



Factors Associated with Motor Competence in Preschoolers from a Brazilian Urban Area

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Abstract

Background Preschool is a crucial period for developing motor skills.

Objective This study evaluated factors associated with motor competence in preschoolers from a Brazilian urban area.

Methods A total of 211 preschoolers (51.2% girls and 48.8% boys) were evaluated. Body mass index was calculated; the Brazilian Economic Research Criterion, the Mini-Mental Scale (MMC) and the Early Childhood Environment Rating Scale®, Revised (ECERS-R™) were applied; the Habitual Physical Activity time was recorded; the Test of Gross Motor Development (TGMD-2) was performed. Univariate analysis was performed using simple linear regression for the independent variables, considering the motor test subscales as dependent variables. Variables with $p < 0.20$ in the univariate analysis were considered for the multiple linear regression model and were entered into the stepwise method.

Results The independent variables remaining in the Standard Score Locomotor model were BMI, presence of park at school, and MMC ($R^2 = 0.16$). The independent variables remaining in the Standard Object Control score were MMC and gender ($R^2 = 0.03$). The variables associated with the highest scores of Gross Motor Quotient were MMC, body mass index, and presence of a park at school, respectively ($R^2 = 0.11$).

Conclusion Male eutrophic preschoolers who are physically active and attend schools with parks or courtyards in a Brazilian urban area have the highest scores for global cognitive function and motor competence.

Keywords Child · Psychomotor performance · Motor skill · Cognition · Leisure activity

Introduction

Motor competence (MC) is a global term referring to an individual's ability in performing a range of motor skills (Malina et al., 2014), including motor control and coordination tasks (Utesch & Bardid, 2019). Motor skills are classified into (1) mobility skills (e.g., running, sliding, jumping), (2) manipulation and control object skills (e.g., hitting, kicking, throwing, catching), (3) stability and body control skills (e.g., balance) (Gallahue et al., 2012). The delay in acquiring MC, particularly during preschool years (Bardid et al., 2016; Niemistö et al., 2019), can negatively impact children's self-esteem (Golding et al., 2014) and physical activity levels (Stodden et al., 2008). The rapid MC development that occurs during the preschool years is supposed to be related to the rapid maturation of the prefrontal cortex and cognitive skills (i.e., working memory, planning, thinking flexibility, attention, and imitation) (Garon et al., 2008; Howard et al., 2015; Cook et al., 2019). We recently found that besides global cognitive function, habitual physical activity levels may also predict MC development in Brazilian preschoolers (Viegas et al., 2021).

Preschoolers' exposure to an environment rich in sensory stimulation can influence their MC development (Niemistö et al., 2019; Dankiw et al., 2020; Herr et al., 2021). Hence, preschool is where children have the greatest opportunity to engage in physical activity practices as it is the local where they spend a considerable amount of their daily time (Herr et al., 2021; Bower et al., 2008). Evidence demonstrates a positive association between outdoor time and children's daily physical activity levels (Määttä et al., 2018; Wray et al., 2020). Thus, the presence of physical space in preschools, such as playgrounds (Broekhuizen et al., 2014) and schoolyards, seems to be crucial to increasing children's physical activity (PA) levels (French et al., 2016; Herr et al., 2021) and, consequently, the MC development (Martínez-Bello & Estevan, 2021).

In high-income countries, evidence demonstrates that during the preschool period, eutrophic and physically active boys reach the highest MC scores (Stodden et al., 2008), (Herrmann et al., 2021) (Matarma et al., 2020; Kakebeeke et al., 2017). On the other hand, high-BMI and insufficiently active girls reach the worst MC scores (Honrubia-Montesinos et al., 2021) (Stodden et al., 2008; Rodrigues et al., 2016).

Brazilian schools generally lack adequate outdoor spaces for physical activity practices (Magalhães et al., 2017), and the preschoolers present low MC scores (Ré et al., 2018; Costa et al., 2014; Cotrim et al., 2011). However, recent studies have found that these low MC scores seem to be influenced by a variety of factors (Santos et al., 2020). Studies involving the MC determinants in preschoolers from low and middle-income countries, such as India, Indonesia, and Brazil (Barnett et al., 2016a; Cook et al., 2019) are scarce; thus, there is an urgent need to understand the MC determinants in preschoolers from these countries. Moreover, the preschooler's MC determinants are not wholly elucidated (Santos et al., 2020) as MC is a complex biocultural attribute that requires a multisectoral, inter, and transdisciplinary approach (Lopes et al., 2021). Thus, the present study aims to verify the determinant factors of MC in preschoolers from a Brazilian urban area.

Materials and Methods

Participants

This is a cross-sectional and exploratory study approved by the Ethics and Research Committee of the Universidade Federal dos Vales do Jequitinhonha e Mucuri - UFVJM (protocol number 2.355.943). This study followed the Declaration of Helsinki and enrolled preschool children aging 3 to 5 years. The children's parents signed an informed consent form explaining the study's aims and approved all study procedures. Children were also orally informed about all study procedures. The sample size was estimated from a pilot study with 10 children. A coefficient of partial determination of at least 0.03 using the subscales of TGMD2 (LP, OC, and GMQ) as a dependent variable was obtained. Based on the coefficient of partial determination, the effect size was estimated at 0.030. Thus, the sample size was estimated at 219 preschoolers from public schools using the subscales of TGMD2 (LP, OC, and GMQ) as a dependent variable and considering an effect size of 0.030, an alpha error of 5%, a power of 80% and a sample loss of 8%. Exclusion criteria were: children with pathologies that could interfere with growth and development; and children who did not complete the tests.

Initially, preschoolers enrolled in 9 public schools from the Brazilian state of Minas Gerais were invited to participate in the study. The parents were required to provide written informed consent and the children verbally agreed to participate in the study. The data collection was carried out between March 2018 and October 2019.

Instruments

Weight and height records were taken during the laboratory visits. The children's weight was measured to the nearest 0.1 kg using an electronic scale and height was measured to the nearest 0.5 cm using a stadiometer. The children removed their shoes and socks before stepping on the scale and were told to stand in an upright position when measuring weight and height. Height and body mass were recorded to calculate the body mass index (BMI) (i.e., the body mass divided by the square of the body height for each child). The Anthro software, version 3.2.2 (Geneva, Switzerland), was used to calculate BMI according to gender, age, and z score (World Health Organization, 2011).

The Brazilian Economic Research Criterion was used to verify the families' economic level. This questionnaire stratifies the general economic pattern of a family resulting in classification from A1 (high economic class) to E (very low economic class) (ABEP Associação Brasileira de Empresas de Pesquisa, 2018). According to the ABEP, the main goal of the "Brazil Criterion" of economic classification is to estimate the purchasing power of individuals and families from urban areas. This stratification criterion presents a standardized scoring system that can predict the individual's and families' financial capacity to consume. The criterion discrimination procedure considers tangible household characteristics, such as possession and quantity of durable goods, number of bathrooms, employment of domestic workers, and educational level of the head of household. Each item receives a score, and the sum of the scores is associated with an economical grade or stratum – A1, A2, B1, B2, C1, C2, D, and E.

Outdoor time was assessed using a validated questionnaire to measure preschoolers' physical activity (PA) - "Outdoor playtime checklist"- (Burdette et al., 2004). The questionnaire has four questions that allow parents to record the time spent on outdoor playtime. The application of the questionnaire lasts an average of seven minutes. Each question is used to identify the location (garden/yard or outside the home), period of the week (day of the week, day of the weekend), and period of the day (from waking time until noon; from noon to six o'clock; from six o'clock until bedtime) in which the activities were carried out. The Habitual Physical Activity (HPA) time in the outdoor environment was recorded by the parents considering five possible options: 0, 1–15, 16–30, 31–60, or more than 60 min. The time of participation in games was calculated by adding the answers for the period of the morning, afternoon and evening, on days of the week, and on weekend days, after which the mean number of minutes spent on outdoor games and play per day was calculated. A child was considered active (HPA_a) when he/she was exposed to any outdoor HPA for more than 60 min per day and underactive (HPA_b) if exposed to less than 60 min per day of outdoor HPA (Burdette et al., 2004; Oliveira et al., 2011). According to Oliveira et al., (2011), the test has good reproducibility in Brazilian preschoolers (ICC: 0.83; $p < 0.01$).

An adapted version (Moura et al., 2017) of the Mini-Mental for Children –MMC (Jain & Passi, 2005) was applied. Each child was evaluated in a reserved room within the school by a trained examiner. The MMC comprises 13 items covering five domains of cognitive function (orientation, attention and working memory, episodic memory, language and constructional praxis) with a maximum score of 37. The Brazilian validation and normalization of MMC showed satisfactory psychometric properties, with 82% specificity and 87% sensitivity. MMC can be applied to individuals from 3 to 14 years old. MMC application lasts from five to seven minutes and has been used in several countries, including Brazil (Shoji et al., 2002; Jain & Passi, 2005; Rubial-Alvarez et al., 2007; Moura et al., 2017; Scarpa et al., 2017; Peviani et al., 2020; Viegas et al., 2021). The evaluation of each child was performed in a reserved room within the school. Cognitive function was evaluated according to the mean score at each age as the main result (Shoji et al., 2002). Children were classified in MMC_a: below the median score; or MMC_b: above the median score. Overall, the MMC is an adequate and usual instrument to screen global cognitive function.

Motor Competence: The Test of Gross Motor Development - second version (TGMD-2)- was used to evaluate gross motor skills development (Ulrich, 2000). TGMD-2 is a standardized norm- and criterion-referenced test for the development of children between 3 and 10 years old and an instrument with validity and reliability for Brazilian children (indices and values from 0.83 to 0.98) (Valentini, 2012). TGMD-2 is composed of 12 fundamental motor skills, which are subdivided into two subtests: six locomotor skills (run, gallop, hop, leap, horizontal jump and slide) and six object control skills (striking a stationary ball, stationary dribble (bounce), kick, catch, overhand throw and underhand roll). The test score for any skill is assessed as pass/fail (1 or 0) for each of the 3 or 4 pattern criteria. The sum of all criteria across all skills within a subtest produces the raw score for each subtest according to gender and age. The raw subtest score (LP: Standard Score Locomotor; OC: Standard Score Object Control) is converted to a standard score using norm tables. High scores indicate good quality of movement patterns. The subtest standard scores are combined and converted to an overall Gross Motor Quotient (GMQ), determining a child's gross motor skills compared to the tests from the standardized population. Each test subscale (LP and OC) and the GMQ (total score) were used as dependent variables for statistical analysis. The GMQ

was obtained by adding the standard subtest scores (LP, OC) and converted to the sum into a quotient (i.e., a standard score with a mean of 100 and a standard deviation of 15). For descriptive analysis, children with gross mean motor performance equal to or greater than 90 were considered within the expected range, and those who reached 89 points were considered below expectations. Four previously trained examiners performed the evaluations. A schedule was used to choose the children's examiners, with two evaluations per examiner per shift in an indoor play area. Of note, all children were evaluated in the same environment, using the same set of equipment/objects and standard attire/shoes for the evaluations. In addition, each child was evaluated individually for a mean time of 20 min. A single researcher guided each child through a standardized demonstration of the task before each child's test. The reliability between examiners presented an intraclass correlation coefficient (95% CI) over 80%, i.e., locomotion subtest 95% CI=0.895 (0.565–0.997); object control subtest 95% CI=0.925 (0.766–0.988); and GMQ 95% CI=0.841(0.520–0.974).

School environment: The quality of the school environment was assessed using the Early Childhood Environment Rating Scale®, Revised (ECERS-R™) (Harms, 2013), which contains 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 ticked (1–7), considering its presence or absence in each classroom. The mean of the seven subscales gives the final score of the scale. It is an ordinal, increasing scale, from 1 to 7, being the interpretation of quality established as 1: inadequate; 3: minimal (basic); 5: good; 7: excellent. For this study, the total score was used to characterize the variable “classroom quality”. The presence of a park or playground in the school was evaluated considering two items from subscale 1, which comprises the presence of a park and toys in addition to the school space. For this variable, a dichotomous variable was created, contemplating the presence or not of a park with toys and a courtyard (1=yes, 2=no). The physical space of the classroom was evaluated using the subscale 1, which assesses the physical space of the classroom considering the number of children. A dichotomous variable was created contemplating the physical space in the child's classroom (1=yes, 2=no).

Statistical Analysis

Data were analyzed using the Statistical Package for the Social Sciences (SPSS version 22.0). The Shapiro-Wilk (SW) test was performed to assess data normality. Spearman correlation or chi-square test/Mann Whitney was performed to check the correlation of the independent variables or dichotomous/ordinal variables, respectively, with each subscale of the motor test -TGMD2. Univariate analysis was performed using simple linear regression for the independent variables, considering the motor test subscales (LP, OC) and GMQ as dependent variables. The variables whose $p < 0.20$ became part of the multiple linear regression model using the stepwise method. The Cohen's post-hoc test was used to measure the effect size (small : $d = 0.20$; medium: $d = 0.50$; or high $d = 0.80$).

Results

A total of 211 preschoolers were evaluated, of whom 108 (51.2%) were girls aged 4.31 ± 0.76 years and 103 (48.8%) were boys aged 4.03 ± 0.81 years. Approximately half of the families belonged to extract C of the Economic classification (54.0%), which corresponds to the lower middle class. Less than half of the participants, i.e., 89 (42%), achieved an above median motor test score (median 97), and more than half of the participants, i.e., 119 (56.4%), presented above median results for age in the MMC cognitive test (Median for 3 years=20 points; median for 4 years=22 points; median for 5 years=25 points). The examined schools had an average quality score of 2.6 ± 0.16 points. Most participants were physically active 188(89.1%). Table 1 presents the characteristics of participants .

Table 2 shows the correlation between independent variables and motor test subscale scores. The variables BMI, MMC, presence of park, schoolyard and physical space in the classroom were associated with the standardized locomotor test score ($p < 0.05$).

The independent variable MMC was associated with the object control subscale. The independent variables child age, BMI, MMC classification, presence of park, courtyard and physical space in the classroom were associated with the gross motor quotient test.

Table 3 presents the simple linear regression results examining the association between the independent variables and the motor subscale test (LP, OC, GMQ). The variables BMI, MMC, presence of park, schoolyard, physical space in the classroom and high scores in classroom quality were associated with the standardized LP test ($p < 0.05$). The variable MMC was associated with the standardized OC test, ($p < 0.05$). The independent variables: gender, age, presence of park and courtyard, classroom space and ECERS were included in the multiple linear regression analysis since presented $p < 0.2$.

BMI, MMC, physical space in the classroom, and ECERS (independent variables) were associated with the gross motor quotient ($p < 0.05$), and the presence of parks and courtyards in the school ($p < 0.2$).

Table 4 presents the multiple linear regression of the independent variables with the motor subscale test. The independent variables remaining in the LP model were BMI, the presence of parks in the school, and MMC ($R^2 = 0.16$). The multiple linear equation used for LP was $LP = 10.38 - 0.475 \text{ BMI} - 1.284 \text{ School with a park} + 1.018 \text{ MMC}$. Thus, an increase of 1 point in the BMI reduced by 0.5 points the LP score. Moreover, studying in a school without parks reduced by 1.2 points the LP compared to students from a school with parks. The increase of 1 point in the cognitive test MMC increased by 1.01 the LP.

The variables MMC and gender ($R^2 = 0.03$) remained in the multiple regression model (equation: $CO = 6.412 + 0.896 \text{ MMC} + 0.658 \text{ Gender}$). An increase by 0.8 points in MMC increased by 1 point the CO. Moreover, being male increased by 0.65 points the CO.

MMC, BMI, and the presence of a park at school were the variables that predicted the highest GMQ scores ($R^2 = 0.11$) (equation: $QMG = 96.81 + 4.99 \text{ MMC} - 1.72 \text{ BMI} - 0.39 \text{ School with a park}$). Specifically, an increase of 4.99 units in the MMC cognitive test score increased by 1 unit the QMG. An increase of 1.72 g in BMI reduced by 1 unit the QMG, while studying in a school without a park reduced by 5.33 units the QMG motor test compared to students who studied in a school with a park.

The effect size was calculated using Cohen's d , (small effect: $d = 0.20$; medium: $d = 0.50$; and high: $d = 0.80$). The post-hoc analysis revealed that the linear multiple regression model had a large power (0.99) and a medium effect size (0.22) for LP, a large power (0.99) and

Table 1 Characteristics of the participants (n=211)

Variables	N (%)	Median (Min-Max)
Child age (in years)		4 (3–6)
Gender		
Female	108 (51.2%)	
Male	103 (48.8%)	
BMI _c		
Low BMI	9 (4.3%)	
Eutrophic	165 (78.2%)	
Overweight	17 (8.1%)	
Obese	20 (9.5%)	
Maternal Education		
Elementary School	37 (17.5%)	
High school	127 (60.2%)	
University education	47 (22.3%)	
Economic status		
Class A	4 (1.9%)	
Class B	65 (30.8%)	
Class C	114 (54.0%)	
Class D-E	28 (13.3%)	
Motor test classification		
Below median	122 (57.8)	
Above or median	89 (42.2)	
Motor test		
Standardized locomotor subscale	10 (4–19)	
Object control subscale	9 (2–16)	
Total Gross Motor Quotient	97 (67–136)	
Cognitive test classification MMC		
Lower cognitive function MMC _a	92 (43.6%)	
Normal cognitive function MMC _b	119 (56.4%)	
School with a park/playground	3 (33.3%)	
Students studying in school with a playground	149 (70.6%)	
Students studying in school without playground	62 (29.4%)	
Students studying in a classroom with adequate space	152 (72.0%)	
Students studying in a classroom with inadequate space	59 (28%)	
Quality of the school environment (ECERS-R) (total score)		2.60 (1.90–2.92)
HPA _a active	23 (10.9%)	
HPA _b underactive	188 (89.1%)	

Note: BMI: body mass index; Min: Minimum, Max: Maximum; MMC: Mini-Mental Scale; MMC_a: below the median score; or MMC_b: above the median score. ECERS- RTM: Early Childhood Environment Rating Scale®. BMI_c according to the World Healthy Organization classification

a small effect size (0.03) for OC, and a large power (0.98) and a small effect size (0.14) for GMQ.

Table 2 Correlation of independent variables with the motor subscale test

Dependent variable	LP		OC		GMQ	
	r	p	r	p	r	p
Gender ^a	0.188 ^a	0.384	1.269 ^a	0.260	0.188 ^a	0.384
Child age ^b	0.129 ^b	0.061	0.100 ^b	0.148	0.136 ^b	0.048*
Maternal Education ^c	5225.500 ^c	0.596	5235.500 ^c	0.715	5381.000 ^c	0.901
Economic status ^c	5298.500 ^c	0.741	5084.500 ^c	0.459	5327.500 ^c	0.797
BMI z score ^b	-0.268 ^b	<0.001*	-0.056 ^b	0.419	-0.190 ^b	0.006*
MMC ^a	10.636 ^a	0.001*	10.510 ^a	0.001*	8.840 ^a	0.003*
HPA ^a	9.571 ^a	0.846	9.961 ^a	0.765	13.268 ^a	0.961
School with a park/playground ^a	11.647 ^a	0.001*	1.725 ^a	0.123	6.223 ^a	0.009*
Classroom with adequate space	11.443 ^a	0.001*	1.596 ^a	0.134	4.575 ^a	0.032*
ECERS-R ^b	0.132 ^b	0.056	0.066 ^b	0.340	0.101 ^b	0.144

Note: ^a= Chi-square; ^b= Spearman's correlation; ^c= MW Mann Whitney test; LP: Standard Score Locomotor; OC: Standard Score Object Control; GMQ: Gross Motor Quotient; MMC: Mini-Mental Scale; BMI: body mass index; ECERS- RTM: Early Childhood Environment Rating Scale®

Table 3 Simple linear regression with motor subscale test (Dependent variable: LP, OC, GMQ) (n=211)

Variable	LP			OC			GMQ		
	R ²	β	p	R ²	B	p	R ²	β	p
Gender	-0.005	0.016	0.814	0.100	0.123	0.074	0.001	0.078	0.259
Child age	-0.005	-0.015	0.830	0.090	-0.116	0.092	0.001	-0.078	0.259
BMI z score	0.083	-0.289	0.001*	-0.004	-0.067	0.335	-0.041	-0.221	0.001*
Maternal Educationc	-0.005	-0.016	0.814	-0.005	-0.011	0.878	-0.004	-0.026	0.710
Economic statusc	0.000	-0.066	0.342	-0.005	-0.010	0.885	-0.003	-0.037	0.596
HPA	-0.004	-0.019	0.782	-0.005	-0.016	0.822	-0.000	-0.018	0.800
MMC	0.056	0.246	0.001*	0.024	0.169	0.014*	0.052	0.239	0.001*
School with a park/ playground	0.053	-0.239	0.001*	0.009	-0.118	0.087	0.042	-0.216	0.002*
Classroom with adequate space	0.047	-0.226	0.001*	0.008	-0.113	0.101	0.037	-0.205	0.003*
ECERS-R TM	0.019	0.153	0.027*	0.004	0.095	0.167	0.017	0.149	0.031*

Note: *p<0.001; LP: Standard Score Locomotor; OC: Standard Score Object Control; GMQ: Gross Motor Quotient; MMC: Mini-Mental Scale; BMI z score: body mass index; ECERS- RTM: Early Childhood Environment Rating Scale®

Discussion

This study sought to understand the associated factors with preschoolers' CM (Lopes et al., 2021) from a Brazilian municipality. The main finding was that eutrophic physically active boys attending schools with parks or courtyards had the highest global cognitive function and motor competence scores. To the best of our knowledge, this is the first study showing in a multisectoral dimension (Lopes et al., 2021) which personal and environmental factors could explain the MC (including locomotor and object control skills) in preschoolers from a Brazilian urban area. The main findings are discussed below.

Table 4 Multiple Linear Regression of the independent variables with the motor subscales test (LP, OC and GMQ) (dependent variables)

LP	Variables	B	p	95%CI	R ² =0.16
	BMI z score	-0.281	0.001	-0.687-(-0.263)	
	School with a park/ playground	-0.211	0.001	-2.060-(-0.507)	
	MMC	0.178	0.007	0.285–1.751	
OC	MMC	0.178	0.009	0.224–1.568	R²=0.03
	Gender	0.135	0.047	0.008–1.309	
QMG	MMC	0.182	0.007	1,387–8.600	R²=0.11
	BMI z score	0.212	0.001	-2.763-(-0.678)	
	School has a park/ playground	0.185	0.006	-9.210-(-1.570)	

Note: β standardized regression coefficient; R²: adjusted coefficient of determination; LP: Standard Score Locomotor; OC: Standard Score Object Control; QMG: Gross Motor Quotient; MMC: Mini-Mental Scale; BMI score z: body mass index

BMI vs. MC

Evidence shows that children with high MC are more physically active (Stodden et al., 2008; Rodrigues et al., 2016 (Robinson et al., 2015)). Thus, fundamental motor skills are considered building blocks of complex and advanced motor skills (Gallahue et al., 2012), being early childhood the best period to develop these skills (Bardid et al., 2016; Wu et al., 2021). Several studies have proven an inverse correlation between BMI and MC (Cattuzzo et al., 2016; Matarma et al., 2020; Coppens et al., 2019; Barnet et al., 2016b). A longitudinal study with children aging 5–10 years found an inverse correlation between BMI and locomotor skills, being high levels of BMI a predictor of low locomotor skills (Cheng et al., 2016). Children with higher BMI have difficulty performing movements and anti-gravity activities and have worsening body image perception than children of normal weight (Prskalo et al., 2015; Okely et al., 2004).

Accordingly, in the present study, overweight/obese children presented the lowest scores in the control object tasks. Henrique and colleagues (2020), using the same motor tests used in the current study, also found an inverse relationship between locomotor skills and central obesity in Brazilian preschoolers. The biomechanical restrictions of overweight children, such as their difficulty in performing tasks that involve changes in the center of mass, seem to be one of the most important determinants of a low MC (Kakebeeke et al., 2017).

Cognitive Function and Cognitive Ability vs. MC

The MMC test's scoring average in children aged 5 to 6 years is 24 points (Moura et al., 2017). The preschoolers (aged 3 to 5 years) in this study had an average MMC score of 22.40 (4.65), which was lower than the average for their age according to the classification by Moura et al., 2017. This result was also found in a recent study with Brazilian preschoolers of the same age as the ones we looked at (Viegas et al., 2021). Cognitive domains can influence the motor memory process in preschoolers (Wang et al., 2014; Peyre et al., 2019). Motor learning depends on domains evaluated by the MMC, such as attention capacity, language skills, short-term limbs/work and executive functions (Krajenbrink et al., 2018; Peyre et al., 2019). Locomotor skills, such as canter and glide, place a high demand on activating

and sequencing this information in working memory (i.e., simultaneous body movements, movement sequences) (Cook et al., 2019). Of note, because the mean scores on the motor test (LP, mean 10.64; SD± 3.02; OC Mean 9.17, SD±2.27; GMQ Mean 99.44, SD±13.76) for preschoolers classified as equal or within the expected age in the cognitive test were higher than the scores achieved in the respective motor test (LP, mean 9.23, SD±2.04; OC Mean 8.32, SD±2.61; GMQ Mean 92.89, SD±11.52) for children classified below expectations in the cognitive test (statistically significant differences, with $p < 0.001$). Since MC involves global cognitive function (Peyre et al., 2019; Viegas et al., 2021), we believe that children with high cognitive function also have high MC.

Gender vs. MC

Despite the small determination coefficient ($R^2 = 0.03$, $p < 0.01$), our data pointed to gender and cognitive function as determinants of Object Control. In addition, girls had lower scores (OC Mean = 8.56, ± 2.68) in the subscale control of objects compared to boys (OC Mean = 9.16, ± 2.12). These results were also found in a previous systematic review (Barnett et al., 2016a, b) and are in line with a previous study conducted by our group (Viegas et al., 2021). We and others (Lee et al., 2010; Oliveira et al., 2013) speculate that cultural factors may account for the lower MC in girls compared to boys since girls seem to have fewer opportunities in tasks involving body movement and, consequently, they might present impairment on gross motor skills development. We elucidate the lack of attention to gender disparities and highlight the importance of offering more motor experiences to girls (Viegas et al., 2021; Santos et al., 2020). Therefore, specific CM intervention programs, especially for girls, may positively influence the improvement of their CM, reducing the differences between gender (Navarro-Patón et al., 2021).

Physical Space and Quality of Preschool vs. MC

The preschool environment should be considered in a context in which peer relationships are encouraged to improve children's MC. (Herrmann et al., 2021). This environment may positively or negatively influence children's physical activity levels and health (Herr et al., 2021; Hodges et al., 2013; Cosco et al., 2010; Timmons et al., 2012). The examined schools had an average quality score of 2.6 ± 0.16 points, which corresponds to a space considered inadequate, corroborating other Brazilian studies (NOBRE et al., 2022). However, it is noteworthy that small improvements in school quality appear to benefit the development of children (Morais et al., 2021). "For example, Trost et al., 2010, argue that the larger the space of schools, the greater the possibility of children's physical activity engagement; consequently, they have more probability of developing MC. Accordingly, evidence indicates that children who engage in unstructured activities in outdoor spaces have high levels of physical activity and, consequently, they have more opportunities for MC development (Barton et al., 2015) (Niemistö et al., 2019), (Martínez-Bello & Estevan, 2021). Moreover, the presence of play equipment extends the preschooler's physical activity possibilities (Broekhuizen et al., 2014; Trost et al., 2010), contributing positively to MC development (Gallahue et al., 2012; Nobre et al., 2021) and locomotion skills (Broekhuizen et al., 2014; French et al., 2016; Herr et al., 2021).

Our findings are in line with all these above-mentioned studies since the classroom size was associated with MC scores in all the subscales (LP subscale $R^2=0.047$, $p=0.001$; OC subscale $R^2=0.008$, $p=0.101$; GMQ $R^2=0.037$, $p=0.003$). In addition, the quality of the classroom environment scores were also associated with CM scores in all subscales (LP Subscales $R^2=0.019$, $p=0.027$; OC Subscales $R^2=0.004$, $p=0.167$; GMQ $R^2=0.017$, $p=0.031$) in the univariate analysis. Our data also evidenced that when the school had a park or courtyard, this was determinant for the highest locomotors test scores (MW=11.647; $p=0.001$). Thus, preschoolers from schools with a park or courtyard had higher locomotion skills (LP $X=10.54$; $SD\pm 2.99$) than those who did not have outdoor spaces in the school (LP $X=9.08$; $SD\pm 1.84$).

The present study's findings cannot be extrapolated to all Brazilian preschoolers, as the sample is from a small city with a different reality to other Brazilian cities. This study has some limitations. First, the present study did not use a cutoff point in the MMC to classify the cognitive function of the preschoolers. Instead, we ranked the preschoolers using the mean age of a known sample to categorize their cognitive function as lower, equal, or greater than a known sample (Viegas et al., 2021). Moreover, we did not use a direct method to measure the children's physical activity levels. However, we used a validated questionnaire (Gonçalves et al., 2021), previously used in another study from our group (Viegas et al., 2021), which presents a strong correlation with the level of physical activity in children (Määttä et al., 2018).

This study also has strengths. We assessed the quality of the school environment (Harms et al., 1998) using an instrument that has been used in other studies with Brazilian children and has psychometric properties for Brazilian preschoolers (Mariano et al., 2019). We also considered personal (Herr et al., 2021) and environmental multivariable factors for the MC analyses, including a park and courtyard presence in the preschools (Hesketh et al., 2017), since the MC is a complex biocultural attribute requiring a multisectoral, inter and transdisciplinary approach.

Moreover, our sample included only children at preschool age, which is the most important phase for acquiring and developing motor skills during childhood. Finally, we focused on Brazilian preschoolers from public schools in an urban area to avoid interpretation bias.

Conclusion

Male eutrophic preschoolers who are physically active and attend schools with parks or courtyards in a Brazilian urban area have the highest scores for global cognitive function and motor competence. Given the evidence of a reduction in children's physical activity levels, which has been exacerbated by the COVID 19 pandemic, these findings highlight the importance of providing spaces for physical activities practices in schools.

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Declarations

Conflict of Interest The authors report there are no competing interests to declare.

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Access to Data Access and responsibility to data with the corresponding author.

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