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The importance of the moderate-to-vigorous physical activity and sedentary behavior combined pattern on the association between body mass index and motor competence in children

A importância do padrão combinado de atividade física moderada a vigorosa e comportamento sedentário na associação entre índice de massa corporal e competência motora em crianças

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ABSTRACT

Objective: To investigate whether the association between body mass index and motor competence in children is modified by patterns of moderate-to-vigorous physical activity and sedentary behavior (SB). Methods: This is a cross-sectional study based on the data from 310 children (5-7 years old) who participated in the Longitudinal Study of Health and Well-Being in Preschool Children (ELOS-Pre Study) in Recife, Brazil. Motor competence was assessed using the Körperkoordination Test für Kinder (KTK). The duration and moderate-to-vigorous physical activity and time spent in SB were measured directly by accelerometer. A multilevel linear regression was performed to verify the association between body mass index and motor competence, moderated by moderate-to-vigorous physical activity and sedentary behavior patterns. Results: Body mass index was significantly related to motor competence (β = -2.38, $p < 0.01$). After considering moderate-to-vigorous physical activity and sedentary behavior patterns, the relationship between body mass index and motor competence was only significant for the group of children exposed to a low pattern of moderate-to-vigorous physical activity and high time spent in sedentary behavior (β = -3.04, $p < 0.01$). Conclusions: The association between body mass index and motor competence in children is moderated by different patterns of moderate-to-vigorous physical activity and sedentary behavior.

Keywords: Psychomotor performance; Child; Adiposity; Motor activity.

RESUMO

Objetivo: Investigar se a associação entre o índice de massa corporal e a competência motora em crianças é modificada por padrões de atividade física moderada a vigorosa e comportamento sedentário. Métodos: Trata-se de um estudo transversal baseado em dados de 310 crianças (5 a 7 anos de idade) que participaram do Estudo Longitudinal de Saúde e Bem-Estar em Crianças Pré-escolares (ELOS-Pre Study) em Recife, Brasil. A competência motora foi avaliada por meio do Körperkoordination Test für Kinder (KTK). A duração da atividade física moderada a vigorosa e o tempo gasto em comportamento sedentário foram medidos diretamente por acelerômetro. Uma regressão linear multinível foi realizada para verificar a associação entre índice de massa corporal e competência motora, moderada pelos padrões de atividade física moderada a vigorosa e comportamento sedentário. Resultados: O índice de massa corporal apresentou associação significativa com a competência motora (β = -2,38; $p < 0,01$). Após considerar os padrões de atividade física moderada a vigorosa e comportamento sedentário, a relação entre índice de massa corporal e competência motora foi significativa apenas para o grupo de crianças exposto a baixo padrão de atividade física moderada a vigorosa e alto tempo em comportamento sedentário (β = -3,04; $p < 0,01$). Conclusão: A associação entre o índice de massa corporal e a competência motora em crianças é moderada por diferentes padrões de atividade física moderada a vigorosa e comportamento sedentário.

Palavras-chave: *Desempenho psicomotor; Criança; Adiposidade; Atividade motora.*

Introduction

Several terminologies have been used to represent motor competence, however, it can be understood as a general construct that encompasses all forms of goal-directed human movement, as well as underlying mechanisms involving motor coordination, body control, and movement quality[1,2]. Motor competence is a key component in promoting active and healthy lifestyles among youth, as well as an important factor in health, physical, cognitive, and social development trajectories from childhood to adolescence[1,3,4]. Therefore, it is pivotal to determine the factors and behaviors associated with motor competence in youth.

A reasonable number of studies reported that children with excessive weight (overweight or obesity) presented lower motor competence[5-7]. These findings were observed in both cross-sectional[8-13] and longitudinal[14-17] studies. Moreover, excessive weight has also been negatively related to motor competence development throughout childhood[14,15,17]. Although the relationship between children's weight status and their motor competence is relatively well-established, some aspects still need further consideration.

Notably, some studies have evaluated the role of physical activity (PA) and sedentary behaviour (SB) patterns on children's motor competence scores or weight status. Specifically, Van Kann et al.[18] evaluated the patterns of moderate-to-vigorous physical activity (MVPA) and SB during and outside the school shift, identifying that a negative pattern in both contexts was related to lower motor competence in children. Adank et al.[19] observed that children with higher MVPA and lower sedentary time exhibited the highest motor competence scores. Similarly, a pattern with higher time in MVPA and lower time in SB was associated with healthier body mass index (BMI) in children[20]. Nevertheless, to our knowledge, no study has investigated the role of MVPA and SB combined patterns in the association between BMI and motor competence in children. Since isolated MVPA and SB patterns are related to weight status and motor competence, the MVPA-SB pattern may impact the relationship between weight status and motor competence in children.

Thus, the purpose of this study was to analyze whether the relationship between BMI and motor competence in children is impacted by their MVPA and SB patterns.

Methods

This is a cross-sectional study. The project was approved by the Human Research Ethics Committee of the University of Pernambuco (protocol no. 0096.0.097.000-10). Parents or legal guardians of participating children signed a free and informed consent form. The target population was preschool children (3-5 years old) enrolled in the public and private preschools in Recife, Brazil. The minimum sample size was defined considering the following parameters: (a) population size estimated as 49,338 children (782 preschools); (b) prevalence of the variables of interest set at 50%; (c) 95% confidence interval; (d) maximum tolerance error of four percentage points; and (e) effect size of the pre-established sampling at 1.5 due to the cluster sampling resource. To minimize possible losses and refusals during follow-up, the minimum sample size at baseline, initially estimated as 890 children, was increased by 20%. The sample selection used a single-stage cluster sampling technique, considering the school as the sampling unit.

Considering an average number of 38.5 children enrolled in each school and to achieve the desired sample size (n = 1,068), it was established that data collection would be performed in 28 schools with preschool classes. To maintain the representativeness of the sample, the proportionality of children in schools according to type (public or private) and their distribution in the six political and administrative regions were also considered in the sampling process. In addition, the size of the school, "small-size" (<50 students), "medium-size" (50 to 199 students), and "large-size" (≥200 students) was adopted as a stratification criterion. All children were followed and evaluated every two years in three surveys. The baseline was run between August and November of 2010, and the re-evaluations were performed in the same months in 2012 and 2014. The data included in the analyses of this study were exclusively from the reevaluation of the children in 2012 (second survey), when they were 5-to-7 years old (n = 352).

Motor competence was assessed using the *Korperkoordinationtest fur Kinder* (KTK) test battery[21]. The KTK consists of four independent tests: (a) balance while moving backward - walking backward on balance beams of decreasing width, including 6.0 cm, 4.5 cm, and 3.0 cm; (b) hopping on one leg over an obstacle - hopping a foam obstacle with increasing height in consecutive steps of 5 cm; (c) jumping laterally - jumping from side to side, two-legged, for 15 s; (d) shifting platforms - moving sideways on wooden boards for 20 s. The sum of the raw scores of each test was used as

the dependent variable. Previous test-retest reliability (intraclass correlation coefficients) ranged from 0.70 (shifting platforms) to 0.94 (hopping on one leg over an obstacle)[22,23].

Weight was obtained using a G.Tech® portable digital scale (model Glass 6) previously calibrated, with a variation of 0.1 kg and maximal capacity of 150 kg. Height was measured using a portable Welmy® stadiometer (model II), with an accuracy of 0.5 cm. The weight and height were used to calculate the BMI.

Objective assessments of PA and SB were performed by monitoring with accelerometers for seven consecutive days. Actigraph accelerometers (model GT3X +, ActiGraph, Pensacola, USA) were used, with recording intervals (epoch's) of 15 seconds[24]. Data were reduced with Actilife software (version 6) using parameters suggested in the literature[25]. To consider a monitoring day as valid, the child was required to have at least eight hours of validated hours. Non-wear time was defined as periods of at least 60 minutes of consecutive zeros and removed from all analyses. For inclusion in the analysis, the child was required to have at least three days of valid monitoring, including one on a weekend day. Previous studies have shown that three days of monitoring is sufficient to ensure reproducible and accurate measurements of PA in children and produce estimates of the level of PA similar to those obtained in longer periods of monitoring[26]. Therefore, those who were not monitored for the three days were considered "dropouts".

To classify the intensity of the PA, the cut-off points suggested by Evenson et al.[27] were used: SB (<100 counts/minute) and MVPA activities (≥2,296 counts/min), being considered in the analysis the wear time of the accelerometer. Time in MVPA and SB was divided into tertiles. Subsequently, the groups in MVPA and SB were combined, considering the groups formed by the health-risk behaviour pattern (MVPA lower tertile and SB upper tertile), healthy behaviour pattern (MVPA upper tertile and SB lower tertile), and intermediate behaviour pattern (all other tertiles of MVPA and SB).

Data entry was performed in duplicate using the EpiData Entry software for Windows (version 3.1), using automatic controls for amplitude and consistency. Descriptive data were performed using mean, standard deviation, and relative and absolute frequency. A chi-squared test and t-tests were used to compare categorical and numerical variables by biological sex, further to compare outcomes between participants who completed the study and those who dropped out.

Multilevel mixed-effects linear regressions were used to analyze the associations between BMI and motor competence. In the multilevel analyses, for each model the variance related to the clusters (schools) and the intraclass correlation coefficients (ICC) were calculated to interpret the variation among schools and individuals. In all regression analyzes the variation (ICC) was at the individual level (the variation from school was always below 12.8%).

The analysis was carried out in different stages. In the null model, a model without predictors was performed to identify how much of the total variance of motor competence can be attributed to the school. In step 1, the variable BMI was added. In step 2, the confounding variables (age, biological sex, and gross family income) were added. Finally, in step 3, the pattern variable was added. Subsequently, we estimated the association coefficients between BMI and motor competence for each of the MVPA and SB contexts using the lincom command in Stata. The quality of models was based on the differences in deviance while the simultaneous estimation of all model parameters was performed based on the maximum likelihood estimation. All analyses were performed in STATA software (version 13.0), reporting 95% confidence intervals and p values.

Results

The final sample included 310 children (166 were male), aged 5 to 7 years (Mean = 6.3 years; SD = 0.7). Descriptive statistics for age, gross family income, BMI, MVPA, SB, and motor competence by dropout and biological sex are shown in Table 1.

The association of BMI and PA-SB with motor competence is provided in Table 2. Based on the null model, the ρ was calculated as follows: ρ = 144.31 / (144.31 + 976.95) = 0,128; i.e., 12.8% of the total variance in children's motor competence is explained by differences in school contexts, whereas the remaining 87.2% is explained by individual predictors. In the first model (model 1), BMI was negatively associated with motor competence (β = -2.23, p<0.01). BMI continued negatively associated with motor competence (β = -2.38, p<0.01) despite the inclusion of the confounders (age, biological sex, and gross family income). Finally, BMI continued to be associated with motor competence regardless in the third model, in which the patterns of MVPA and SB were included, demonstrating

an association with the BMI (β = -3.04, p<0.01).

Table 3 presents the PA-SB patterns as a potential moderator of the relationship between weight status and motor competence. We observed an inverse association only in the health-risk behaviors (↓MVPA↑SB) group (β = -3.04, p<0.01). Thus, weight status was not associated with motor competence neither in the healthy behaviors group (↑MVPA↓SB) nor in the group with an intermediate pattern of PA-SB pattern (Table 3).

Discussion

The aim of this study was to analyze whether the relationship between BMI and motor competence in children is moderated by different patterns of MVPA and SB. The moderation analysis indicated that BMI was negatively associated with motor competence only in the group of children with the unhealthy PA-SB pattern group (lowest MVPA tertile and highest SB tertile). In other words, children with higher BMI could preserve motor competence if engaged in lower time spent in SB with higher time spent in MVPA.

Previous studies have shown clear evidence that BMI is negatively associated with motor competence among children[1,5]. However, the present study raises the question whether this association would hold true if the SB and MVPA pattern were considered in the

Table 1 – Descriptive variables and comparison of groups by biological sex and dropout (n = 310).

Variables	Total (n = 352) Mean (standard deviation)	Dropout (n = 42) Mean (standard deviation)	p	Male (n = 166) Mean (standard deviation)	Female (n = 144) Mean (standard deviation)	p	Final Sample (n = 310) Mean (standard deviation)
Age (years)	6.30 (0.73)	6.47 (0.70)	0.11	6.27 (0.74)	6.29 (0.73)	0.79	6.28 (0.74)
Body mass index (kg/m²)	16.71 (3.03)	16.21 (2.59)	0.25	16.81 (3.32)	16.73 (2.79)	0.81	16.77 (3.08)
Moderate to vigorous physical activity (min)	59.64 (23.61)	54.80 (24.60)	0.15	60.31 (22.97)	60.29 (24.05)	0.99	60.30 (23.44)
Sedentary behavior (min)	411.39 (68.68)	383.11 (83.31)	<0.01	414.48 (64.14)	416.14 (67.57)	0.82	415.25 (65.65)
Motor competence (points)	96.28 (33.90)	100.66 (36.85)	0.37	96.37 (34.96)	94.91 (31.83)	0.70	95.69 (33.50)
			Frequency (%)				
Gross family income (Tertile)			0.53			0.02	
Low	110 (35.48)	18 (42.86)		70 (42.16)	40 (27.78)		110 (35.48)
Medium	155 (50.00)	20 (47.62)		73 (43.98)	82 (56.94)		155 (50.00)
High	45 (14.52)	4 (9.52)		23 (13.86)	22 (15.28)		45 (14.52)

Table 2 – Multilevel analysis between body mass index and motor competence (n = 310)

Regression coefficients (fixed effects)	Null model		Model 1		Model 2		Model 3	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Intercept	94.60 (88.50 to 100.69)	<0.001	131.91 (112.86 to 151.53)	<0.001	19.26 (-15.26 to 53.78)	0.27	32.86 (-4.43 to 70.16)	0.08
Body mass index (kg/m²)			-2.23 (-3.35 to -1.11)	<0.001	-2.38 (-3.42 to -1.34)	<0.001	-3.04 (-4.15 to -1.93)	<0.001
Age (years)					18.99 (14.50 to 23.48)	<0.001	18.89 (14.38 to 23.40)	<0.001
Biological sex (female)					-2.19 (-8.63 to 4.24)	0.50	-1.75 (-8.16 to 4.64)	0.59
Gross family income (tertile)					-0.02 (-6.22 to 6.17)	0.99	-0.54 (-6.74 to 5.65)	0.86
Intermediate behaviors pattern§							-2.86 (-13.62 to 7.90)	0.60
Healthy behaviors pattern§							-3.36 (-11.97 to 5.24)	0.44
Variance components (random effects)								
Variance between schools	144.31		131.98		25.06		26.29	
Variance between children	976.95		933.10		820.15		797.99	
Deviance	3037.96		3023.08		2967.32		2940.24	
Number of parameters	3		4		7		9	

§(Health-risk behavior pattern - reference).

Table 3 – Moderation analyses for the association between body mass index and motor competence according to the patterns of physical activity and sedentary behavior (n = 310).

	Motor competence (points)					
	Health-risk behaviors ↓moderate to vigorous physical activity ↑sedentary behavior n = 57		Intermediate behaviors moderate to vigorous physical activity and sedentary behavior * n = 199		Healthy behaviors ↑moderate to vigorous physical activity↓ sedentary behavior n = 54	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Body mass index (kg/m²)	-3.04 (-4.15 to -1.93)	<0.001	-0.18 (-10.98 to 10.61)	0.97	0.32 (-8.23 to 8.87)	0.94
Age (years)	18.89 (14.38 to 23.40)	<0.001	21.75 (10.47 to 33.03)	<0.001	22.25 (13.20 to 31.31)	<0.001
Biological sex (female)	-1.75 (-8.16 to 4.64)	0.59	1.10 (-11.48 to 13.68)	0.86	1.60 (-8.74 to 11.95)	0.76
Gross family income (tertile)	-0.54 (-6.74 to 5.65)	0.86	2.31 (-9.42 to 14.05)	0.69	2.81 (-7.49 to 13.13)	0.59

↓ lower; ↑ higher; * all other tertiles of moderate to vigorous physical activity and sedentary behavior.

BMI-motor competence relationship analyses. So far, studies suggest a negative association between SB and motor competence, independent of MVPA, highlighting that higher levels of PA could not overcome the impairment caused by higher levels of SB in motor competence[5, 28]. Additionally, Estevan et al.[29] in a longitudinal study identified that a daily reallocation of 10 minutes of SB or light PA for 10 minutes of MVPA can contribute to an increase in motor competence in children aged 5 to 10 years. This argument is the key element for our hypothesis, which considers the two variables in determining patterns that may moderate the relationship between BMI and motor competence.

Recently, three studies have longitudinally evaluated the combination of MVPA and SB and their association with the risk of obesity[30-32], demonstrating that exposure to healthy behavior patterns (↑MVPA↓SB) were a protective factor for children and adolescents to develop obesity. In this scenario, the conceptual model developed by Stodden et al.[4] establishes a reciprocal and synergistic relationship between PA and motor competence throughout the developmental cycle. Thus, higher levels of PA in childhood can allow the development of motor competence and, consequently, a lower risk of obesity[3-5]. Our results allow us to assume that, in addition to the model proposed by Stodden et al.[4], the combination of PA-SB patterns need to be considered from childhood as a way to develop MC and reduce the risk of obesity.

Our results suggest that children with healthier behavior patterns are protected from the negative association between BMI and motor competence. Thus, it is necessary to use the built environment to promote a reduction in SB and increased the engagement in MVPA, and meeting PA recommendations[13,33,34], given that children with low motor skills have fewer minutes of MVPA[14,35], and more time in SB[19]. Thus, evidence demonstrating a reciprocal relationship between motor competence and PA[15] may indicate that the development of motor competence is stimulated by increased levels of PA and/or decreased SB[18]. The results of our study indicate that a healthy pattern of MVPA and SB plays an important role in the development of motor competence independent of the child's BMI.

The use of a representative school age sample, good psychometric scores for all tests, and the use of experienced researchers to assess motor competence tasks are strengths of the current study. However, some limitations should be considered. The cross-sectional design precludes inferred causality. In addition, possible changes in exposure time in MVPA and SB at different life stages may modify the relationship between motor competence and BMI differently.

The findings of this study highlight the importance of promoting healthy motor behavior patterns from early childhood by increasing time spent in MVPA and reducing SB. Children with risk patterns characterized by low levels of MVPA and high levels of SB showed greater vulnerability to the negative association between BMI and motor competence, which calls for special attention and targeted interventions. Furthermore, the fact that part of the variance in motor competence is explained by differences in the school context reinforces the need for structured educational environments that provide regular opportunities for movement, such as active recess, physical education classes focused on motor development, and adequate spaces for play and games.

These results reinforce the need to expand and integrate public health policies aimed at the child population by coordinating actions across the sectors, including health and education policies. The focus should be

on creating school and community environments that minimize risk behaviors and prevent negative outcomes such as sedentary behavior, excess weight, and impaired motor competence.

In conclusion, the association between BMI and motor competence is moderated by different patterns of MVPA and SB. BMI was not negatively associated with motor competence in children with higher time in MVPA and less time in SB. These results reinforce the need for a combined action focusing on increased participation in MVPA and reduced exposure to SB in children of 5-7 years of age.

Conflict of interest

The authors declare no conflict of interest.

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Declaration regarding the use of artificial intelligence tools in the article writing process

The authors did not use artificial intelligence tools for preparation of the manuscript.

Availability of research data and other materials

The contents underlying the research text are contained in the manuscript.

Authors contribution

Queiroz DR: Conceptualization; Methodology; Formal analysis; Investigation; Visualization; Writing – original draft; Writing – review & editing; Approval of the final version. Aguilar JA, Martins-Guimarães TG: Formal analysis; Investigation; Writing – original draft; Writing – review & editing; Approval of the final version. Lima MMA, Rocha KBS, Germano-Soares AH, Hardman CM and Tassitano RM: Investigation; Writing – review & editing; Approval of the final version. Lima RA and Santos MAM: Methodology; Writing – review & editing; Approval of the final version. Barros MVG: Conceptualization; Methodology; Formal analysis; Data curation; Supervision; Funding acquisition; Writing – review & editing; Approval of the final version.

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Reviewers' assessment

The reviews of this article were originally conducted in Portuguese. This version has been translated using ChatGPT and subsequently reviewed by the Chief Editors.

Reviewer A

Anonymous

- Was any evidence of plagiarism observed in the manuscript?
  No
- Did the authors provide clarification regarding the ethical procedures adopted for conducting the research?
  Yes

Comments to the author

- The topic did not present innovation or important aspects that could contribute to the field. Regarding the study, the author indicates possible limitations, such as not having conducted a follow-up study but only a cross-sectional assessment. This is important, but other studies have already shown that there is no relationship with the proposed topic. The study did not identify children's exposure to physical activity, specifically at school.
- Since this is a cross-sectional study, the sample could have been more representative of the population. It would be important to conduct analyses stratified by socioeconomic status and its relationship with moderate-to-vigorous physical activity and sedentary behavior in the association between body mass index and motor competence in children. I believe this may have an impact.

Final decision

- Accept

Reviewer B

Anonymous

- Was any evidence of plagiarism observed in the manuscript?
- No
- Did the authors provide clarification regarding the ethical procedures adopted for conducting the research?
- Yes

Comments to the author

- Dear authors, congratulations on developing a study of great scientific relevance for the field of physical activity and child health. The proposal to evaluate the combined patterns of vigorous and moderate physical activity and sedentary behavior in relation to BMI and motor competence is well-grounded and demonstrates originality, with up-to-date references.

Final decision

- Accept