**	0.36**	0.34**
Weight-for-age (*z*-scores)	0.03	0.09	0.14	0.05	0.21*
Height-for-age (*z*-scores)	−0.03	−0.13	0.11	0.04	0.12
BMI-for-age (*z*-scores)	0.06	0.22*	0.07	0.02	0.16
5 years ($n=115$)					
Age (months)	−0.02	0.28**	0.28**	0.15	0.35**
Weight-for-age (*z*-scores)	0.12	0.08	−0.11	−0.07	0.01
Height-for-age (*z*-scores)	0.19*	0.12	0.16	0.10	0.02
BMI-for-age (*z*-scores)	0.01	0.01	−0.25**	−0.16	0.00

*$p<0.05$ (2-tailed), **$p<0.01$ (2-tailed).

Table 3. Multiple regression final models for each motor sub-test and age group.

	B	S.E.	β	R^2 change	R^2	*p* Value
Grasping						
3 years						
Constant	39.708	2.638				
Age (months)	0.238	0.062	0.315	0.094	0.187	<0.001
Sex	−1.555	0.422	−0.305	0.093		
4 years						
Constant	46.053	1.943				
Sex	−0.859	0.254	−0.281	0.096	0.144	<0.001
Age (months)	0.097	0.036	0.222	0.048		
5 years						
Constant	51.298	0.093				
Height-for-age (*z*-score)	0.197	0.096	0.189	0.036	0.036	0.043
Visual-Motor Integration						
3 years						
Constant	78.000	6.642				
Age (months)	1.108	0.157	0.533	0.278		
Sex	−2.923	1.062	−0.208	0.043	0.321	<0.001
4 years						
Constant	91.620	6.677				
Age (months)	0.831	0.126	0.505	0.255	0.255	<0.001
5 years						
Constant	119.396	6.657				
Age (months)	0.319	0.103	0.279	0.078	0.078	0.002
Stationary						
3 years						
Constant	31.023	3.617				
Age (months)	0.418	0.086	0.400	0.158	0.202	<0.001
Height-for-age (*z*-score)	0.857	0.335	0.210	0.044		
4 years						
Constant	36.573	4.507				
Age (months)	0.325	0.085	0.320	0.103	0.103	<0.001
5 years						
Constant	42.516	4.603				
Age (months)	0.239	0.071	0.292	0.079	0.146	<0.001
BMI-for-age (*z*-score)	−0.542	0.183	−0.259	0.067		
Locomotion						
3 years						
Constant	86.973	8.445				
Age (months)	1.355	0.200	0.526	0.277	0.277	<0.001
4 years						
Constant	118.276	9.368				
Age (months)	0.781	0.176	0.364	0.133	0.133	<0.001
5 years			No significant predictors			

(*continued*)

Table 3. Continued

	B	S.E.	β	R^2 change	R^2	*p* Value
Object Manipulation						
3 years						
Constant	2.789	4.457				
Age (months)	0.563	0.105	0.428	0.189	0.240	<0.001
Sex	2.020	0.713	0.227	0.051		
4 years						
Constant	−1.114	6.675				
Age (months)	0.600	0.125	0.371	0.114	0.271	<0.001
Sex	3.996	0.872	0.353	0.132		
Weight-for age (*z*-score)	0.949	0.467	0.156	0.024		
5 years						
Constant	5.354	8.011				
Sex	4.861	0.793	0.472	0.254	0.344	<0.001
Age (months)	0.488	0.125	0.301	0.090		

The sex variable was recoded as a dummy variable: girls = 0, boys = 1; B, Unstandardized coefficient; S.E., standard error of the regression coefficient; β, Standardized coefficient.

accounted for an extra 4.4% explanation of Stationary (3 years) and 3.6% of Grasping variance (5 years); BMI-for-age added 6.7% to Stationary variance (5 years); and weight-for-age 2.4% to Object Manipulation (4 years) variance.

Discussion

The aim of this study was to analyse the influence of age, sex and selected somatic measures in pre-schooler's motor development. As expected, age in months was the best predictor for motor performance and more notably in the youngest age group. Age is a variable that reflects the child's biological and neurological maturity as well as the accumulated effects of stimulation and environmental factors. It is also reasonable that the interaction of maturation and environmental effects may help to explain the increased variability in motor development with advancing age. This interaction is also present in the fact that being a boy or a girl predicts distinct motor performance outcomes at these young ages. Sex explains a substantial part of the variance for Grasping, Visual-motor integration and Object Manipulation sub-tests, boys performing better in object manipulation skills and girls with a better performance in fine motor skills. This is consistent with the findings of previous studies which reported sex differences in specific motor skills for pre-schoolers, with boys showing to be more proficient in object manipulation skills (Chow et al., 2001; Düger et al., 1999; Engel-Yeger et al., 2010; Giagazoglou et al., 2011; Hardy et al., 2010; Ikeda & Aoyagi, 2008; Kroes et al., 2004; Livesey et al., 2007; Loovis & Butterfield, 2003; Oja & Jürimäe, 1997; Shala, 2009; Spessato et al., 2012; Thomas & French, 1985; Toriola & Igbokwe, 1986; Vandaele et al., 2011), while girls tend to exhibit superior performance in manual dexterity (Chow et al., 2001; Düger et al., 1999; Kroes et al., 2004; Lejarraga et al., 2002; Livesey et al., 2007; Sigmundsson & Rostoft, 2003).

Sex was not a good predictor in the case of stationary and locomotion competence. This finding is not consistent with previous studies that detected a better performance of girls in Stationary/balance skills (Chow et al., 2001; Engel-Yeger et al., 2010; Ikeda & Aoyagi, 2008; Kroes et al., 2004; Krombholz, 2006; Lam & Schiller, 2001; Livesey et al., 2007; Shala, 2009; Sigmundsson & Rostoft, 2003). Mixed results were reported regarding the locomotion skills: some studies showing no sex differences (Barnett et al., 2010; Vandaele et al., 2011), while others reported boys (Krombholz, 2006; Oja & Jürimäe, 1997; Toriola & Igbokwe, 1986) or girls (Cliff et al., 2009; Hardy et al., 2010; Ikeda & Aoyagi, 2008) as more proficient. Our results do not support sexual differences in locomotion, in line with Barnett et al. (2010) and Vandaele et al. (2011) findings.

The effect of age and sex is visible in the final model regressions for the Grasping, Visual-motor integration and Object manipulation sub-tests, but the magnitude of its effect varied across age groups. The influence of age decreases throughout age cohorts; whereas the influence of sex may increase or decrease depending on the motor domain. Within the Object manipulation competence, the results clearly showed that the influence of sex increases along age cohorts. This tendency was also reported by Ikeda & Aoyagi (2008) and Thomas & French (1985) in their meta-analysis. Both studies were unanimous in concluding that the boys' advantage in Object manipulation skills becomes progressively greater throughout childhood and adolescence. In the literature the explanation for this fact has been based in arguments such as social and environmental effects, opportunities for motor experiences, sex stereotyped games and toys and parental and social expectations (Barnett et al., 2009; Cools et al., 2011).

On the other hand, the final model regressions of Grasping and Visual-motor integration indicated that sex differences decrease in older age cohorts. It is interesting to observe that girls' superiority at the age of 3 years, in Grasping and Visual-motor integration skills, disappeared by the age of 5 years. The evidence of early sex differences in motor ability is not new in the literature, suggesting strong early effects of biological variables in motor development and a progressive modulation effect of motor experiences across childhood. For example, neonatal girls imitate finger movements more accurately than boys (Nagy et al., 2007) and recent studies have identified sex differences in the infant's brain structuring and function (e.g. Liu et al., 2011). Other studies also show that girls attain some fine motor tasks earlier, such as drawing a person and grasping a pencil (Lejarraga et al., 2002; Richter & Janson, 2007). Social class, maternal education and sex (female) were associated with earlier attainment of some selected development items after the first year of life (Lejarraga et al., 2002). These facts reinforce the idea that the child's motor development is clearly dependent on the interaction between biological and socio-cultural factors. In our study, the narrowing of differences between boys and girls in fine motor skills throughout pre-school ages might be explained by school practices in which both sexes are equally stimulated, but this hypothesis claims for further research.

The somatic measures (height-for-age z-score, weight-for-age z-score and BMI-for-age z-score) played a small role in predicting motor development of pre-schoolers. The boys and girls of this study had similar morphological characteristics, except in the 3-year-old age group in which girls exhibited higher values for weight-for-age z-score ($p = 0.016$) and BMI-for-age z-score ($p = 0.049$). The effects of height-for-age z-score and BMI-for-age z-score were visible in Stationary skills. Apparently, the 3-year-old children, who presented greater height for their age, tend to perform better. Five-year-old children with a low BMI for their age showed a better performance in Stationary skills. The inverse relationship between BMI and gross motor performance has been documented in previous studies for school children (D'Hondt et al., 2009; Graf et al., 2004; McKenzie et al., 2002; Okely et al., 2004; Southall et al., 2004). On the other hand, recent studies (Bonvin et al., 2012; Castetbon & Andreyeva, 2012; Logan et al., 2012; Nervik et al., 2011) suggest that the association between BMI and motor performance is small during early years but increases throughout later childhood (D'Hondt et al., 2011; Lopes et al., 2011b). In another study, Oja & Jürimäe (1997) concluded that the motor performance of pre-school children aged 4–5 years was often dependent on height and body mass, but not on BMI. Age, height and body mass of children explained only a small percentage of the variance in motor performance (6%) and the authors suggested that somatic measures are not strong predictors of motor performance in pre-school age.

Our results suggest that, at the age of 4 years, a higher weight-for-age is a significant and positive predictor for Object manipulation skills. Although counter-intuitive to the general idea that weight and motor competency should be negatively associated, this result aligns with several literature findings. There is a clearly documented negative association between weight status and motor skills that requires propulsion or lifting of the body mass (Marshall & Bouffard, 1994; Morano et al., 2011; Okely et al., 2004; Southall et al., 2004). However, positive effects of weight can often be observed in specific motor tasks that require power or strength, like throwing skills (Malina & Bouchard, 1991). Hence, more studies are needed to clarify the effect of the weight and IMC according to each specific motor skill at the pre-school age including specific measures of adiposity and fat-free mass.

In conclusion, the influence of most variables on pre-schooler's motor performance varied with age and motor specificity. Age and sex stood out as predictors of motor performance. In this study, somatic measures cannot be considered good predictors of the motor development in pre-schoolers. Along cohorts, the decrease of the age effects in the majority of the sub-tests and the increase of the sex effect on object manipulation suggests that motor development might also be moderated by other environmental factors. Longitudinal studies are necessary in order to confirm these findings.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

Barnett LM, Morgan PJ, van Beurden E, Ball K, Lubans DR. 2011. A reverse pathway? Actual and perceived skill proficiency and physical activity. Med Sci Sports Exerc 43:898–904.

Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Beard JR. 2009. Childhood motor skill proficiency as a predictor of adolescent physical activity. J Adolesc Health 44:252–259.

Barnett LM, van Beurden E, Morgan PJ, Brooks LO, Beard JR. 2010. Gender differences in motor skill proficiency from childhood to adolescence: a longitudinal study. Res Q Exerc Sport 81:162–170.

Bonvin A, Barral J, Kakebeeke T, Kriemler S, Longchamp A, Marques-Vidal P, Puder J. 2012. Weight status and gender-related differences in motor skills and in child care – based physical activity in young children. BMC Pediatrics 12:23.

Castetbon K, Andreyeva T. 2012. Obesity and motor skills among 4 to 6-year-old children in the United States: nationally-representative surveys. BMC Pediatr 15:12–28.

Chow SM, Henderson SE, Barnett AL. 2001. The Movement Assessment Battery for Children: a comparison of 4-year-old to 6-year-old children from Hong Kong and the United States. Am J Occup Ther 55: 55–61.

Cliff DP, Okely AD, Morgan PJ, Jones RA, Steele JR, Baur LA. 2012. Proficiency deficiency: mastery of fundamental movement skills and skill components in overweight and obese children. Obesity (Silver Spring) 20:1024–1033.

Cliff DP, Okely AD, Smith LM, McKeen K. 2009. Relationships between fundamental movement skills and objectively measured physical activity in preschool children. Pediatr Exerc Sci 21:436–449.

Cools W, De Martelaer K, Samaey C, Andries C. 2011. Fundamental movement skill performance of preschool children in relation to family context. J Sports Sci 29:649–660.

D'Hondt E, Deforche B, De Bourdeaudhuij I, Lenoir M. 2009. Relationship between motor skill and body mass index in 5- to 10-year-old children. Adapt Phys Act Q 26:21–37.

D'Hondt E, Deforche B, Vaeyens R, Vandorpe B, Vandendriessche J, Pion J, Philippaerts R, et al. 2011. Gross motor coordination in relation to weight status and age in 5- to 12-year-old boys and girls: a cross-sectional study. Int J of Pediatr Obes 6:556–564.

de Kieviet JF, Piek JP, Aarnoudse-Moens CS, Oosterlaan J. 2009. Motor development in very preterm and very low-birth-weight children from birth to adolescence: a meta-analysis. JAMA 302:2235–2242.

de Onis M, Onyango A, Borghi E, Siyam A, Nishida C, Siekmann J. 2007. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Organ 85:661–668.

Düger T, Bumin G, Uyanik M, Aki E, Kayihan H. 1999. The assessment of Bruininks–Oseretsky test of motor proficiency in children. Pediatr Rehabil 3:125–131.

Engel-Yeger B, Rosenblum S, Josman N. 2010. Movement Assessment Battery for Children (M-ABC): establishing construct validity for Israeli children. Res Dev Disabil 31:87–96.

Folio R, Fewell R. 2000. Peabody Developmental Motor Scales-2. Austin, TX: Pro–ed.

Gabbard C. 2011. Lifelong motor development. 6th ed. San Francisco, CA: Benjamin Cummings.

Giagazoglou P, Kabitsis N, Kokaridas D, Zaragas C, Katartzi E, Kabitsis C. 2011. The movement assessment battery in Greek preschoolers: the impact of age, gender, birth order, and physical activity on motor outcome. Res Dev Disabil 32:2577–2582.

Goyen T, Lui K. 2009. Developmental coordination disorder in ''apparently normal'' schoolchildren born extremely preterm. Arch Dis Child 94:298–302.

Graf C, Koch B, Kretschmann-Kandel E, Falkowski G, Christ H, Coburger S, Lehmacher W, et al. 2004. Correlation between BMI, leisure habits and motor abilities in childhood (CHILT-project). Int J Obes 28:22–26.

Hardy L, King L, Farrell L, Macniven R, Howlett S. 2010. Fundamental movement skills among Australian preschool children. J Sci Med Sport 13:503–508.

Ikeda T, Aoyagi O. 2008. Meta-analytic study of gender differences in motor performance and their annual changes among Japanese preschool-aged children. Jpn J School Health 4:24–39.

Kroes M, Vissers YL, Sleijpen FA, Feron FJ, Kessels AG, Bakker E, Kalff AC, et al. 2004. Reliability and validity of a qualitative and quantitative motor test for 5-to 6-year-old children. Eur J Paediatr Neurol 8:135–143.

Krombholz H. 2006. Physical performance in relation to age, sex, birth order, social class, and sports activities of preschool children. Percept Mot Skills 102:477–484.

Kuklina E, RamaKrishan U, Stein A, Barnhart H, Martorell R. 2006. Early childhood growth and development in rural Guatemala. Early Human Dev 82:425–433.

Lam H, Schiller W. 2001. A Pilot study on the gross motor proficiency of Hong Kong preschoolers aged 5 to 6 Years. Early Child Dev Care 171: 11–20.

Lejarraga H, Pascucci M, Krupitzky S, Kelmansky D, Bianco A, Martinez E, Tibaldi F, Cameron N. 2002. Psychomotor development in Argentinean children aged 0-5 years. Paediatr Perinat Epidemiol 16:47–60.

Liu Y, Metens T, Absil J, De Maertelaer V, Balériaux D, David P, Denolin V, et al. 2011. Gender differences in language and motor-related fibers in a population of healthy preterm neonates at term-equivalent age: a diffusion tensor and probabilistic tractography study. AJNR 32:2011–2016.

Livesey D, Coleman R, Piek J. 2007. Performance on the Movement Assessment Battery for Children by Australian 3 to 5 year-old children. Child Care Health Dev 33:713–719.

Logan SW, Scrabis-Fletcher K, Modlesky C, Getchell N. 2012. The relationship between motor skill proficiency and body mass index in preschool children. Res Q Exerc Sport 82:442–448.

Lohman T, Roche A, Martorell R. 1988. Antropometric standardization reference manual. Champaign, IL: Human Kinetics Books.

Loovis E, Butterfield S. 2003. Relationship of length to catching performance by children in kindergarten to grade 2. Percept Mot Skills 96:1194–1196.

Lopes VP, Rodrigues LP, Maia JA, Malina RM. 2011a. Motor coordination as predictor of physical activity in childhood. [Research Support, Non-U.S. Gov't]. Scand J Med Sci Sports 21:663–669.

Lopes VP, Stodden DF, Bianchi MM, Maia JA, Rodrigues LP. 2011b. Correlation between BMI and motor coordination in children. J Sci Med Sport 15:38–43.

Lubans DR, Morgan PJ, Cliff DP, Barnett LM, Okely AD. 2010. Fundamental movement skills in children and adolescents: review of associated health benefits. Sports Med 40:1019–1035.

Lung FW, Chiang TL, Lin SJ, Feng JY, Chen PF, Shu BC. 2011. Gender differences of children's developmental trajectory from 6 to 60 months in the Taiwan Birth Cohort Pilot Study. Res Dev Disabil 32:100–106.

Malina RM. 2004. Motor development during infancy and early childhood: overview and suggested directions for research. Int J Sport Health Science 2:50–66.

Malina RM, Bouchard C. 1991. Growth, maturation, and physical activity. Champaign, IL: Human Kinects Books.

Marshall J, Bouffard M. 1994. Obesity and movement competency in children. Adapt Phys Act Q 11:297–305.

McKenzie TL, Sallis JF, Broyles SL, Zive MM, Nader PR, Berry CC, Brennan JJ. 2002. Childhood movement skills: predictors of physical activity in Anglo American and Mexican American adolescents? Res Q Exerc Sport 73:238–244.

Morano M, Colella D, Caroli M. 2011. Gross motor skill performance in a sample of overweight and non-overweight preschool children. Int J Pediatr 6:42–46.

Nagy E, Kompagne H, Orvos H, Pal A. 2007. Gender-related differences in neonatal imitation. Infant Child Dev 16:267–276.

Nervik D, Martin K, Rundquist P, Cleland J. 2011. The relationship between body mass index and gross motor development in children aged 3 to 5 years. Pediatr Phys Ther 23:144–148.

Oja L, Jürimäe T. 1997. Assessment of motor ability of 4 and 5 year-old children. Am J Hum Biol 9:659–664.

Okely AD, Booth ML, Chey T. 2004. Relationship between body composition and fundamental movement skills among children and adolescents. Res Q Exerc Sport 75:238–247.

Okely AD, Booth ML, Patterson JW. 2001. Relationship of physical activity to fundamental movement skills among adolescents. Med Sci Sports Exerc 33:1899–1904.

Richter J, Janson H. 2007. A validation study of the Norwegian version of the Ages and Stages Questionnaires. Acta Pædiatr 96:748–752.

Roberts D, Veneri D, Decker R, Gannoti M. 2012. Weight status and motor skill in kindergarten children. Pediatr Phys Ther 24:353–360.

Saraiva L, Rodrigues LP, Barreiros J. 2011. Adaptation and Validation of the Portuguese Peabody Developmental Motor Scales-2 version: a study with Portuguese Preschoolers. J Phys Educ/UEM 22:511–521.

Shala M. 2009. Assessing gross motor skills of Kosovar preschool children. Early Child Dev Care 179:969–976.

Sigmundsson H, Rostoft MS. 2003. Motor development: exploring the motor competence of 4-year-old Norwegian children. Scand J Edu Res 47:451–459.

Sommerfelt K, Sonnander K, Skranes J, Andersson H, Ahlsten G, Ellertsen B, Markestad T, Jacobsen G, Hoffman H, Bakketeig L. 2002. Neuropsychological and motor function in small-for-gestation preschoolers. Pediatr Neurol 26:186–191.

Southall JE, Okely A, Steele JR. 2004. Actual and perceived physical competence in overweight and nonoverweight children. Pediatr Exerc Sci 16:15–24.

Spessato BC, Gabbard C, Valentini N, Rudisill M. 2012. Gender differences in Brazilian children's fundamental movement skill performance. Early Child Dev Care. [Epub ahead of print]. doi: 10.1080/03004430.2012.689761.

Stodden DF, Goodway JD, Langendorfer SJ, Roberton MA, Rudisill ME, Garcia C, Garcia LE. 2008. A developmental perspective on the role of motor skill competence in physical activity: an emergent relationship. Quest 60:290–306.

Thomas J, French K. 1985. Gender differences across age in motor performance: a meta-analysis. Psychol Bull 98:260–282.

Toriola A, Igbokwe N. 1986. Age and sex differences in motor performance of pre-school Nigerian children. J Sports Sci 4:219–227.

Vandaele B, Cools W, de Decker S, de Martelaer K. 2011. Mastery of fundamental movement skills among 6-year-old Flemish pre-school children. Eur Phys Edu Rev 17:3–17.

WHO Multicentre Growth Reference Study Group. 2006. WHO Child Growth Standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: methods and development. Geneva: World Health Organization.

Williams HG, Pfeiffer KA, O'Neill JR, Dowda M, McIver KL, Brown WH, Pate RR. 2008. Motor skill performance and physical activity in preschool children. Obesity (Silver Spring) 16:1421–1426.

Wrotniak BH, Epstein LH, Dorn JM, Jones KE, Kondilis VA. 2006. The relationship between motor proficiency and physical activity in children. Pediatrics 118:e1758–e1765.