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Study of body composition and motor competence in children from the 1st basic cycle and their relationship with school performance

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Abstract

Childhood obesity is a public health problem that affects many parts of the world, and is one of the factors that has negatively influenced levels of motor competence at an early age. However, these relationships remain poorly investigated. The aim of this study was to assess body composition (BC) and motor competence (MC), as well as to study their relationship with school performance in primary school children in Portugal. A quantitative study was carried out with a sample of 272 children aged between 6 and 10 years old, divided into 4 years of schooling. The Motor Competence Assessment was used to assess motor competence (MC) and a bioimpedance scale (InBody) was used to assess body composition (BC). The results showed that, with the exception of 1st year, all the children were overweight and this worsened as the school year progressed. As for motor competence, it increases as the children grow, but at low levels for their age, with only the 3rd and 4th years showing a relationship between MC and BC. The results also showed a positive relationship between academic achievement and MC only in the 4th year of schooling. These results highlight the need for intervention in primary schools to combat childhood obesity and motor illiteracy, as well as demonstrating that the better children's MC, the better their school performance.

Keywords Motor competence, Physical activity, Child motor development, Body composition, School performance, Child obesity

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Introduction

Childhood obesity has emerged as an alarming and worrying issue, both for the World Health Organization and for various government bodies in several countries around the world [1]. According to recent data from the European Union, one in three children is obese as a child [1]. This condition negatively affects children's physical and mental health, with severe long-term repercussions that extend into adulthood [2]. The term obesity refers to the excessive presence of body fat, representing a health risk and, for this reason, the need has arisen to systematically assess nutritional and physical status in the pediatric population; This excess adiposity can be assessed and classified using various measures, including the body mass index (BMI) or other more accurate and reliable methods [2]. Bioimpedance assessment (BIA) emerges in this context as a technique that measures impedance (Z) through a low-voltage alternating electric current through the human body [3]. This tool is low-cost, portable and easy to apply, helping to normalize results [3]. In the last decade, children between the ages of 2 and 5 have been the most affected by the rise in obesity rates in early childhood [4] and some studies have suggested that percent body fat (%BF) values above 30% for girls and 25% for boys are associated with poor health outcomes [5–7].

On the other hand, current physical activity (PA) guidelines for early childhood indicate that children should be motivated to move and engage in activities of various intensities [8]. Since PA is a complex and multi-dimensional behavior, the literature states that its regular practice can have a cascading effect on various areas of child development, especially by improving obesity rates [9] and promoting the increased development of motor competence (MC) [10, 11]. Adequate motor development and sufficient levels of PA during the first few years of life are fundamental to an individual's long-term psychological and physiological health [12], although the low levels of MC in childhood have alarmed some researchers in the fields of health, education and sport.

MC is a global term used to describe gross goal-oriented movements involving large muscle groups or all body segments (running, jumping or balancing) [13]. Although it is an independent concept and different from the concept of PA, authors recognize that specific movement experiences and practices may be necessary to promote the development of fundamental skills during early childhood [12]. As with body composition, some authors emphasize the importance of systematically assessing BMI during childhood, showing a positive correlation between the results of the Motor Competence Assessment (MCA) and health-related physical fitness, regardless of age and gender [13]. Taking into account the study by Chagas and Joia [14], MC is related to lower rates of obesity in children, suggesting that the development of

MC may serve as a protective factor against childhood obesity. In addition, it is crucial to understand which factors can influence MC and, consequently, delay the acquisition of certain fundamental skills in the child's development process. In this sense, environmental factors, opportunities and experiences related to cardiovascular and muscular fitness, body composition, among others, have been highlighted in this process [13]. Delayed MC acquisition in children can result in uncoordinated movements, slowness in performing tasks and difficulty in daily activities such as getting dressed or using cutlery [15]. In the long term, this can negatively affect self-esteem, self-concept and the ability to maintain a healthy lifestyle [15], which can lead to cardio-metabolic, musculoskeletal, cognitive and psychosocial problems [16].

In terms of school performance, based on some research, both MC and the practice of PA positively influence children's cognitive functioning and school performance, emphasizing the importance of movement in early childhood education [17, 18]. In addition, motor and cognitive development are interrelated in children [17].

The relationship between MC, body composition and school achievement is multifaceted, with evidence suggesting that these factors significantly influence each other. Research indicates that children with superior motor competence tend to do well at school [19], while body composition, particularly BMI, plays a critical role in MC [20, 21]. Therefore, a better understanding of these relationships is essential in order to determine effective intervention strategies. Hence, the main objective of this study was to analyze the relationship between MC and body composition in primary school children; and the secondary objective was to investigate whether the variables of body composition and MC differ in school performance (taking into account the overall average of grades), in the different years of schooling. Based on the literature and the current paradigm, we expect to find children with high levels of body composition that negatively impact BM and, consequently, school performance.

Materials and methods

Participants

This cross-sectional study included data collected from primary school in Castelo Branco, Portugal. The sample consisted of a total of 272 children of both genders (8.09 ± 1.21 years), aged between 6 and 10 years ($F = 138$, 8.22 ± 1.81 ; $M = 134$, 7.97 ± 1.32 years) and subdivided into 4 groups according to year of schooling: 1st year ($N = 51$; 6.57 ± 0.51 years; $F = 16$, 6.51 ± 0.23 years; $M = 35$, 6.62 ± 0.44 years), 2nd year ($N = 59$; 7.22 ± 0.74 years; $F = 33$, 7.41 ± 0.56 years; $M = 26$, 7.34 ± 0.67 years), 3rd year ($N = 75$; 8.27 ± 0.75 years; $F = 37$, 8.71 ± 0.32 years;

M = 38, 8.32 ± 0.56 years) and 4th year ($N = 87$; 9.42 ± 0.47 years; F = 48, 9.26 ± 0.34 years; M = 39, 9.45 ± 0.65 years).

The following exclusion criteria were considered: (a) children who had been diagnosed with learning difficulties and/or developmental impairments and (b) children with some kind of diagnosed disability.

Instruments

The MCA test battery, duly validated for the Portuguese population, was used to assess MC [13]. This battery is made up of 2 tests for each category of motor competence, stability, locomotor and manipulative, and is an easy-to-use quantitative instrument that allows you to obtain a specific value of the child's MC [13]. To assess body composition, we used a bioimpedance scale (InBody 270), because it is easy and quick to use and because it allows us to obtain absolute and reliable values [13, 22]. Both instruments are recognized for their validity and reliability in assessing the MC and body composition of children, respectively, and the data collected provides valuable information on the anthropometric and motor profile of children [13, 22].

Procedures

After institutional approval, an informed consent form was sent to the parents/legal guardians and they were asked to fill in the child's characterization form. All ethical principles and international norms and standards relating to the Declaration of Helsinki and the Convention on Human Rights and Biomedicine were followed, respected and preserved [23], having been approved by the authors' Institutional Ethics Committee.

All the assessments, including body composition, were carried out over a period of 5 months, during the physical education lessons of each class, under the supervision of the school principal.

Firstly, body composition was assessed using a bioimpedance scale, where each child climbed onto the device, placing their feet on the specific electrode location. At the indication of the device, they grabbed the two electrodes with their hands and held their arms away from their torso, maintaining this position for 60 s while the device carried out the test [24]. The data was then collected using the lockinbody software. We specifically analyzed muscle mass (MM), fat mass (FM), body fat percentage (%BF) and BMI, as this is a commonly used measure in children to assess body composition, helping to identify potential health risks [25, 26].

Motor assessment was then carried out using the MCA test battery, in which each child performed 2 tests for each motor skill category: locomotion, stabilization and manipulation. In the locomotion and stabilization skills tests, the children had 2 attempts, with only the best counting, and the locomotion tests were the

shuttle run (4×10 m) and the horizontal jump with their feet together. The stabilization tests were lateral jumps and platform transfers; in the tests to assess manipulative skills, the children had 3 attempts with the best one counting, the tests being ball throwing speed and ball kicking speed. The highest value was verified in all the tests, with the exception of the shuttle run, since the fastest result counted in this assessment. Next, the values in the reference tables were reviewed, matching the child's result with their decimal age, obtaining the percentile for each test. The score for each of the strands is the average of the percentile values of the 2 respective tests and the MCA score was calculated using the average of the 6 individual tests [13]. The children were previously informed about the purpose and procedure of each test through clear information so that they could perform them accurately, quickly and consistently, taking into account the factor to be assessed. In addition, each test had specific instructions communicated verbally to each child. They were also allowed to try each item to familiarize themselves with the tests. After this phase, the children took the tests and the results were recorded.

Regarding school performance, the grades were given to us by the class director and were classified on a scale of 1 to 3, where 1 corresponded to "Insufficient", 2 to "Good", and 3 to "Very Good". These ratings were given for each of the three subjects: Portuguese, Mathematics and Environmental Studies. To calculate each child's overall school performance, the arithmetic mean of the grades obtained in these three subjects was used. Thus, school performance in our study was represented by a continuous value that could vary between 1 and 3.

Statistical analysis

All the analyses were carried out using the SPSS program, version 25.0 for Windows. Descriptive statistics (mean and standard deviation) were used for all the variables under study. The normality of the data distribution was checked using the Kolmogorov-Smirnov test and Spearman's correlation test was used to check the relationship between body composition variables and BM and the Kruskal-Wallis test to check the differences in body composition variables and BM in school performance, by year of schooling.

Results

Table 1 shows a descriptive analysis of body composition variables and MC tests by year of schooling. On average, all the groups except 1st year were overweight; The MM and FM variables showed a gradual increase as the school year progressed, while %BF was higher in the 2nd and 4th years. As for the MC tests, there was a general progression over the years, except for the plate transfer (PT), where the 1st year had the best performance, and the

Table 1 Descriptive analysis of body composition variables and motor competence tests, by year of schooling

| Variables | 1st Year (N=51) | 2nd Year (N=59) | 3rd Year (N=75) | 4th Year (N=87) |
|-----------|--------------------|--------------------|--------------------|--------------------|
| | M ± SD | M ± SD | M ± SD | M ± SD |
| BMI | 16,43 ± 2,45 | 17,40 ± 3,10 | 17,47 ± 3,45 | 18,99 ± 2,78 |
| MM | 8,83 ± 1,64 | 9,79 ± 1,75 | 12,06 ± 2,31 | 12,91 ± 1,84 |
| FM | 5,02 ± 3,65 | 6,78 ± 4,07 | 7,43 ± 5,34 | 8,21 ± 4,11 |
| %BF | 20,61 ± 8,76 | 23,95 ± 9,46 | 21,93 ± 9,16 | 23,25 ± 8,21 |
| PT | 14,37 ± 3,58 | 14,27 ± 3,38 | 16,02 ± 3,77 | 18,90 ± 3,36 |
| SJ | 22,05 ± 6,29 | 27,79 ± 7,92 | 30,68 ± 6,49 | 33,11 ± 7,14 |
| SR | 16,34 ± 2,13 | 15,23 ± 1,84 | 14,15 ± 1,38 | 13,28 ± 1,00 |
| HJ | 124,37 ± 23,56 | 134,37 ± 21,74 | 122,28 ± 23,33 | 123,55 ± 29,69 |
| TS | 8,10 ± 2,03 | 9,81 ± 2,42 | 10,40 ± 2,11 | 12,75 ± 2,64 |
| KS | 8,70 ± 2,18 | 9,03 ± 2,63 | 11,15 ± 9,35 | 12 ± 2,82 |
| TMC | 42,54 ± 16,67 | 52,01 ± 17,35 | 43,50 ± 17,17 | 49,08 ± 19,78 |

M – Mean; SD – Standard Deviation; N – Number of subjects; BMI – Body Mass Index; MM – Muscle Mass; FM – Fat Mass; %GC – Body Fat Percentage; PT – Plate Transfer; SJ – Side Jump; SR – Shuttle Run; HJ – Horizontal Jump; TS – Throwing Speed; KS – Kicking Speed; TMC – Total Motor Competence (Middle Percentile)

Table 2 Spearman’s correlation coefficients between body composition variables and motor competence by year of schooling

| Body composition | Motor Competence | | | |
|------------------|--------------------|--------------------|--------------------|--------------------|
| | 1st Year (N=51) | 2nd Year (N=59) | 3rd Year (N=75) | 4th Year (N=87) |
| MM | 0,142 | -0,021 | -0,013 | -0,135 |
| FM | -0,177 | -0,222 | -0,285 | -0,462 |
| BMI | -0,025 | -0,076 | -0,196 | -0,427 |
| %BF | -0,181 | -0,199 | -0,340 | -0,432 |

* $p \leq 0.05$ used in Spearman’s correlation test; N – Number of subjects; MM – Muscle Mass; FM – Fat Mass; BMI – Body Mass Index; %BF – Body Fat Percentage

horizontal jump (HJ)), with superior performance in the 2nd year. Total motor competence (TMC), expressed as the average of the percentiles of the different categories (locomotor (shuttle run and horizontal jump), postural (side jump and plate transfer) and manipulative (throwing speed and kicking speed)), indicates that only the 2nd year has a percentile above 50 ($P = 52.01 \pm 17.35$), indicating an adequate level of MC for their age. All the other years had percentiles below 50, suggesting low motor development for their age. For more transparency and

methodological rigor, the descriptive body composition data was also made available in a stratified format by gender and school year in the supplementary material (see Supplementary Table 1).

Table 2 shows the results of the Spearman correlations between body composition variables and MC, by year of schooling. In the 1st and 2nd years, no significant correlations were observed, suggesting that in this age group, MC may not depend directly on body composition. In 3rd year, we found significant negative correlations between FM, %BF and MC, suggesting that higher FM and %BF may be associated with lower levels of MC. In 4th year, we found significant correlations between FM, BMI, %BF and MC, suggesting that children with higher FM, higher BMI and higher %BF tend to have lower MC.

Finally, Table 3 shows the mean and standard deviation of each variable in the different years of schooling, and the Kruskal-Wallis test was used to compare the distribution of each variable between the different years of schooling, since the data did not follow a normal distribution. The p-values reflect the significance of these comparisons. A significant difference was only observed in the TMC in the 4th year ($p < 0.05$), suggesting that motor competence can vary significantly in this group. No significant differences were found for the other variables.

Discussion

The dual objective of this study was to analyze the differences in MC and body composition in primary school children between different years of schooling and to investigate whether the variables of body composition and MC differ in school performance (considering the overall average of grades).

Current literature indicates that there is a tendency for MC to improve as children get older [27]. In fact, in our sample, we observed an upward trend in MC variables throughout the school years, which is consistent with the motor development expected with advancing age. However, these values do not yet reach a normal profile for age (MC percentile ≥ 50).

The relationship between body composition, physical fitness, and PA is complex, although several studies

Table 3 Comparison of body composition variables and total motor competence by year of schooling

| Variables | 1st Year (N=51) | | 2nd Year (N=59) | | 3rd Year (N=75) | | 4th Year (N=87) | |
|-----------|--------------------|-------|--------------------|-------|--------------------|-------|--------------------|--------------|
| | M ± SD | p | M ± SD | p | M ± SD | p | M ± SD | p |
| MM | 8,83 ± 1,64 | 0,617 | 9,79 ± 1,75 | 0,534 | 12,06 ± 2,31 | 0,931 | 12,91 ± 1,84 | 0,140 |
| FM | 5,02 ± 3,65 | 0,956 | 6,78 ± 4,07 | 0,458 | 7,43 ± 5,34 | 0,541 | 8,21 ± 4,11 | 0,488 |
| BMI | 16,43 ± 2,45 | 0,469 | 17,40 ± 3,10 | 0,547 | 17,47 ± 3,45 | 0,416 | 18,99 ± 2,78 | 0,433 |
| %BF | 20,61 ± 8,76 | 0,995 | 23,95 ± 9,46 | 0,615 | 21,93 ± 9,16 | 0,441 | 23,25 ± 8,21 | 0,559 |
| TMC | 42,54 ± 16,67 | 0,362 | 52,01 ± 17,35 | 0,062 | 43,50 ± 17,17 | 0,107 | 49,08 ± 19,78 | 0,033 |

* $p \leq 0.05$ used in the Kruskal–Wallis test; M – Mean; SD – Standard Deviation; N – Number of subjects; MM – Muscle Mass; FM – Fat Mass; BMI – Body Mass Index; %BF – Body Fat Percentage; TMC – Total Motor Competence (Middle Percentile)

indicate that low levels of physical fitness and PA are associated with high BMI values [20, 21]. In this study, we found that body composition variables (FM, BMI and %BF) differed between school years and seemed to have an impact on motor development, especially at older ages. Specifically, MC was lower in children with higher %BF and BMI in the upper school years. This finding suggests that the impact of body composition variables on motor development may become more pronounced with age. On the other hand, the MM variable showed no significant differences between school years in relation to MC, which suggests that MM alone may not be a determining factor in motor development, possibly due to the complexity of the factors that influence MC.

A current cross-cultural and multi-country review in children found an inverse association between MC and BMI, suggesting that improving MC in overweight or obese children may be a promising intervention strategy to promote PA and, consequently, lead to a healthy BMI [28]. Based on the vast number of overweight and obese children around the world, and our sample is a reflection of this, with all groups on average except for the 1st year being overweight, it is essential to draw attention to this public health issue so that future longitudinal studies can trace a possible causal path between MC and BMI from early childhood.

The literature indicates that children with low MC are more likely to have low academic performance and that strengthening MC can contribute to better educational results [17, 29–32]. At the same time, some authors point out that well-developed MC for their age can influence children's cognitive development, favoring school performance [8, 33]. However, the results of the present study only show a significant difference in MC in the 4th year of schooling. This difference suggests that MC may vary in this school year, but it cannot be concluded that there is a direct or causal relationship with school performance. The Kruskal-Wallis test made it possible to identify differences in the distribution of MC between school years, but it was not designed to assess direct associations between MC and school performance.

The difference observed in 4th year may be related to factors specific to this age group, such as changes in the school curriculum or motor maturation. In addition, the high proportion of children with a low level of MC (62.5%) may have influenced the differences observed between the school years. It is important to note that the absence of significant differences in the previous years does not imply that there is no relationship between MC and school performance, but only that no overall differences were observed in the medians of the distributions.

This study has some limitations. Its cross-sectional design does not allow us to infer causality or determine the direction of associations between variables. Although

BIA is a practical and increasingly reliable method for assessing body composition, it may present limitations in pediatric population due to growth related variability. Another limitation is the absence of sex-stratified inferential analysis. The decision to analyze boys and girls together was based on the exploratory nature of the study, which aimed to identify general patterns between body composition, MC, and school performance in a school context. Given this objective, an aggregated approach was considered appropriate to provide an overall picture of the sample and the studied relationships. While preliminary exploration suggested similar trends between sexes, the sample size in each subgroup limited the statistical robustness of stratified analyses. Nevertheless, we recognize that sex differences in body composition and MC may influence the observed associations. To address this, descriptive sex-stratified data were included in the supplementary material, and we strongly recommend stratified analyses in future research.

Future studies should consider longitudinal designs to explore the trajectory of motor development and its possible influence on school performance over time. It is also recommended to include correlation analyses and regression models to investigate direct associations between body composition variables, MC and school performance. Finally, it would be relevant to consider other environmental and individual variables that may impact these relationships. This approach would contribute to a more comprehensive understanding of the complex interaction between motor development, body composition and school performance.

Conclusions

The results of this study indicated that body composition is negatively correlated with MC, particularly in the 4th year of school. In addition, MC showed a significant association with school performance in the last year of primary school. These findings suggest that the relationship between body composition and MC may become more pronounced as children progress through school, potentially influencing academic performance in the final years of primary school.

School programs that promote PA and motor development can be particularly beneficial in the last year of primary school, helping to improve MC and academic performance. Future studies should consider gender-specific analyses and longitudinal approaches to explore the direction of these associations.

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12887-025-05792-5>.

Supplementary Material 1

Author contributions

Conceptualisation, M.R.; data curation, S.H., A.P. and P.A.; formal analysis, J.S. and P.A.; investigation, M.R., A.P. and P.A.; methodology, S.H. and J.S.; software, C.M. and A.D.; writing—original draft, C.M. and J.S.; writing—review and editing, M.R., S.H., P.A., C.M. and J.S. All authors have read and agreed to the published version of the manuscript.

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Data availability

No datasets were generated or analysed during the current study.

Declarations**Ethics approval and consent to participate**

The research was waived with a favorable opinion by the Review Board of the Polytechnic University of Castelo Branco (code 20180777/CTC-IPCB/2023), and written informed consent was obtained from all parents or legal guardians of participants included in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Conflict of interest

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