



Can motor competence be a better predictor of adiposity indicators than physical activity in children? A longitudinal study

A competência motora pode ser um melhor preditor dos indicadores de adiposidade do que a atividade física em crianças? Um estudo longitudinal

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ABSTRACT

Introduction: Adiposity indicators are considered key components of body composition and reliable health markers throughout childhood. **Objective:** This study analyzed whether motor competence (MC) and moderate-to-vigorous physical activity (MVPA) in children were predictors of adiposity indicators after two years. **Methods:** A longitudinal study (Longitudinal Study of Health and Wellbeing in Preschool Age - ELOS-Pré) was conducted since 2010 and reassessed in 2012 and 2014. The current study followed 391 children (mean age 6.34 ± 0.72 years) enrolled in public and private schools during 2012 and 2014, from Recife, Pernambuco, Brazil. Adiposity indicators were evaluated using waist circumference (WC), the sum of tricipital and subscapular skinfolds (Σ SF), and body mass index (BMI). MVPA was measured using accelerometers. MC was assessed using the Körperkoordination Test für Kinder (KTK), considering the sum of raw scores. Linear regressions were performed for all analyses. Results: MC showed negative association with Σ SF ($\beta = -0.09$; $p < 0.01$), BMI ($\beta = -0.02$; $p < 0.01$) and WC ($\beta = -0.07$; $p < 0.01$); for both the total sample and girls/boys separately. MVPA was negatively associated with BMI ($\beta = -0.01$; $p = 0.01$); however, differences were observed between girls and boys. **Conclusions:** MC and MVPA predict adiposity indicators in children after two years. However, MC seems to be a more suitable predictor of adiposity indicators in childhood.

Keywords: Adiposity; Motor competence; Physical activity; Children.

RESUMO

Introdução: Os indicadores de adiposidade são considerados componentes-chave da composição corporal e marcadores de saúde confiáveis durante a infância. **Objetivo:** Este estudo analisou se a competência motora (CM) e a atividade física de moderada a vigorosa (AFMV) em crianças foram preditores de indicadores de adiposidade após dois anos. **Método:** Um estudo longitudinal (Estudo Longitudinal de Observação da Saúde e Bem-estar da Criança em Idade Pré-escolar - ELOS-Pré) foi conduzido desde 2010 e reavaliado em 2012 e 2014. O estudo atual acompanhou 391 crianças (6,34 ± 0,72 anos) matriculadas em escolas públicas e privadas durante 2012 e 2014, de Recife, Pernambuco, Brasil. Os indicadores de adiposidade foram avaliados usando a circunferência da cintura, a soma das dobras cutâneas tricipital e subescapular (Σ DC) e o índice de massa corporal (IMC). A AFMV foi medida com acelerômetros. A CM foi avaliada usando o Körperkoordination Test für Kinder, considerando a soma dos escores. Regressões lineares foram realizadas para todas as análises. **Resultados:** A CM mostrou associação negativa com Σ DC ($\beta = -0,09$; $p < 0,01$), IMC ($\beta = -0,02$; $p < 0,01$) e CC ($\beta = -0,07$; $p < 0,01$); tanto para a amostra total quanto para meninas/meninos separadamente. A AFMV foi negativamente associada ao IMC ($\beta = -0,01$; $p = 0,01$); no entanto, foram observadas diferenças entre meninas e meninos. **Conclusões:** CM e AFMV predizem indicadores de adiposidade em crianças após dois anos. No entanto, a CM parece ser um preditor mais adequado dos indicadores de adiposidade na infância.

Palavras-chave: Adiposidade; Competência motora; Atividade física; Crianças.

Introduction

The high prevalence of childhood overweight and obesity remains a significant global public health concern, primarily due to its association with adverse health consequences that can persist throughout life, such as metabolic diseases and cardiovascular risk factors^{1,2}.

The assessment of adiposity in children is a way to identify at-risk individuals before reaching high levels. Literature shows that adiposity excess in children is related to cardiometabolic health and fundamental motor skills³. Moreover, adiposity plays an essential role in the relationship between physical fitness and cardiometabolic risk factors. Some indicators are more commonly used to assess adiposity, such as body mass index (BMI), sum of skinfolds (Σ SF), and waist circumference (WC), which are used in a complementary way⁴. BMI provides a general and indirect description of adiposity⁵; Σ SF is a measure strongly related to the percentage of body fat⁴, whereas WC is used as a potential measure of central body fat and is associated with cardiovascular risk factors⁶.

It is known that childhood and adolescence are crucial periods of life, since during these phases, physiological and psychological changes occur, and lifestyles are established⁵. From a developmental perspective, the theoretical model by Stodden et al.⁷ suggests the existence of a dynamic and reciprocal relationship between obesity and health-related factors, including motor competence (MC) and physical activity (PA). However, it is recognized that the real role of these factors and the influence of any one on the others depend on the specific life stage. The mentioned model indicates that during early childhood, PA plays a key role in the development of MC; however, this relationship changes in second childhood and adolescence, where MC is an underlying mechanism that contributes to the initiation, participation, and maintenance of PA levels. Excessive body weight is considered both a product and a factor that feeds back into the relationships previously established within the model, which can affect the engagement, maintenance, or disengagement of children to remain physically active⁷.

The benefits of PA are well established, since PA is associated with protection from lifestyle diseases and the development of cardiovascular risk factors^{8,9}. In particular, moderate-to-vigorous physical activity (MVPA) could have important effects on the prevention and treatment of childhood and adolescent obesity¹⁰. Worldwide recommendations suggest that

children and adolescents practice MVPA for at least 60 minutes a day; however, recent trends indicate that they meet these recommendations less frequently¹¹. Cross-sectional¹¹ and longitudinal studies^{12,13} have shown negative associations between MVPA and adiposity indicators such as BMI, WC, and body fat. Nonetheless, these studies analyzed MVPA isolated from other health-related factors, which are present in childhood and adolescence, as MC.

Referring to MC, it is a global term describing an individual's degree of proficiency in performing a wide variety of motor skills, as well as the mechanisms underlying this performance¹⁴. Studies have revealed that MC is a key factor in the promotion of active and healthy lifestyles during childhood and adolescence^{15,16}. Longitudinal studies have also provided evidence that MC levels during childhood are associated with adiposity indicator levels in later years^{17,18}. Despite the findings already reported, few studies have simultaneously analyzed the potential influence of PA and MC on diverse adiposity indicators during childhood from a longitudinal perspective. While many studies have investigated these variables separately^{10,12,13} or in cross-sectional designs^{11,19,20}, a significant gap remains in understanding their simultaneous longitudinal influence during middle childhood (6–9 years). This developmental period is critical, as the theoretical model suggests the relationship between MC and PA begins to solidify, with MC becoming a key mechanism for PA engagement. However, this specific age group is often overlooked in longitudinal cohorts, which tend to focus either on preschool entry or later adolescence. Therefore, this study provides a specific and necessary contribution by addressing this gap, analyzing two key predictors concurrently. Thus, this study aimed to analyze whether MVPA and MC are predictors of distribution-related fat indicators in children over a two-year period.

Methods

Study design and participants

This study utilized secondary data from the Longitudinal Study of Health and Wellbeing in Preschool Age - ELOS-Pré Project (*Estudo Longitudinal de Observação da Saúde e Bem-estar da Criança em Idade Pré-escolar - ELOS-Pré*). The ELOS-Pré Project is a longitudinal study that started in 2010, where the initial target population was preschool children (3 to 5 years old) enrolled in public and private schools from the Regional Education Management of Recife, State of Pernambu-

co, Brazil. The present analysis included 391 children who were successfully tracked and evaluated at both the 1st wave (2012) and the 2nd wave (2014), representing a two-year follow-up period. The ELOS-Pré study was approved by the local scientific ethics committee (CAAE – 0096.0.097.000-10).

In the original 2010 study, schools were selected via cluster sampling. Parents/guardians of all eligible children (ages 3–5) at these schools were then contacted, informed of the study objectives, and invited to participate. Written informed consent was obtained from parents/guardians who agreed. Given the children's young age at recruitment, formal written assent was not collected; instead, all procedures were explained in age-appropriate language, and verbal willingness to participate was respected throughout the data collection.

Sample

The minimum sample size was established considering the following parameters: (a) population estimated at 49,338 children; (b) prevalence of the variables of interest in the target population was set at 50%, (c) 95% confidence interval, (d) maximum tolerance error of four percentage points, and (e) effect size of the pre-established sampling of 1.5 due to the cluster sampling resource. To minimize possible losses and refusals during follow-up, the minimum sample size of 890 children was increased by 20%, for a final target sample of 1,068.

The sample was selected using a cluster sampling single-stage technique, with the school as the sample unit. All schools with preschool students were considered eligible for inclusion in the study. Considering an average number of 38.5 children enrolled in each school it was established that data collection would be performed in 28 schools. To select a representative sample of preschoolers, we considered the proportion of children in schools according to type (public or private), school size (small, medium and large) and their distribution throughout the six political-administrative regions of Recife, Pernambuco, Brazil.

Inclusion and Exclusion Criteria

For this specific longitudinal analysis (2012–2014), children were included if they had complete data for all independent variables (MC and MVPA in 2012) and outcome variables (adiposity indicators in 2014). Children with physical disabilities, syndromes, or health conditions that would prevent their participation in

the Körperkoordination Test für Kinder (KTK)²¹ or PA monitoring, as reported by parents, were excluded from the original ELOS-Pré cohort.

Measurements and variables

All data collection in both waves (2012 and 2014) followed standardized procedures and was conducted by a trained research team supervised by the lead researchers. Anthropometric measurements and KTK tests were administered individually to each child in a quiet, reserved space (e.g., a gym, classroom or library) within the school environment.

Outcomes

The results from adiposity indicators (Σ SF, BMI, and WC) in 2014 were used as outcome measures. Body mass was obtained using portable digital scales (G. Tech, Accumed Produtos Medico Hospitalares Ltda, Brazil, model Glass 6), previously calibrated, with a precision of 0.1 kg variation and capacity of up to 150 kg. Height was assessed using a portable stadiometer (Welmy, Brazil, model II), with 0.5 cm scales. BMI was calculated using the standard formula [$\text{BMI} = (\text{kg}) / \text{height} (\text{m})^2$]. WC was measured using a tape at the umbilical level with an accuracy of 0.5 cm. Two measurements were performed, and in cases where there was a difference between the first and second measurements greater than 1.0 cm, a third measurement was performed. The tricipital and subscapular skinfolds were measured three times using an adipometer (Lange, Brazil, model 68902). The mean of each skinfold measure was added (sum of skinfolds) (Σ SF) for use in the analysis.

Independent variables

MC was measured using the KTK test battery²¹. KTK consists of four independent tests: (a) balance while moving backwards - 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 for each of the four tests was used for the analysis. The test-retest reliability (intraclass correlation coefficients) ranged from 0.70 (shifting platforms) to 0.94 (hopping on one leg over an obstacle), presenting satisfactory indices according to previous studies²¹.

PA was measured by accelerometers (GT3X+, ActiGraph, USA). The children's parents/guardians were instructed by the researchers regarding the use of accelerometers. The device was placed on the waist, at the height of the right upper iliac crest, in the early morning, and removed only when the child went to sleep, swim, or bathe. During the monitoring period, parents were trained to fill in a diary reporting the time for placing and removing the device as well as the reasons for not using accelerometers. Throughout the collection period, parents were contacted by phone to identify possible doubts and difficulties in keeping their child with the device in use. Recording intervals (epochs) of 15 seconds were used. All children were monitored for seven consecutive days, including weekends. Data were downloaded using software (ActiLife, ActiGraph, USA). Raw data were reduced using the parameters suggested in the literature. To be included in the analysis, the child should have at least three days of valid monitoring on one of the weekends. To consider a day of monitoring as valid, the child should use an accelerometer for at least eight hours. Periods of 60 minutes of consecutive zeros were considered as accelerometers were not used, and were excluded from the analyses. The time spent on MVPA was estimated from the cutoff points suggested by Evenson et al.²², based on an awake 16-hour day. In this study, daily time of physical activities of moderate to vigorous intensity was included in the analysis.

Covariates

For the measurement of sitting height (trunk-encephalic stature), the children remained seated on a bench, keeping their heads in the horizontal plane of the Frankfurt. Subsequently, they were measured from the highest point of the head (vertex) to the hip support plane (ischial spine). Leg length was calculated by obtaining the difference between the child's height measurement and the sitting height measurement. All measurements were in accordance with the standard procedures set forth by Lohman, Roche and Martorell²³. Somatic maturation status was determined by calculating the maturity offset (years from peak height velocity) obtained from the chronological age in years and the measures of height, BMI, sitting height, and leg length. It used the age calculation equations in years for peak height velocity (PHV) proposed by Mirwald et al.²⁴ The analyses also included covariates such as gender (male and female), family income (categorized

as low, medium, and high), and birth weight (kg).

Data analysis

Data tabulation was performed by EpiData Entry software (EpiData, Denmark, version 3.1), using a cross-reference for amplitude and consistency in data entry. Outliers and normality of the data were examined (Kolmogorov test). For descriptive purposes, the means, standard deviations, and frequencies were calculated. To assess potential attrition bias, 1st wave characteristics (2012) were compared using Student's t-tests and Chi-square tests between the final follow-up (2014) sample and the drop-out group. Additionally, Chi-square and Student's t-tests were used to analyze comparisons between gender in longitudinal follow-up of participants.

Multiple linear regressions were performed for each dependent variable (1 – sum of skinfolds/2014; 2 – BMI/2014; 3 – WC/2014), using the automatic selection and backward method. It was adopted with a significance level of $p < 0.20$ for permanence of variables in the model. All models were tested for independent variables (1 – MC; 2 – MVPA) and possible confounding variables (1, variation of Σ SF, variation of BMI, or variation of WC; 2, age; 3, gender; 4, family income; 5, variation in PHV; 6, birth weight). All analyses were adjusted by “wear time” of the accelerometer. Subsequently, the analyses were stratified by gender. The following criteria were used for the quality of analysis: (1) Akaike information criterion (AIC) and (2) variance inflation factor (VIF < 5) as an indicator of the absence of collinearity. All analyses were performed using the Stata software (version 13.0), with a significance set at $p < 0.05$.

Results

Table 1 presents the sample characteristics at 2nd wave and compares them with the dropout. From an initial cohort of 1,034 children at baseline, 766 were evaluated in the 1st wave (2012) and 415 in the 2nd wave (2014). Participant drop-out was mainly due to parental refusal or because children were no longer found at the schools upon follow-up. The present analysis includes the 391 children from the second wave who had complete MC data. None of the variables showed a significant difference between the 1st wave and 2nd wave ($p > 0.05$). The final sample consisted of 391 children ($n = 183$ boys) with no missing data across the two study waves. The descriptions of the variables used in

this study are shown in Table 2. Girls showed a significantly greater change in PHV and higher birth weight compared to boys ($p < 0.01$).

In the multiple linear regression analysis for ΣSF (Table 3), the adjusted model showed a negative association with MC ($\beta = -0.09$; $p < 0.01$). In the analysis stratified by gender, these negative associations with

MC ($\beta = -0.11$; $p < 0.01$) and MVPA ($\beta = -0.06$; $p = 0.03$) remained significant for boys. For girls, only the association with MC remained significant ($\beta = -0.17$; $p < 0.01$).

When BMI was the outcome (Table 4), the adjusted model showed negative associations with MC ($\beta = -0.02$; $p < 0.01$) and MVPA ($\beta = -0.01$; $p = 0.01$). In

Table 1 – Comparison for variables in 2nd wave (2014) and drop-out.

Variables	2014 (n = 391) Mean (standard deviation)	Drop-out (n = 228) Mean (standard deviation)	P	Total (n = 619) Mean (standard deviation)
Age (years)	6.34 (0.72)	6.24 (0.74)	0.11	6.30 (0.73)
Birth weight (kg)	3.26 (0.69)	3.23 (0.64)	0.62	3.25 (0.67)
Body mass index (kg/m ²)	16.86 (3.24)	16.98 (3.18)	0.64	16.91 (3.22)
Waist circumference (cm)	57.86 (7.90)	58.04 (8.33)	0.79	57.93 (8.05)
Skinfolds – triceps+subscapular (mm)	19.20 (8.99)	19.79 (10.22)	0.45	19.42 (9.45)
Motor competence – Körperkoordination Test für Kinder (points)	96.81 (34.89)	93.84 (32.51)	0.28	95.77 (34.03)
Moderate to vigorous physical activity (min)	60.27 (24.02)	60.81 (20.65)	0.79	60.44 (22.73)
	Frequency n (%)	Frequency n (%)	p	Frequency n (%)
Gender				
Male	183 (46.8)	115 (50.4)	0.37	298 (48.1)
Female	208 (53.2)	113 (49.6)		321 (51.9)
Family income				
Low	147 (37.6)	88 (38.6)	0.37	235 (38.0)
Average	181 (46.3)	115 (50.4)		296 (47.8)
High	63 (16.1)	25 (11.0)		88 (14.2)

Table 2 – Descriptive variables and comparison by gender of subjects monitored from 2nd wave (2014).

Variables	Boys (n = 183) Mean (standard deviation)	Girls (n = 208) Mean (standard deviation)	P	Total (n = 391) Mean (standard deviation)
Age in 2012 (years)	6.32 (0.74)	6.35 (0.70)	0.75	6.34 (0.72)
Birth weight (kg)	3.16 (0.65)	3.35 (0.72)	<0.01	3.26 (0.69)
Body mass index in 2014 (kg/m ²)	17.71 (3.99)	17.85 (4.13)	0.75	17.78 (12.37)
Waist circumference in 2014 (cm)	63.13 (9.91)	64.47 (10.31)	0.19	63.85 (10.13)
Summation skinfold in 2014 (mm)	26.45 (12.84)	24.15 (13.96)	0.09	25.23 (13.48)
Motor competence – Körperkoordination Test für Kinder in 2012 (points)	94.01 (33.51)	99.27 (35.96)	0.13	96.81 (34.89)
Moderate to vigorous physical activity in 2012 (min)	58.32 (24.38)	61.96 (23.66)	0.23	60.27 (24.02)
Variation skinfold (2014-2012)	5.80 (7.90)	6.21 (7.67)	0.60	6.02 (7.77)
Variation body mass index (2014-2012)	1.11 (2.57)	1.12 (2.25)	0.95	1.12 (2.41)
Variation waist circumference (2014-2012)	5.72 (4.50)	6.17 (4.63)	0.33	5.96 (4.57)
Variation peak height velocity (2014-2012)	0.17 (0.20)	2.54 (0.58)	<0.01	1.40 (1.26)
	Frequency n (%)	Frequency n (%)	P	Frequency n (%)
Family income in 2012				
Low	73 (39.9)	74 (35.6)	0.60	147 (37.6)
Average	80 (43.7)	101 (48.6)		181 (46.3)
High	30 (16.4)	33 (15.9)		63 (16.1)

the analysis stratified by gender, both MC ($\beta = -0.03$; $p < 0.01$) and MVPA ($\beta = -0.02$; $p < 0.01$) remained negatively associated with BMI for boys. For girls, however, only the negative association with MC remained significant ($\beta = -0.02$; $p < 0.01$).

In the analysis for WC as the outcome (Table 5), the adjusted model showed a significant negative association only with MC ($\beta = -0.07$; $p < 0.01$). In the stratified analysis, boys showed negative associations with both MC ($\beta = -0.08$; $p < 0.01$) and MVPA ($\beta = -0.05$; $p = 0.02$). For girls, only the negative association

with MC was significant ($\beta = -0.08$; $p < 0.01$).

Discussion

The objective of this study was to analyze whether MC and MVPA predict adiposity indicators: Σ SF, BMI, and WC in children over a two-year period. The main results showed the existence of a negative association between MC and each adiposity indicator (Σ SF, BMI, WC), both for the total sample of children and when stratified by gender. However, MVPA was negatively associated only with BMI for the total sample and only

Table 3 – Association between motor competence, moderate-to-vigorous physical activity and sum of skinfolds.

	Sum of skinfolds in 2014 (mm)							
	Unadjusted Model		Adjusted Model		Boys		Girls	
	β (Standard error)	P	β (Standard error)	P	β (Standard error)	P	β (Standard error)	P
Intercept	-	-	17.68 (6.80)	0.01	13.65 (11.98)	0.25	7.53 (11.34)	0.50
Motor competence – Körperkoordination Test für Kinder in 2012 (points)	-0.14 (0.01)	<0.01	-0.09 (0.01)	<0.01	-0.11 (0.02)	<0.01	-0.17 (0.03)	<0.01
Moderate-to-vigorous physical activity in 2012 (min)	-0.03 (0.03)	0.32	-0.03 (0.02)	0.05	-0.06 (0.02)	0.03		
Age in 2012 (years)	0.40 (0.94)	0.67			2.13 (1.13)	0.06	3.17 (1.90)	0.09
Gender (Girls)	2.29 (1.36)	0.09	-2.76 (0.98)	<0.01				
Family income in 2012	1.71 (0.97)	0.07						
Variation skinfold (2014-2012)	1.33 (0.05)	<0.01	1.36 (0.06)	<0.01	1.21 (0.09)	<0.01		
Variation peak height velocity (2014-2012) (years)	-0.43 (0.55)	0.43			-9.11 (3.78)	0.01	5.16 (1.74)	<0.01
Birth weight (kg)	0.90 (1.00)	0.36			1.89 (0.99)	0.06		
Coefficient of determination	-		0.71		0.70		0.22	
Variance Inflation Factor	-		1.02		1.18		1.20	
Akaike Information Criterion	-		1535.61		748.83		917.77	

All models were adjusted for accelerometer usage time.

Table 4 – Association between motor competence, moderate-to-vigorous physical activity and body mass index.

	Body mass index in 2014 (kg/m ²)							
	Unadjusted Model		Adjusted Model		Boys		Girls	
	β (Standard error)	P	β (Standard error)	P	β (Standard error)	P	β (Standard error)	P
Intercept	-	-	12.44 (3.12)	<0.01	11.75 (3.99)	<0.01	16.71 (1.48)	<0.01
Motor competence – Körperkoordination Test für Kinder in 2012 (points)	-0.03 (0.01)	<0.01	-0.02 (0.01)	<0.01	-0.03 (0.01)	<0.01	-0.02 (0.01)	<0.01
Moderate-to-vigorous physical activity in 2012 (min)	-0.01 (0.01)	0.89	-0.01 (0.01)	0.01	-0.02 (0.01)	<0.01		
Age in 2012 (years)	0.13 (0.29)	0.64	0.50 (0.28)	0.08	0.77 (0.35)	0.03		
Gender (Girls)	0.13 (0.43)	0.75	-1.60 (1.01)	0.11				
Family income in 2012	0.02 (0.30)	0.93						
Variation body mass index (2014-2012)	1.22 (0.06)	<0.01	1.14 (0.07)	<0.01	1.18 (0.08)	<0.01	1.22 (0.11)	<0.01
Variation peak height velocity (2014-2012) (years)	0.37 (0.17)	0.02	0.82 (0.40)	0.04	-3.98 (1.41)	<0.01	0.92 (0.44)	0.03
Birth weight (kg)	0.34 (0.31)	0.28	0.40 (0.26)	0.13	0.91 (0.31)	<0.01		
Coefficient of determination	-		0.63		0.72		0.61	
Variance Inflation Factor	-		2.72		1.22		1.11	
Akaike Information Criterion	-		1069.08		486.04		562.06	

Table 5– Association between motor competence, moderate-to-vigorous physical activity and waist circumference.

	Waist circumference 2014 (cm)							
	Unadjusted Model		Adjusted Model		Boys		Girls	
	β (Standard error)	p	β (Standard error)	p	β (Standard error)	p	β (Standard error)	p
Intercept	-	-	43.01 (7.31)	<0.01	32.48 (10.46)	<0.01	46.77 (6.42)	<0.01
Motor competence – Körperkoordination Test für Kinder 2012 (points)	- 0.09 (0.01)	<0.01	- 0.07 (0.01)	<0.01	- 0.08 (0.02)	<0.01	- 0.08 (0.02)	<0.01
Moderate-to-vigorous physical activity 2012 (min)	- 0.02 (0.02)	0.35	- 0.03 (0.01)	0.11	- 0.05 (0.02)	0.02		
Age 2012 (years)	0.96 (0.71)	0.17	-2.49 (0.73)	<0.01	3.31 (1.00)	<0.01	2.04 (1.08)	0.06
Gender (Girls)	1.33 (1.02)	0.19						
Family income 2012	1.16 (0.73)	0.11			1.17 (0.89)	0.19		
Variation waist circumference (2014–2012)	1.45 (0.08)	<0.01	1.33 (0.10)	<0.01	1.25 (0.13)	<0.01	1.33 (0.15)	<0.01
Variation peak height velocity (2014–2012) (years)	0.80 (0.40)	0.04	0.68 (0.37)	0.06	- 8.81 (3.36)	0.01	2.00 (1.00)	0.04
Birth weight (kg)	1.20 (0.75)	0.10			1.74 (0.87)	0.04		
Coefficient of determination	-		0.51		0.57		0.54	
Variance Inflation Factor	-		1.12		1.16		1.20	
Akaike Information Criterion	-		1543.15		712.62		788.10	

All models were adjusted for accelerometer usage time.

for boys in each outcome (Σ SF, BMI, WC) when the analysis was stratified by gender. In the case of girls, there was no association between MVPA in any of the adiposity indicators.

Studying the relationships and mechanisms that may predict adiposity indicators in children is a way to assess and identify individuals at risk before adiposity reaches high levels. In the present study, BMI, Σ SF and WC were applied, which are used in a complementary way to indicate adiposity⁴. Taking a developmental perspective and in accordance with the theoretical model proposed by Stodden et al.⁷, it was expected that adiposity indicators in children aged 7–9 years would be associated with MVPA and MC acquired earlier. Overall, the results partially confirm this hypothesis, showing a negative association with MC. In other words, boys and girls who had higher MC scores in 2012 reduced their adiposity indicators after two years.

MC can be understood as a key variable in childhood because of its importance to health trajectories. Unlike other factors that can be reversed on a shorter timescale, the acquisition of motor skills is a phenomenon that tends to persist over time¹⁵. Stodden et al.⁷ indicated that PA practiced in early childhood lays the foundation for motor skill acquisition. This acquisition reinforces the model and enhances children's PA levels, further increasing their MC. This mechanism is known as the "positive engagement"⁷, which tends to remain throughout life, promoting a healthy weight status. The development of MC is essential for promoting an

active lifestyle in childhood and adolescence, which is fundamental to understanding why individuals choose to be active or inactive^{7,25}. The present study appears to reinforce this cycle of dynamic interactions. The results also provide additional support for previously reported associations between MC and adiposity indicators^{3,17,26,27}.

Specifically, MVPA is associated with significant health benefits and is particularly important in the prevention and treatment of childhood obesity¹¹. In this study, MVPA was negatively associated with BMI in the total sample, and in boys, all adiposity indicators were negatively associated with MVPA, in agreement with other studies^{12,13}. However, for girls, no significant association was found. One possible explanation could be the differences in growth and development²⁰. A recent meta-analysis¹⁰ found that the negative percentage variation in MVPA per year is higher in girls (-5.3%) than in boys (-3.4%). Although the 1st wave data did not show significant differences in MVPA, this steeper decline in girls could explain the absence of association with adiposity after two years.

Based on these findings, it can be inferred that MC is a more consistent predictor of adiposity indicators in both boys and girls. Martins et al.¹⁷ showed partially similar results in a longitudinal study, where PA was not significantly associated with changes in BMI, but children with higher MC had lower BMI values over 5 years.

From a biological perspective, differences in motor

performance between the gender become more pronounced with age²⁷. According to Malina²⁸, larger body size in boys provides them with better performance in gross motor tasks, whereas a greater amount of body fat in girls can make displacement difficult. Another important aspect is the difference in the PHV. Girls in this sample were significantly closer to PHV than boys. Some studies have reported that the association between MC and BMI decreases as children approach PHV^{27,29}. An early “adiposity rebound” is associated with an increased risk of obesity³⁰, and since girls in our follow-up were likely in this period, this could explain the increased adiposity.

Although there were no significant differences in age between gender, girls were significantly closer to PHV than boys. Some studies have reported that the strength of the association between MC and BMI decreases as children begin to reach PHV^{27,29}. Considering the differences in growth reported between the gender, variation in PHV was included as an adjusting variable. The findings of our study confirmed these differences, showing a negative association between PHV variation (2012-2014) and all adiposity indicators in boys. Conversely, in the case of girls, there was a positive association between PHV variation and adiposity indicators (Σ SF, BMI, WC). That is, with each passing year in PHV variation, boys experienced a significant decrease in the sum of skinfold thickness, BMI, and WC, while girls exhibited the opposite trend, with a significant increase in their adiposity indicators.

The present study has some limitations that should be reported, among which are: (i) The use of anthropometric measures to assess adiposity indicators may limit the interpretation of the results. Although DEXA has been suggested as the gold standard for assessing body composition in individuals, its complexity and cost limit its use. In this case, BMI, Σ SF and WC become advantageous for epidemiological studies in a pediatric population as they are easy, safe to obtain, and well-tolerated by children. (ii) A moderate percentage of losses and refusals (36.8%), commonly observed in longitudinal studies (drop-out). (iii) The use of only MVPA measures, without considering total or light PA, could have limited the interpretation of the relationships found in this study.

On the other hand, this study has strengths that deserve to be highlighted: (i) This study is the first to assess the association of MVPA and MC as potential predictors of adiposity indicators in Brazilian children;

(ii) The study design allowed for causal inferences regarding the findings; (iii) The study was conducted with a representative sample of school-age children, drawn from preschoolers enrolled in public and private schools in a capital city in Northeast Brazil, and none of the variables showed significant differences between the participating children and those lost to follow-up after 2 years; (iv) Objective measurement of PA was directly performed through accelerometer monitoring; (v) The use of control strategies in analyses adjusted for main confounding variables; (vi) Pre-training of the research team and satisfactory levels of validity and reproducibility of the measurement instruments used in the fieldwork.

In accordance with the objectives established in this study, it is possible to conclude: (1) MC is a predictor of BMI, Σ SF and in school-age girls and boys; (2) MVPA is a predictor of BMI, sum of skinfolds, and WC in boys; (3) MVPA does not predict adiposity indicators in girls; (4) Growth and developmental differences between school-age boys and girls are associated with their adiposity indicators.

These findings have direct implications for school-based health policies. Given that MC appears to be a more robust predictor of adiposity than MVPA alone. For girls, in whom MVPA showed no predictive association, interventions should prioritize the development of fundamental motor skills within physical education curriculum. Simply promoting “more activity” may be insufficient if children lack the underlying MC to engage in such activities efficiently and enjoyably.

In conclusion, there is a need for intervention in the prevention of childhood obesity. The presented findings align with important information regarding the relationships established between MVPA and MC with adiposity indicators in school-age children after two years. Specifically, according to the research findings, it is recommended that future interventions focus on developing motor skills from preschool to minimize adiposity indicators and prevent obesity in children. The school is where children spend most of their days and are exposed to systematically organized and professionally guided activities. Understanding these relationships will serve as guidance for both Physical Education teachers in planning their classes and other professionals working with children outside the school environment. The synergy between PA and MC is a key element, and considering it from early childhood is a transcendental responsibility for parents

and professionals to contribute to healthy adiposity trajectories and, consequently, better health outcomes in adulthood.

Conflict of interest

The authors declare no conflict of interest.

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Author's contributions

Alarcón-Aguilar J and Queiroz DR: Conceptualization; Methodology; Formal analysis; Writing – original draft; Approval of the final version. Soares FC and Wanderley Júnior RS: Formal analysis; Investigation; Data curation; Writing – review & editing; Approval of the final version. Lima MMA: Investigation; Writing – review & editing; Approval of the final version. Hardman CM: Data curation; Writing – review & editing; Approval of the final version. Mota J and Cristi-Montero C: Methodology; Writing – review & editing; Approval of the final version. Barros MVG: Conceptualization; Methodology; Writing – review & editing; Approval of the final version. Santos MAM: Conceptualization; Methodology; Formal analysis; Writing – original draft; Approval of the final version.

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 anonymized dataset that supports the findings of this study is available from the corresponding author upon reasonable request. Due to ethical guidelines and privacy restrictions related to the participants (minors), the data are not publicly deposited, but can be made available for verification purposes following a data use agreement.

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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

Flávia Evelin Bandeira Lima Valério 

State University of Northern Paraná, Jacarezinho, Paraná, Brazil.

Format

- Does the article comply with the manuscript preparation guidelines for submission to the Revista Brasileira de Atividade Física e Saúde?

Yes

- Regarding formal aspects, is the manuscript well structured, containing the sections introduction, methods, results and discussion (with the conclusion as part of the discussion)?

Yes

- Is the language appropriate, and is the text clear, precise and objective?

Yes

- Was any indication of plagiarism observed in the manuscript?

No

Suggestions/comments:

The topic is highly relevant and demonstrates originality.

Abstract

- Are the Portuguese abstract and the English abstract adequate (containing the objective, information about study participants, studied variables, main results and a conclusion) and do they reflect the content of the manuscript?

Yes

Suggestions/comments:

No comments

Introduction

- Was the research problem clearly stated and delimited?

Partially

- Is the research problem adequately contextualized in relation to existing knowledge, moving from the general to the specific?

Partially

- Are the reasons that justify the study, including the authors assumptions about the problem, well established in the writing?

Partially

- Are the references used to support the presentation of the research problem current and relevant to the topic?

Yes

- Was the objective clearly presented?

Yes

Suggestions/comments:

The introduction could include more studies showing that the selected age group is underrepresented in the literature. The scarcity of studies is mentioned, but not justified with evidence. It would be beneficial to show that the two themes are widely discussed, bringing more references, although often focusing on other age groups or different relationships. This would make the introduction more robust and emphatic.

Methods

- Are the methodological procedures generally adequate to study the research problem?

Yes

- Are the methodological procedures adopted for conducting the study sufficiently detailed?

Partially

- Was the procedure used to select or recruit participants adequate and described clearly, objectively and with sufficient detail?

Partially

- Were information about the data collection instruments, their psychometric properties (for example reproducibility, internal consistency and validity) and, when relevant, the operational definitions of variables presented?

Partially

- Is the data analysis plan adequate and well described?

Yes

- Were the inclusion and exclusion criteria for participants described and adequate for the study?

No

- Did the authors provide clarification on the ethical procedures adopted in the research?

Yes

Suggestions/comments:

- The methodology needs to be more detailed. For example, the longitudinal design should specify the duration (only two years or longer). In some sections, it seems that data were taken from an existing project. It should be clarified whether the data were already collected or whether only the children from that project were used. This generates uncertainty.
- How were the children initially recruited? The manuscript states that parents were contacted for testing, but the step by step procedure is not described.
- Were the conditions of the baseline and final assessments comparable (time of day, approximate hour, etc.)?
- The tests include classifications indicating whether children are within the age appropriate standard. Even if not the main objective, presenting these data and mentioning them in the methodology would be valuable.
- Although the children were not literate, they did not provide assent (even in an adapted form).
- The manuscript does not present inclusion and exclusion criteria.
- How were assessments conducted? In groups or individually? In what physical spaces?
- The methodology is the heart of the research, the recipe, and therefore it needs to include as many details as possible, even if concisely presented.

Results

- Is the use of tables and figures appropriate and does it facilitate adequate presentation of the study results?
Yes
- Is the number of illustrations in accordance with the journal guidelines?
Yes
- Are the number of participants at each stage of the study, as well as the number and reasons for losses and refusals, presented?
Yes
- Are the characteristics of the participants presented and sufficient?
Partially
- Are the results adequately presented, highlighting the main findings and avoiding unnecessary repetition?

Yes

Suggestions/comments:

A suggestion: if three ages were assessed at baseline and follow up, and considering that most current studies in motor behavior no longer separate boys and girls (despite many protocols still doing so), I suggest presenting the data by age group (pre and post). This could even be done within sex, if necessary to avoid abrupt changes, but it would provide a parameter, especially for motor variables, making the study more complete.

Discussion

- Are the main findings of the study presented?
Yes
- Are the limitations and strengths of the study presented and discussed?
Yes
- Are the results discussed in light of study limitations and existing knowledge?
Yes
- Do the authors discuss the potential contributions of the main findings to scientific development, innovation or real world interventions?
Yes

Suggestions/comments:

If changes are made in the presentation of results, the discussion should be adjusted accordingly, becoming more robust.

Conclusion

- Is the study conclusion adequately presented and coherent with the objective?
Yes
- Is the study conclusion original?
Yes

Suggestions/comments:

The entire text should be written in an impersonal tone (for example, this research, this study). First person and third person expressions should not be used (for example, based on our findings). There should be textual consistency, and in some sections the writing deviates from this standard.

References

- Are the references up to date and sufficient?
Partially
- Are most references original research articles?
Yes

- Do the references comply with journal guidelines regarding quantity and formatting?

Yes

- Is in text citation adequate, meaning all statements are supported by appropriate references?

Yes

Suggestions/comments:

No comments

Comments to the author

- This is a relevant study, but it requires some adjustments to avoid generating doubts. Another sug-

gestion is to make the data available on a public platform such as Zenodo. This platform works as a multidisciplinary repository, ideal for researchers who want to make their work publicly accessible and ensure digital preservation. This should be stated in the manuscript.

Final decision

- Minor revisions required

Reviewer B

- Did not authorize publication.