Is Body Fat Mass Associated with Worse Gross Motor Skills in Preschoolers?

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Research Article

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Abstract

Objectives: To compare the motor competence of overweight/obese preschoolers with eutrophic peers with a similar level of physical activity, sex, age, socioeconomic status, maternal education, quality of the home environment and quality of the school environment, and to verify the association of body fat mass with gross motor skills in preschoolers.

Design: Quantitative, exploratory, cross-sectional study design.

Methods: Forty-nine children, aged 3 to 5 years old, from public schools in a Brazilian city were classified into eutrophic and overweight/obese groups.

Results: Overweight/obese preschoolers had worse Locomotor subtest standard scores than their eutrophic peers ($p = 0.01$), but similar skills, Object Control subtest scores and Gross Motor Quotient ($p > 0.05$). Excess body fat mass explained 13% of the low Locomotor subtest standard scores in preschoolers ($R^2 = 0.13$; $p = 0.007$).

Conclusion: Excess body fat mass is associated with worse locomotor performance when the model is adjusted for contextual factors such as level of physical activity, sex, age, socioeconomic status, maternal education, quality of the home environment and quality of the school environment. Thus, excess body fat mass partly explains lower locomotor skills in preschoolers. These findings may assist with the development of public guidelines aimed at child health in order to outline strategies that enable the stimulation of locomotor skills in preschoolers with excess body fat mass.

1. Introduction

Pediatric obesity is a serious public health issue around the world and is associated with environmental, social, psychological and genetic factors[1]. Early detection and knowledge on factors that influence children's lifestyle habits may support public policies and promote the creation of healthy lifestyle habits in subsequent life stages, including among adults [2].

Early childhood, especially the preschool period between 3 to 5 years [3], is the stage of life when the body mass index (BMI) is reduced to a minimum physiological value known as adiposity rebound [4]. It is also considered a sensitive phase for learning fundamental movements; it is a time to expand the motor repertoire and experience the movements that will contribute to the development of future skills that will evolve into sports or leisure practices [5]. Studies indicate the preschool period as the critical moment for the development of motor skills and healthy behaviors that may last with physical activity (PA) practices throughout life [6, 7].

In a systematic review [8] on obesity in Brazilian children, the authors stated that studies are scarce, although there has been an increase in publications in recent years. Thus, there is lack of studies

including only children in the preschool phase, since the literature presents research with children in a wide range of ages, and at many stages of biological maturation [9].

Regarding motor competence (MC), studies that examined the relationship between MC and body fat mass in preschoolers used variables such as BMI [9], waist-hip circumference [7], or body fat mass measured with bioelectrical impedance [10]. Research indicates that there is an inverse relationship between excess weight and MC [11], and it has been suggested that overweight/obese children have worse motor skills [7, 12]. However, to avoid bias in data interpretation, it is crucial to verify the relationship between excess weight and MC while controlling for other factors that may influence motor development in preschoolers, such as socioeconomic status, maternal education[13], home environment, school environment[14], and PA[10]. Thus, to the best of our knowledge, there remains a gap in the literature regarding the control of these factors in studies with preschoolers. In addition, the wide age range of previous studies limits the validity, interpretation and extrapolation of the results for preschoolers [8].

In light of the above, is excess body fat mass a factor associated with worse gross motor skills when factors such as socioeconomic status, home and school environment, maternal education, and PA are controlled in preschoolers? Thus, the objective of the study was: 1) To compare the gross MC of overweight/obese preschoolers with eutrophic peers, controlling for PA, sex, age, socioeconomic status, maternal education, quality of the home environment and quality of the school environment. 2) Investigate to what extent excess body fat mass explains gross motor skills in preschoolers. The strength of the present study is the consideration of multiple factors that influence child development [10, 14].

2. Methods

This is a quantitative, exploratory, cross-sectional study approved by the Research Ethics Committee of Universidade Federal dos Vales do Jequitinhonha e Mucuri UFVJM (Protocol: 2.773.418), with written informed head parent consent and participant assent. All methods were carried out in accordance with relevant guidelines and regulations in the manuscript. Data collection took place from July to December 2019. Pre-school children, that is, children from 3 to 5 years old, from public schools in a Brazilian municipality, were eligible.

Exclusion criteria were: preterm and low birth weight infants; infants with pregnancy and delivery complications; infants with signs of malnutrition or illness that interfere with growth and development; and infants who had been subject to an infectious process (such as fever, influenza, and diarrhea) in the previous 21 days.

The sample size was based on a pilot study with five children in each group, in which a minimum difference of 2.70 was found between the groups for Locomotor subtest standard scores of the TGMD2, with a standard deviation (SD) of 3.50. For sample calculation, a power of 90%, and an alpha error of 5% were considered, with 20 participants thus being required for each group, totaling 40 subjects.

For the assessment of body composition, total body mass was measured and body fat mass was found using dual energy radiological absorptometry (DEXA) (Pediatric medium scan mode software, Lunar Radiation Corporation, Madison, Wisconsin, USA, model-DPX).

Weight and height measurements were taken during the study visits. The children's weight was measured to the nearest 0.1 kg with an electronic scale. The standing height of the children was measured to the nearest millimeter with a wall-mounted stadiometer. The children removed their shoes and socks before stepping on the scale and were told to stand in an upright position when measuring height. Age-specific BMI was calculated as body weight (kg) divided by body height squared (m^2) [16].

Considering the high correlation found between the amount of body fat mass and BMI ($r = 0.90$, $p = 0.00$), and according to studies on body composition and BMI [15], participants were classified into groups according to BMI, following World Health Organization (WHO) recommendations. The WHO reference curves by gender and age were considered, using the calculation software WHO Anthro version 3.2.2 [16]. Children with a BMI < 85 were considered eutrophic and allocated to Group 1, whereas children with a BMI ≥ 97 were considered overweight/obese and allocated to Group 2.

Sex, age, socioeconomic status, maternal education[13], PA[10], quality of the home environment and quality of the school environment[14] were collected for control.

Sociodemographic variables were collected using a specific questionnaire. To verify the economic level of families, the Brazil economic classification criterion, from the Brazilian Association of Research Companies was used. This is a questionnaire that stratifies the general economic classification resulting from this criterion from A1 (high economic class) to E (very low economic class) [17].

The quality of the environment in which the child lives was assessed using the Early Childhood Home Observation for Measurement of the Environment (EC_HOME) [18]. The EC_HOME is applied through observation and semi-structured interviews during home visits, standardized for children aged 3 to 5 years. The instrument contains 55 items divided into 8 scales: I-Learning materials, II-Language stimulation, III-Physical environment, IV-Responsiveness, V-Academic stimulation, VI-Modeling, VII-Variety, VII-Acceptance. For analysis, the sum of the raw scores of the subscales was used.

The quality of the school environment was assessed using the Early Childhood Environment Rating Scales (ECERS) [19], which contain inclusive and culturally sensitive indicators for many items. The scale consists of 43 items organized into 7 subscales (1-Space and Furnishings, 2-Personal Care Routines, 3-Language and Literacy, 4-Learning activities, 5-Interactions, 6-Program Structure, 7- Parents and staff). Each quality indicator was marked, considering its presence or absence in each collective environment (classroom), with the items scored from 1 to 7. The final score of the scale is given by the mean of the seven subscales. It is an ordinal, increasing scale, from 1 to 7, the interpretation of quality being 1: inadequate; 3: minimal (basic); 5: good; 7: excellent.

The PA level was measured using an accelerometer (Actigraph®- Model GT9X); for a period of 3 days, without including the weekend [21], for a minimum of 570 minutes a day [10], which is considered suitable for preschoolers [21]. Accelerometers were initialized and analyzed using 5-second epochs. In all analyses, consecutive periods of ≥ 20 minutes of zero counts were defined as non-wear time [20], with a sampling rate of 60 Hz. The acceleration units were expressed in triaxial vector magnitude (VM). The accelerometer was positioned on the right side of the hip to capture accelerations and decelerations of the body and determine objective measurements of gross acceleration, intensity of physical activity, heart rate intervals and total time of suspension of use [20]. Pediatric cutoff points validated for preschool children, with score values, classify as sedentary (0 to 819 counts / m), mild (820 to 3907), moderate (3908 to 6111) and vigorous (above 6612) [22]. For this study, the child's mean time at these intensities was used. The classification adopted for “active” or “insufficiently active” was established according to the WHO, which considers an active child to be one who has a PA of at least 180 minutes/day, with a minimum of 60 minutes/day in moderate to vigorous PA [2].

In addition, information was gathered on environmental opportunities for active and sedentary behavior, such as the time of exposure to screens; the presence of internal (30 m^2 per inhabitant) and external (backyard) physical space at home; and the presence of a playground at school, among other variables relevant to the study. The variable “time of exposure to screens” was classified considering the parents' report of the time in minutes that the child was exposed to a screen (television and cell phone) and later classified within the recommended limit (less than two hours) and above the recommended limit (two hours and over) according to the guidelines of the American Pediatric Association [23].

MC was measured using the Test of Gross Motor Development second edition (TGMD-2). The reference is based on a norm and criterion for the development of children between three and ten years old. It consists of 12 motor skills divided into two subtests, locomotor (run, leap, gallop, hop, jump, and slide) and object control (catch, strike, bounce, over and underhand throw, and kick). For each skill, specific motor criteria was observed, based on mature movement patterns referenced in the literature and by professionals in the field. The results obtained for each subtest were added and the raw scores were converted into normalized scores for sex and age with a mean of 100 ± 15[24], validated for Brazilian children [25]. For the study, the standardized scores described in Locomotor subtest standard scores (LS), Object Control subtest (OC) and Sum of the Gross Motor Quotient (GMQ) (which includes the LS and OC) were used. The reliability for TGMD2 showed intra-class correlation coefficients (ICC) of 0.895 for the LS, 0.925 for OC and 0.841 for GMQ.

All tests and measurements including body weight, height, assessment of gross MC, as well as questionnaires were applied by one trained examiner. The children were evaluated in the same places, following the order of previously defined evaluations, with an interval between collections of a maximum of 3 weeks.

The data were analyzed using the *Statistical Package for the Social Sciences (SPSS* version 2.2). First, the Shapiro-Wilk test was performed to assess data normality, followed by Levene's test to verify the homogeneity of the variance. Subsequently, the descriptive statistics of continuous variables were demonstrated as median (minimum and maximum) and mean (standard deviation), as appropriate. Subsequently, Chi-squared tests were applied to compare the proportion of eutrophic groups (G1) and overweight (G2). To verify differences between groups, the t-test for independent samples (for variables with normal distribution) or the Mann-Whitney test (for variables with non-normal distribution) was used.

Spearman's or Pearson’s correlation was performed to verify the relationship between body fat mass and gross motor competence variables, followed by the multiple linear regression model. Statistical significance was set at 5%. Since sex, age, maternal education, socioeconomic status, PA level, quality of the home environment and quality of the school environment could be confounding factors, the analysis was adjusted for these variables. A residual analysis showed a normal distribution and homogeneous variance in all regression models. The magnitude of the effect (d) was also verified.

3. Results

Forty-nine children, 25 eutrophic and 24 overweight were evaluated and their characteristics are shown in Table 1. Of the group with excess body weight, 17 children (70.8%) were obese and 7 (29.2%) were overweight.

Table 1
Characterization of participants

Variable	Eutrophic	Overweight	Test	p-value
	N = 25	N = 24		
Age (years)	5(3–5)	5(3–5)	274.0 [a]	0.534
School shift (Full-time)	10(40.0)	7(29.1)	0.63[c]	0.420
Sex			0.19[c]	0.656
Female	12(48.0)	10(41.6)		
Male	13(52.0)	14(58.3)		
Mother's age (years)	31.17 ± 5.92	31.88 ± 5.81	-0.41[b]	0.670
economic status			225.50[a]	0.121
B	4(16.0)	9(37.5)		
C	18(72.0)	13(54.1)		
D-E	3(12.0)	2(8.3)		
Maternal Education			290.50 [a]	0.827
Primary	3(12.0)	5(20.8)		
Secondary	18(72.0)	12(50.0)		
Higher	4(16.0)	7(29.1)		
School has playground / space			0.01[c]	0.921
Yes	17(68.0)	16(66.6)		
No	8(32.0)	8(33.3)		
House has 30 m^2 / inhabitant			2.48[c]	0.115
Yes	10(40.0)	15(62.5)		
No	15(60.0)	9(37.5)		
House has backyard			0.02[c]	0.869
Yes	11(44.0)	10(4.6)		

Data presented by mean ± standard deviation, median (min-max) or n (%). PA: physical activity. EC-HOME: Early Childhood Home Observation for Measurement of the Environment. ERCS: Early Childhood Environment Rating Scales. [a]Mann-Whitney U Test. [b]T test for independent samples. [c]chi-squared test. [d] N = 48.

Variable	Eutrophic	Overweight	Test	p-value
No	14(56.0)	14(58.3)		
Screen time (%)			1.64[c]	0.200
Less than two hours	17(68.0)	12(50.0)		
Two hours and over	8(32.0)	12(50.0)		
Amount of body fat mass	3.74(2.49–6.47)	11.10(6.14–18.12)	1.00[a]	< 0.001
Mean Intensity of PA(minutes)				
Sedentary	398.29 ± 40.7	397.74 ± 46.42	0.04[b]	0.965
Light PA	190.23 ± 36.8	185.08 ± 32.94	0.51[b]	0.612
Moderate PA	37.33 ± 10.93	42.02 ± 9.51	-1.43[b]	0.158
Moderate to Vigorous PA	58.93 ± 15.15	61.09 ± 14.30	-0.50[b]	0.614
Classification of PA[d] N = 48			0.07[c]	0.509
Active	12 (50)	14 (58.33)		
Insufficiently active	12 (50)	10 (41.66)		
EC-HOME	37(30–47)	41(30–50)	212.5[a]	0.077
ECERS Room quality	2.6(1.9–2.9)	2.7(1.9–2.9)	288.0[a]	0.809

Data presented by mean ± standard deviation, median (min-max) or n (%). PA: physical activity. EC-HOME: Early Childhood Home Observation for Measurement of the Environment. ERCS: Early Childhood Environment Rating Scales. [a]Mann-Whitney U Test. [b]T test for independent samples. [c]chi-squared test. [d] N = 48.

The mean age in both groups of preschoolers was 5 years. Most of the children belong to extract C in the economic classification. In both groups there was a predominance of young adult mothers with complete high school education. Of the participants, more than half study part-time in schools whose facilities contain a playground and some physical space for PA, assessed with marks corresponding to the minimum rating for quality of the school environment (Table 1).

There was no difference between groups for variables that influence children's motor behavior and others that characterize them. However, the amount of body fat mass differed between groups (Table 1).

There was no difference between groups for OC subscales and GMQ. A significant difference was found in the LS between the groups, with lower values for the group with excess body weight compared to normal weight peers (Table 2). The post-hoc analysis, considering an effect size of 0.73 (alpha value = 0.05), revealed a large statistical power for the LS (Power = 0.81).

Table 2
Comparison between groups for Motor Competence

	Eutrophic (N = 25)	Overweight (N = 24)	Difference between groups*	p-value	95%CI
TGMD2 LS	9.08 ± 1.86	7.63 ± 2.08	2.58	0.013	0.31–2.59
TGMD2 OC	8(4–15)	8(6–12)	287.5	0.800	0.39–0.41
TGMD2 GQM	93.20 ± 10.97	87.54 ± 9.09	1.96	0.055	-0.14-11.46

Data presented by Mean ± standard deviation or median (Minimum-Maximum). *T-test for independent samples u Mann-Whitney U test. Abbreviations: TGMD2 LS = Locomotor subtest standard score. TGMD2 OC = standardized Object Control subtest, TGMD2 GMQ = Gross Motor Quotient.

The amount of body fat mass correlated with the LS (inverse relationship, r = -0.38, p-value = 0.007).

Multiple linear regression analysis showed that there was an inverse relationship between body fat mass and LS. The increase for body fat mass explained 13% of the low values in the LS in preschoolers. In other words, the increase of 1 kg of body fat mass leads to a reduction of 0.38 points in the LS, with medium effect size (d = 0.16) (Table 3). Finally, control variables were inserted in the regression model, but they did not affect the values of β and R^2.

Table 3
Multiple linear regression between body fat mass and Locomotor standard score (N = 49).

Variable					
	β	B	95% CI	*p-value*	R^2
Body fat mass	-0.388	-0,199	-0.341– (-0.057)	0.007	0.13

Note: β= standard regression coefficient; B = non-standard regression coefficient; 95% CI = 95% confidence interval; estimate of the increase or decrease of the dependent variable for each increase of one unit of the independent variable; p = statistical significance; R^2 = coefficient of determination.

4. Discussion

This study aimed to verify the MC of overweight/obese and eutrophic preschoolers controlled for PA [10], sex, age, socioeconomic status, maternal education [13], quality of the home environment and quality of the school environment [14]. The identification of variables that could interfere with development has an important clinical meaning, since the child's reciprocal relationships with the environment can influence child development [14, 26].

Regarding gross MC, body fat mass was the only factor that showed a difference between the groups. To the best of our knowledge, this study is the first that presents robustness in the comparison between

eutrophic and overweight/obese preschoolers, as direct measurement of energy expenditure was used. Moreover, variables that interfere in the development of preschoolers were controlled, these being socioeconomic status, maternal education [13], the quality of the domestic environment and with it, availability of resources and toys, trips and opportunities for stimulating experiences, use of free time, family routines and meetings, physical space of the home environment and the direct involvement of parents in the child's life [18, 14]. In addition, the quality of the school environment [19], and screen time [23] were also controlled. As such, none of the controlled variables differed between the groups.

The amount of body fat mass, namely excess body fat mass, appears as a factor that interferes with MC in LS; however, it did not interfere with OC skills, which are tasks that require more specific skills without large displacements [7]. Being overweight/obese seems to hinder displacements and body image, since antigravity activities are more difficult [27, 9] due to the morphological restrictions to movement within high biomechanical restrictions that make it more challenging to perform tasks involving changes in the center of mass [12]. Other studies have also found an inverse relationship between weight and motor skills [28, 26] and between excess body fat mass and motor skills in preschoolers [10, 12]. In Brazil, studies [7] using the same motor test as the present study found an inverse relationship between LS and central obesity in preschoolers in the same age group (3 to 5 years). The authors also found no association between central obesity and OC.

Excess body fat mass is associated with worse MC [10], as being overweight/obese seems to contribute to declines in motor proficiency. Cheng et al., [29] investigated temporal precedence in the relationship between MC and weight status in schoolchildren aged between 5 and 10, finding that poor MC did not predict weight gain. However, higher weight status is a precursor and not a consequence of poor MC. These data corroborate the findings of the present study and confirm the hypothesis, since having a greater amount of body fat mass predicts 13% of the worse result on the LS. Thus, the results of the present study add to the current literature, as they provide additional evidence for the development of protective policies related to pediatric health, since the relative declines in children's motor proficiency can serve as a catalyst for inactivity and consequent weight gain with advancing age [26, 30].

This study has both limitations and strengths. The sample was small. However, the sample calculation and post hoc analysis demonstrated that the sample size was sufficient to achieve a medium to large effect size. The study has a cross-sectional format, which does not allow inferring a cause-and-effect relationship, requiring more longitudinal studies that examine the development of MC over time and its relationship with other health-related results. However, as far as is known, this is the first study that controlled for determining factors in development to compare overweight/obese and paired-eutrophic preschoolers. Among the strengths are the short data collection interval (maximum of three weeks), the use of a standardized instrument for assessing MC [24], validated for Brazilian children [25], direct measurement of PA [10], and a gold-standard measure to determine body fat [15]. Finally, relevant factors that interfere in child development were taken into account, these being socioeconomic level, maternal schooling[13], quality of the school environment [14, 20] and quality of the home environment [14,18].

5. Conclusions

Children with excess body fat mass in developmental conditions similar to eutrophic children have worse LS, demonstrating that excess body fat mass influences competence in locomotor skills in the preschool phase. These findings may assist with the development of public guidelines aimed at child health in order to outline strategies that enable the stimulation of locomotor skills in preschoolers with excess body fat mass.

Practical implications:

- When factors that interfere with child motor development, i.e., maternal education, socioeconomic status, PA, sex, age, quality of the home environment and quality of the school environment are controlled, preschoolers with excess body fat mass have worse locomotor skills than eutrophic preschoolers.
- Excess body fat mass is probably a precursor to lower locomotor competence, showing the importance of strategies to stimulate locomotor skills in preschoolers, especially in the context of pediatric obesity.
- Public guidelines could include strategies that enable the stimulation of locomotor skills in preschoolers with excess body fat mass.

Declarations

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was approved by the Research Ethics Committee of Universidade Federal dos Vales do Jequitinhonha e Mucuri UFVJM (Protocol: 2.773.418), with written informed head parent consent and participant assent. All methods were carried out in accordance with relevant guidelines and regulations in the manuscript.

CONSENT FOR PUBLICATION

The researchers of this study confirm that they have given due consideration to protect the intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

AVAILABILITY OF DATA AND MATERIALS

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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AUTHORS' CONTRIBUTIONS

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