Turkish Archives of Pediatrics

ORIGINAL ARTICLE
DOI: 10.65717/TurkArchPediatr.2026.25460

Relationship Between Motor Competence and Weight Status from Childhood to Adolescence (3-19 Years)

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What is already known on this topic?

- *Motor competence (MC) and weight status (WS) are inversely associated, particularly during childhood and early adolescence, with lower MC being linked to higher body mass index (BMI) and adiposity.*
- *Evidence from longitudinal studies shows that excess weight in early childhood negatively predicts later MC, especially in locomotor and coordination skills, while the reverse pathway (MC predicting later WS) remains inconsistent.*
- *Despite clear associations in children, there is limited and fragmented understanding of how this relationship evolves across the full developmental span.*

ABSTRACT

Objective: To evaluate the relationship between motor competence (MC) and weight status (WS) from childhood through adolescence.

Methods: A total of 4537 participants (2425 boys) aged 3-19 years were assessed. The MC was measured using the MC Assessment (MCA) instrument, and body mass index was calculated from height and weight.

Results: An inverted U-shaped relationship was observed between WS and MC. Participants with a healthy weight (HW) consistently showed higher total MCA scores compared to those with underweight (UW) ($P = .002$), overweight (OW), and obesity (OB) (both $P < .001$). The OB participants had the lowest MC scores overall (OB < OW < HW; $P < .001$), with UW also performing significantly worse than HW. This pattern was consistent in the Stability and Locomotor components. However, in the Manipulative component, UW participants scored significantly lower than all other groups (HW $P = .028$; OW $P = .024$; OB $P = .017$), while HW, OW, and OB did not differ significantly. These patterns were consistent across sex and age groups (all $Ps > .05$).

Conclusion: An association between WS and MC was observed across developmental stages, suggesting that HW profiles may be related to higher MC. The consistency of these patterns across age and sex suggests that biological and sociocultural mechanisms may jointly influence this relationship throughout development.

Keywords: Body mass index. health. lifespan. motor competence

INTRODUCTION

Over the past 4 decades, physical activity (PA) levels in Western societies have significantly declined compared to previous generations.[1-3] Behavioral risk factors, including poor dietary habits, sedentary lifestyles, and overall physical inactivity, are leading contributors to physiological risks, with obesity (OB) and overweight (OW) being among the most prevalent outcomes.[4]

The PA habits of the Portuguese population are deteriorating, placing the country at the top of the list of European nations with the lowest levels of PA. According to the most recent data,[5] 73% of Portuguese people never engage in any form of PA or sport, reflecting an increasingly sedentary lifestyle. Among men, 36% of those aged 15-24 never or rarely engage

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Received: November 10, 2025
Revision Requested: January 10, 2026
Last Revision Received: February 12, 2026
Accepted: March 19, 2026
Publication Date: June 2, 2026

Cite this article as: Pombo A, Luz C, Cordovil R, et al. Relationship between motor competence and weight status from childhood to adolescence (3-19 years). *Turk Arch Pediatr.*, 2026;61(7):615-623.

What this study adds on this topic?

- *Continuous age coverage and large sample: For the first time, the relationship between MC and WS was examined continuously from ages 3 to 19 in a single study, involving over 4500 participants and using the same standardized instrument MC Assessment (MCA). This makes it possible to observe the consistency of the relationship across the full developmental span, something that earlier, age-specific studies could only suggest.*
- *Identification of an inverted U-shaped pattern: The study shows empirically that both underweight and obesity are associated with lower MC, while the best MC performance is observed in the healthy-weight group.*
- *Cross-sectional stability of the relationship: By demonstrating that the MC–BMI association remains independent of age and sex, the study provides evidence that the underlying mechanisms (biological and sociocultural) operate similarly across all developmental stages, reinforcing and refining Stodden's bidirectional model.*

in PA, a figure that rises to 62% in the 25-39 age group. For men aged 40-54, the proportion of inactive individuals reaches 81%, and among those over 55, it climbs to 91%. For women, the figures are similarly concerning. In the 15-24 age group, 37% never or rarely engage in PA. This figure increases significantly to 79% between the ages of 25 and 39 and remains high for women aged 40-54, with 80% not participating in any exercise. The situation is critical for women over 55, where, similar to men, 91% do not engage in any regular PA.

The case is no different for Portuguese children. Objective data indicate that only 36% of children aged 10 to 11 years meet the World Health Organization (WHO) PA guidelines, which recommend a minimum of 60 minutes of moderate-to-vigorous PA per day.[6] Furthermore, Portuguese children exhibit low levels of independent mobility, defined as the ability to move freely within their environment without adult supervision. For instance, 69.2% of children aged 6-10 commute to school by car, while only 20.5% walk or cycle. Screen time is prevalent, with 27.4% of children exceeding 1 hour of screen-based activities on weekdays, and this proportion increases to 74.3% on weekends.[7]

During early childhood, the development of movement skills is essential as it forms the foundation for PA.[8] At this stage, children begin acquiring a set of fundamental movement skills, which include skills such as locomotor (running, galloping, skipping), stabilization (hopping, sliding, leaping), and manipulative (throwing, catching, kicking).[9] The development of these skills creates a diverse motor repertoire, enabling children to perform adaptive and skilled movements that can be tailored to various contexts. Without adequate proficiency in these essential skills, children may face limited opportunities to participate in PA later in life, as they will lack the necessary skills to be active.[8]

The best way to check the development of these movement skills is by understanding that motor competence (MC), defined as the ability to be proficient in a broad range of motor tasks (locomotor, stability, and manipulative),[10] is a critical determinant of PA and overall health.[11] According to the conceptual model proposed by Stodden et al. (2008),[12] MC influences various health-related outcomes, including PA levels, body weight status (WS), perceived MC, and health-related fitness.[13] This model outlines the bidirectional relationship between MC and PA,[13] suggesting that higher levels of MC during childhood are associated with increased PA, improved physical fitness, and healthier WS, while lower MC is linked to reduced PA and elevated adiposity.[14,15] Importantly, emerging evidence suggests that the relationship between body WS and MC may not be strictly linear, but rather curvilinear, with both low and high body mass index (BMI) values being associated with poorer motor performance, while intermediate BMI levels tend to be related to higher MC.[16] Nevertheless, it must be acknowledged that motor performance tends to improve from childhood to adolescence but declines from early adulthood into old age,[17] which can impact WS and overall PA.

Empirical evidence underscores the association between low MC and increased adiposity in childhood.[18,19] Several studies have reported inverse relationships between MC and anthropometric measures such as waist circumference,[20,21] highlighting the role of MC as a critical factor in the prevention of childhood OB. However, this association is still not fully understood across the lifespan. Inverse associations between MC and WS begin to appear in preschool-aged children and become more pronounced during primary school years; however, beyond this stage, the evidence is less consistent. In particular, most studies have relied on linear analytical approaches and have focused primarily on comparisons between normal-weight and OW/obese groups, often neglecting the potential motor implications of low BMI and the possibility of non-linear associations across the full BMI spectrum.[16] While some studies suggest that the strength of this association diminishes during puberty and adolescence, others report stronger correlations in young adults and adolescents compared to those observed in childhood.[11] Evidence from childhood samples indicates that curvilinear relationships between BMI and MC tend to be more apparent in later childhood than in early childhood, suggesting that developmental stage may moderate both the strength and the shape of this association.[16]

The primary risk factors for OB are well-documented and include age, tobacco use, consumption of sugary beverages, socioeconomic status, fast food intake, sleep patterns, diet, blood pressure, blood glucose levels, lipid profiles, body fat distribution, physical inactivity, and family history. In summary, the key contributors to OB and OW are nutritional habits,

education levels, dietary shifts, and insufficient PA, which are usually correlated with lower education levels and socioeconomic conditions.[4]

Childhood and adolescent OB are widely acknowledged as one of the most significant public health challenges of the 21st century.[22] Children with OB, particularly adolescents, are at an elevated risk of becoming adults with OB,[23] thereby increasing their susceptibility to a wide range of chronic diseases.[24,25] Over the past decade, the rapid proliferation of technology has contributed to a shift toward more sedentary behaviors and a decline in PA levels among children,[26,27] compared to previous generations,[28] posing a considerable public health concern.

Knowing that MC is a key determinant of both PA and body WS, there is a growing need for reliable tools to assess MC across various age groups. Recently, a new instrument was developed based on the strengths and limitations of other tools—the MCA Assessment (MCA).[29] The MCA consists of 6 motor tasks that cover 3 movement components: stability, locomotor, and manipulative skills. Additionally, it is a quantitative protocol with no developmental (age) ceiling effect and is designed to be easy to use and reproducible across observers. In recent years, studies have been conducted to establish the construct validity and normative values of the MCA for individuals aged 3-23 years.[10,30] As an objective and standardized method to evaluate MC from early childhood to adulthood, the MCA is an ideal tool for investigating the relationship between MC and BMI in children and adolescents. Therefore, this relationship will be examined across childhood and adolescence.

MATERIALS AND METHODS

Ethical Approval

Ethics approval was obtained from the Ethics Committee of the Polytechnic Institute of Castelo Branco (Approval no: 184/CE-IPCB/2024; Date: 8 January 2025). The study followed ethical guidelines for research involving human subjects, including the principles outlined in the Declaration of Helsinki. Written informed consent was obtained from a parent or legal guardian for each participant. After receiving parental consent, participants were informed about the research procedures and their right to withdraw from participation at any time and provided verbal assent to take part in the study.

Procedures

Schools were invited to participate through regional educational networks, and data collection was conducted during regular school hours in schools that agreed to take part in the study. Within each participating school, all children and adolescents enrolled in regular kindergarten or school classes and present on the day of assessment were invited to participate, subject to parental consent and child assent.

Assessments took place during school hours, conducted either individually (for height and weight measurements) or collectively (for MC tasks) in a gymnasium. The entire assessment process lasted approximately 20 minutes per participant. A warm-up, including both static and dynamic exercises, was performed beforehand to enhance performance and minimize the risk of injury. Data collection was carried out by a well-trained team with expertise in human kinetics and extensive experience in conducting assessments.

Participants

Participants were 4537 children and adolescents (52.6% boys), aged 3-19 years (Mage = 9.67 SD = 3.05) recruited from all the NUTS II (Territorial Units for Statistics, a system of regional divisions used by all member countries of the European Union for statistical purposes). Participants were divided into 4 age groups (3-5, 6-10, 11-16, and 17-19 years) corresponding to the structure of the Portuguese education system: pre-school, First Cycle of Basic Education (primary education), Second and Third Cycles of Basic Education, and Secondary Education. This classification aligns developmental stages with formal educational levels, ensuring greater homogeneity within groups in terms of curricular exposure, cognitive development, and institutional context. Such alignment facilitates meaningful comparisons and strengthens the interpretability of the findings within the Portuguese educational framework. No predefined regional quotas or population-weighted criteria were applied to ensure statistical representativeness within each region. No formal exclusion criteria were applied. Based on information provided by parents or legal guardians, none of the participants presented motor, cognitive, or health impairments that could affect performance in the MCA, and no cases of syndromic OB or other diagnosed medical conditions associated with OB were reported in the sample.

Measures and Instruments

Motor Competence

Motor competence in children and adolescents was evaluated using the MCA instrument. The MCA is a product-oriented instrument designed to assess 3 correlated theoretical components through 6 motor tasks, as validated by its construct: stability (i.e., jumping sideways and shifting platforms), locomotor skills (i.e., standing long jump and 4 × 10 m shuttle run), and manipulative skills (i.e., ball kicking velocity and ball throwing velocity).[29] The construct validity and normative values of the MCA have been established for individuals ranging from early childhood to adolescenthood.[10,30] The overall MCA score is calculated from the mean of the 3 categories, each calculated as the average of the percentiles of its 2 associated tasks. Performance on the 6 tasks is converted into age- and gender-specific percentiles (0-100) based on the normative values by the MCA.[10] Children completed all tasks within small groups of 4-5 participants per task. Each assessment lasted approximately 10-15 minutes per child and followed the protocol outlined by Luz et al. Before each task, a demonstration and verbal explanation were provided to the group. Participants were also given the opportunity to perform a test trial for practice. During the assessment, examiners encouraged participants to perform at their best, offering motivational feedback throughout the process.

Body Mass Index and Body Mass Index Z-score

Children wore lightweight clothing, and shoes were taken off prior to taking measurements. The height (Seca®, model 213) and weight (Tanita®, model UM-076) of the children and adolescents were measured, and BMI was computed, defined as kg/m^2. The BMI percentiles were calculated for each participant,

considering age and gender, according to WHO growth standard.[31,32] The BMI was used to define underweight (UW), normal weight, OW, and OB (age- and gender-specific BMI cutoffs).[31,32] The BMI was recoded into BMI z-score standardized for age and gender. Cut-off points were used to define if children were UW (BMI $z \leq -1.99$), had healthy weight (HW) ($-2 <$ BMI $z < 0.99$), were OW ($1 <$ BMI $z < 1.99$), or obese (BMI $z \geq 2$).

Data Analysis

An a priori power analysis was conducted using G*Power (version X.X) for F tests analysis of variance (ANOVA: fixed effects, special, main effects and interactions), assuming a medium effect size (Cohen's $f = 0.25$), a significance level of $\alpha = 0.05$, and a statistical power of 0.95. Considering a factorial design with 4 weight-status categories, 3 age groups, and sex as a factor, the minimum required sample size ranged from 227 participants (main effect of age group, $df = 2$) to 341 participants (interactions between weight-status and age group, and between weight-status, age group, and sex, $df = 6$). The final sample of 4537 participants largely exceeded these requirements, ensuring sufficient statistical power to detect both main effects and interaction effects across all analyses. All data were analyzed using IBM SPSS Statistics (Version 24, IBM SPSS Corp.; Armonk, NY, USA), and statistical significance was set at $P < .05$. Descriptive statistics (means, standard deviations, and minimum and maximum values) were calculated for MCA and BMI. Given the unequal group sizes of each factor tested in the analyses and the potential violations of homogeneity of variance, a bootstrap procedure with 1000 resamples was applied for each analysis, to obtain more robust estimates of standard errors and significance levels. When significant effects were identified and homogeneity of variance was missing, the Welch correction was used for testing the general effects on the one-way ANOVA, and the Tamhane test for post-hoc comparisons. If homogeneity of variance was found, post-hoc comparisons were tested using the least significant difference. To examine the relationship between MC and WS across development, a 1-way ANOVA was conducted with MCA as the dependent variable and weight-status as a factor. Subsequently, a 3-way ANOVA tested the effect of 3 factors (weight-status categories, age groups, and sex) on the MCA. Main effects and interaction effects were examined.

RESULTS

The overall mean sample of the normative values for the total MCA was at the 52nd percentile (±19.2), and the 51st (±24.2), 57th (±25.5), and 49th (±25.1) percentiles, respectively, for the stability, locomotor, and manipulative components. Boys and girls showed similar values on the Total MCA (boys = 52.8 ± 19.4 vs. girls = 51.7 ± 19.0; p = .056), and on the manipulative component (48.7 ± 25.7 vs. 49.3 ± 24.4; $P = .446$). Boys showed better performance on the stability (51.9 ± 24.2 vs. 50.4 ± 24.2; $P = .042$) and on the locomotor component (57.7 ± 25.7 vs. 55.3 ± 25.3; $P = .002$).

The BMI classification of the participants indicates that 2.1% (boys = 46; girls = 48) were UW, 62.7% (boys = 1526; girls = 1319) had a normal weight, 13.6% (Boys = 305; Girls = 313) were classified as having OW, and 21.6% (boys = 548; girls = 432) had OB, with a similar distribution between the WS group for both sexes (chi-square $_{(3,4537)} = 7.38$; $P = .061$).

Analysis of the general effects of the relationship between WS and MC (total MCA) relative to age and sex (Figure 1, Table 1), indicates an inverted U-shaped relationship, where HW individuals show significantly better MC results than those with UW ($P = .002$), OW ($P < .001$), and OB ($P < .001$). Individuals with OB and low weight do not differ from each other, but those with OB stand out with the lowest average MC values (OB < OW; OB < HW; $P < .001$).

In the stability component, the U-shaped pattern persists, with HW showing higher MC values than all other weight groups (UW $P = .010$; OW $P = .001$; OB $P < .001$), and the group with

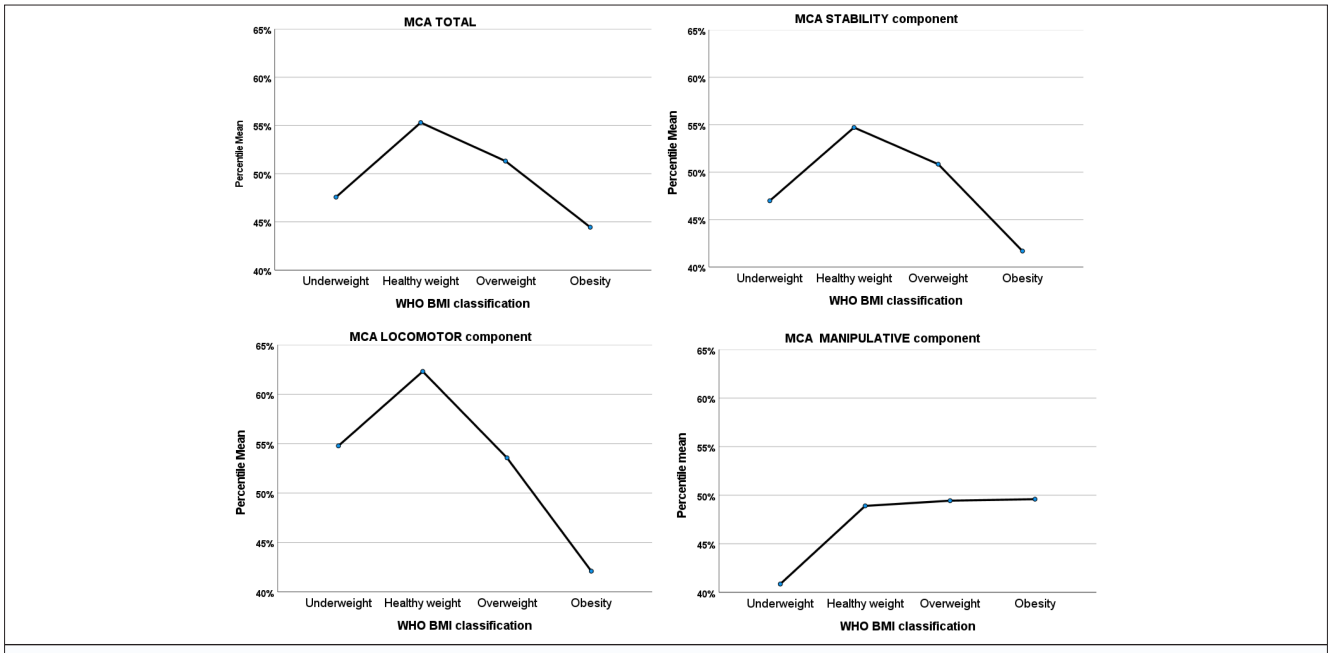

Figure 1. Representation of the mean percentile values of the MCA according to WS groups of the WHO BMI classification.

Table 1. Descriptive Values of MCA Total and Components by WS, and Significant Post-hoc Comparisons Between Groups

	Underweight	Healthy Weight	Overweight	Obesity
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	**Mean ± SD**
	(n = 94)	**(n = 2845)**	**(n = 618)**	**(n = 980)**
MCA total (percentile)	47.6 ± 19.5	55.3 ± 18.5	51.3 ± 19.3	44.5 ± 19.2
	UW < HW > OW > OB; UW = OW; UW = OB			
Stability (percentile)	45.0 ± 22.8	54.7 ± 23.5	50.8 ± 23.3	41.7 ± 24.2
	UW < HW > OW > OB; UW = OW; UW = OB			
Locomotor (percentile)	54.8 ± 27.0	62.3 ± 23.6	53.6 ± 25.7	42.1 ± 24.5
	HW > OW > OB; UW = HW, OW; UW > OB			
Manipulative (percentile)	40.9 ± 26.6	48.9 ± 24.9	49.4 ± 25.3	49.6 ± 25.3
	UW < HW, OW, OB; HW = OW = OB			

HW, healthy weight; OB, obesity; OW, overweight; UW, underweight.

OB showing the lowest values, although not distinct from LW (P = .190).

In the locomotor component, the pattern repeats, despite some differences as HW distinguishes themselves positively from OW (P < .001) and OB (P < .001), but not from UW (P = .053), while OB distinguishes themselves significantly from all other groups (P < .001). In turn, UW shows mean values similar to OW (P = .999).

For the manipulative component there is a change of the previously observed pattern, as UW shows significantly lower values compared to all other weight groups (HW P = .028; OW P = .024; OB P = .017), and HW, OW, and OB do not differ in the performance.

As shown in Table 2 and Figure 2, there were no significant effects of sex on the values of any of the components or on the overall MCA value, which can be explained by the fact that values are expressed in percentiles normalized to age and sex. Nevertheless, the results of each sex were tested to evaluate whether the relationship between the 2 would be similar across the entire spectrum of WS and for all MCA components. The univariate analysis of the interaction effect between sex and WS (Table 2) shows that there are no differences (P values from .0684 to .984) between sexes in this relationship. Boys and girls demonstrate identical profiles of the relationship between MC and WS, maintaining similar MC values for each WS group, thus following the general description previously made for each MCA component and total values.

Table 2. Descriptive and ANOVA Results Regarding Main Effects and Interaction Effects of WS, Sex, and Age Group on Overall Motor Competence and Components

	Underweight		Healthy Weight		Overweight		Obesity	
	Mean ± SD		**Mean ± SD**		**Mean ± SD**		**Mean ± SD**	
	Boys (n = 46)	**Girls (n = 48)**	**Boys (n = 1526)**	**Girls (n = 1319)**	**Boys (n = 305)**	**Girls (n = 313)**	**Boys (n = 548)**	**Girls (n = 432)**
MCA	44.3 ± 17.4	50.8 ± 21.0	56.3 ± 18.5	54.2 ± 18.5	51.1 ± 19.2	51.5 ± 19.5	44.6 ± 19.2	44.3 ± 18.2
Stability	44.1 ± 19.6	49.7 ± 25.4	55.8 ± 23.1	53.1 ± 23.9	49.8 ± 23.5	51.8 ± 23.1	42.8 ± 25.0	40.3 ± 23.0
Locomotor	53.2 ± 23.8	56.3 ± 30.1	64.1 ± 23.6	60.3 ± 23.6	55.0 ± 25.0	52.2 ± 26.3	41.9 ± 24.6	42.4 ± 24.3
Manipulative	35.5 ± 24.7	46.0 ± 27.6	49.0 ± 25.6	48.8 ± 24.1	48.4 ± 25.4	50.4 ± 25.1	49.0 ± 26.0	50.3 ± 24.4
	3-5 Years		**6-10 Years**		**11-16 Years**		**17-19 Years**	
	Mean ± SD		**Mean ± SD**		**Mean ± SD**		**Mean ± SD**	
	Boys (n = 83)	**Girls (n = 72)**	**Boys (n = 1760)**	**Girls (n = 1528)**	**Boys (n = 475)**	**Girls (n = 450)**	**Boys (n = 107)**	**Girls (n = 62)**
MCA	50.1 ± 20.9	49.6 ± 17.9	53.5 ± 19.2	51.3 ± 18.9	50.1 ± 20.2	53.3 ± 18.9	54.1 ± 16.4	51.5 ± 23.4
Stability	49.8 ± 24.8	48.3 ± 25.3	52.5 ± 24.2	50.0 ± 24.0	49.9 ± 24.1	52.6 ± 24.2	52.7 ± 23.8	49.0 ± 27.1
Locomotor	45.4 ± 27.5	49.0 ± 21.2	60.4 ± 24.8	56.3 ± 24.9	50.3 ± 27.0	53.7 ± 26.0	54.9 ± 22.8	52.6 ± 27.5
Manipulative	55.0 ± 23.9	51.6 ± 20.5	47.7 ± 26.2	47.7 ± 24.6	49.9 ± 24.7	53.6 ± 23.3	55.0 ± 21.7	52.9 ± 28.6
ANOVA main effects and interaction effects for WS, sex, and age group								
MCA	F_{WS} (3.4508) = 13.63, P < .001; F_{Sex} (1.4508) = 0.11, P = .736; F_{AGrp} (1.4508) = 2.06, P = .103 $F_{SEX \times WS}$ (3.4508) = 0.53, P = .663; $F_{SAGr \times WS}$ (8.4508) = 1.04, P = .401							
Stability	F_{WS} (3.4508) = 10.95, P < .001; F_{Sex} (1.4508) = 0.17, P = .684; F_{AGrp} (1.4508) = 2.52, P = .056 $F_{SEX \times WS}$ (3.4508) = 0.70, P = .551; $F_{SAGr \times WS}$ (8.4508) = 1.33, P = .225							
Locomotor	F_{WS} (3.4508) = 28.25, P <.001; F_{SEX} (1.4508) = 0.06, P = .799; F_{AGrp} (1.4508) = 13.87, P <.001 $F_{SEX \times WS}$ (3.4508) = 0.84, P = .469; $F_{SAGr \times WS}$ (8.4508) = 1.64, P = .106							
Manipulative	FWS (3.4508) = 1.64, P = .178; F_{Sex} (1.4508) = 0.00, P = .984; F_{AGrp} (1.4508) = 3.792, P = .010 $F_{SEX \times WS}$ (3.4508) = 0.52, P = .666; $F_{AGr \times WS}$ (8.4508) = 0.622 P = .760							

Agrp, age group; AGrp × WS, interaction effect between age group and weight status; SEX × WS, interaction effect between sex and age group; WS, weight status.

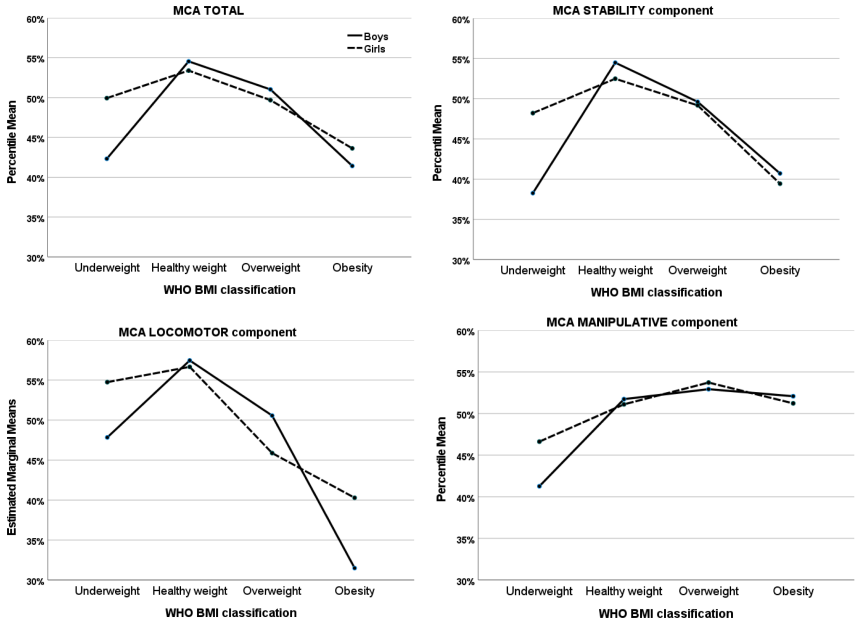

Figure 2. Representation of the mean percentile values of the MCA for boys and girls, according to WS groups of the WHO BMI classification.

Regarding the univariate analysis by age group (Table 2, Figure 3), no significant effects were found related to age groups or the interaction between these and WS (*P* values from .106 to .706; Table 2). This indicates that the relationship between MC and WS remains relatively stable across age and according to the patterns previously presented for each MC component.

DISCUSSION

The aim of this study was to assess the relationship between MC and WS across childhood and adolescence.

Weight Status Results

Overall, the BMI classification revealed a predominance of normal weight among participants, alongside a substantial proportion of children classified as OW or obese. Importantly, WS distribution was comparable between boys and girls, suggesting that sex-related differences in BMI were not evident in this sample. These findings are of particular concern, as they corroborate the notion that OB represents a significant public health challenge among younger cohorts in Portugal. Data from the 2022 Survey on Income and Living Conditions[33] reveal that individuals enrolled in basic education exhibit the highest prevalence of weight-related deviations: 1.4% are classified as UW, 35.2% maintain a normal weight, 41.9% are OW, and 21.5% have OB.

In the secondary and post-secondary education strata, the distribution shifts as follows: 3.1% UW, 51.8% normal weight, 33.6% OW, and 11.5% OB. Among those pursuing higher education, the proportion of individuals with normal weight further increases

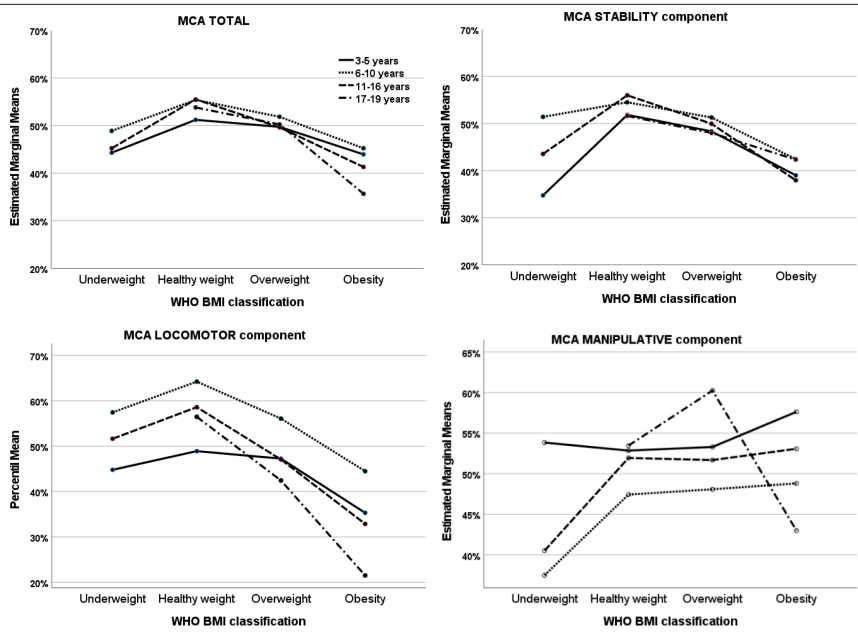

Figure 3. Representation of the mean percentile values of the MCA for age group, according to WS groups of the WHO BMI classification.

to 57.3%, while the prevalence of UW, OW, and OB stands at 2.3%, 31.6%, and 8.8%, respectively.

Motor Competence Results

Mean percentile values found for MCA (*p*52) and its components (*p*49 to *p*57) are near the 50th percentile. Furthermore, boys and girls showed similar values on Total MCA and the manipulative component. Even for stability and locomotor components, although significant differences were found, their absolute values were very small considering the percentile scale (mean difference of 1.5 for stability, and 2.3 for locomotor). This analysis confirms that the sample can be considered average and representative of a normal population.

General Relationship Between Motor Competence and Weight Status

The findings indicate significant variations in MC across different BMI categories, with individuals in the HW category performing significantly better than all other weight-status groups in the stability and locomotor components, as well as in total MCA values. In the Manipulative component, healthy-weight individuals also showed the highest performance, although they did not differ significantly from those classified as OW or obese. Overall, the analysis (Figure 1) revealed a clear inverted U-shaped pattern, with MC improving from UW to HW and declining at higher BMI categories. Notably, participants with OB presented lower MC scores than those classified as UW.

Importantly, the consistently lower MC observed in UW participants reinforces the need to consider the full BMI spectrum, as insufficient body mass may also impose biomechanical and strength-related constraints on motor performance. A similar inverted U-shaped pattern has also been reported in the relationship between BMI and physical fitness.[34,35]

These findings align with previous evidence indicating that BMI is negatively associated with MC, particularly in tasks requiring body control.[13] Evidence consistently shows that children with a HW tend to demonstrate higher levels of MC, whereas increasing BMI is associated with poorer performance as children age.[36] Specifically, OW and OB have been associated with impairments in locomotor, coordination, and balance skills.[36] Importantly, there is also evidence suggesting a reciprocal association, whereby poor MC may contribute to the development of excess weight, reinforcing a negative developmental cycle.[12]

The fact that this relationship is clear for total MCA, Stability, and Locomotor components, but not for the Manipulative component, may be explained by the nature of typical stand-alone manipulative tasks (e.g., throwing, dribbling, kicking), which can benefit from greater body mass due to increased absolute strength. Indeed, studies examining maximal isotonic, isometric, and isokinetic strength across the lifespan consistently report higher absolute strength in individuals with OB.[37] However, when strength is normalized to total body mass, individuals with OB exhibit lower relative strength in the loaded musculature.[37] Moreover, recent studies have shown that MC and body composition are significantly associated with academic performance in school-aged children, highlighting the broader developmental and educational relevance of these findings.[37]

The Effect of Sex in the Motor Competence × Weight Status Relationship

No significant differences in MC were observed based solely on sex. Boys and girls maintain a very similar pattern of association between MC and WS, as denoted on Figure 2. The only average visual dissimilarity in Figure 2 is in the UW groups, where there is a tendency for UW girls to have a higher average result than boys, but this difference was not statistically significant. This consistency in the relationship between MC and WS in both sexes is notable, regardless of the widely described marked gender differences in sociocultural factors. Boys traditionally receive more encouragement and positive reinforcement to engage in movement opportunities, sports activities, and gross motor skill development,[38] from early on but especially during adolescence.[38] It is also well-known that boys present better values in MC and physical fitness, regardless of age.[38] In fact, in this study, MCA and BMI values represent percentile values of the normative references for age and sex, and that is why no differences are found between sexes. But, despite all the known differences in absolute MCA and BMI, the relationship between MC and WS remains the same for boys and girls, giving their respective age and sex specificity, strengthening the conclusions on the phenomenon.

The Effect of Age in the Motor Competence × Weight Status Relationship

A secondary question raised was on the age effect on the MC-WS relationship. Does the relationship between MC and WS remain consistent across all ages from childhood to adolescence? The results of the univariate analysis in Table 2 seem to generally support this, as no significant effects of age groups were recorded in the distribution of total MCA values by WS group ($P = .103$) or in the interaction with WS ($P = .401$). A similar result was found for the stability component, but not for the other 2 components, Locomotor and Manipulative. In the last 2 cases, there is a significant variation in MC values between age groups ($P < .001$ and $P = .010$, respectively for the locomotor and manipulative components), which persists across WS categories, as indicated by the interaction values between age group and WS ($P = .106$ and $P = .760$). From the analysis of the results and the graph (Figure 3), it can be inferred that there is a change over the years in the locomotor component towards a stronger association pattern between MC and WS, with an increasing difference between HW relative to OW and the latter relative to OB. In the manipulative component, and looking exclusively at the last 3 WS groups, the behavior of adolescents stands out, where the MC of the OW and OB groups shows a different pattern from the others, which may indicate a greater manipulative MC with OW status, while obese participants lose relative MC quality.

In any case, it is evident that the manipulative component of MC shows the most significant age-related changes in the association between MC and WS.

This study presents several limitations and strengths that should be considered when interpreting the findings. Although the analysis aimed to explore developmental patterns across childhood and adolescence, its cross-sectional design requires cautious interpretation and precludes any causal inference[39] regarding the relationship between MC and WS, which must

be understood strictly as a concurrent association.[40] In addition, several relevant confounding variables were not directly assessed, including levels of PA and sports participation, biological maturation, socioeconomic status, dietary patterns, and access to structured or unstructured PA opportunities, all of which have been shown to relate to both MC and adiposity.[11,12,41] The magnitude of bias introduced by these unmeasured factors cannot be directly quantified and may vary across developmental stages.

Furthermore, the number of participants classified as UW was relatively small, particularly during adolescence, which may have limited statistical power and introduced bias in comparisons involving this category. A similar limitation applies to the youngest age group (3-5 years), which was also underrepresented. Although the large sample size (N = 4537) and its broad geographic distribution across Portugal constitute clear strengths of the study, nationwide data collection required the involvement of multiple research teams. While the MCA and anthropometric assessment protocols are simple, standardized, and supported by assessor training, some degree of inter-observer variability cannot be entirely excluded.

On the other hand, the use of a large sample allows for a more robust examination of MC patterns across developmental stages. An additional strength is the use of the MCA, which was validated using Portuguese data and provides age- and sex-specific normative values spanning from early childhood to adolescence, thereby enhancing the interpretability of the results.

Future research should prioritize longitudinal designs to better understand the temporal and potentially causal relationships between WS and MC. Particular attention should be given to mediating and moderating variables such as PA, sports participation, psychosocial factors, and biological maturation. Moreover, incorporating more precise indicators of body composition (e.g., bioimpedance measures of fat and lean mass) may improve assessment accuracy beyond BMI alone, and accounting for pubertal stage would further strengthen the interpretation of developmental differences in MC.

CONCLUSION

The results of this study suggest that WS has an important relationship with MC across childhood and adolescence. Healthy weight participants consistently outperformed their OW and obese peers, with the highest MC scores observed in the HW category for both boys and girls. In particular, the normal-weight group demonstrated better MC across all components, while those with UW, OW, and OB exhibited lower MC scores. Interestingly, while MC improved from UW to normal weight, it declined in OW and OB groups, with participants with OB scoring the lowest overall. Highlighting a close and potentially reinforcing association between higher BMI and lower MC, supporting the notion that healthy WS and higher levels of MC are intertwined in promoting healthier developmental trajectories from childhood through adolescence.

Additionally, the study revealed that when using age and sex appropriate measures, the shape, characteristics, and values of the relationships between MC and WS are similar, meaning that the underlying mechanisms that support this relationship across developmental times seem to be adjusted for the biological sex mechanisms and accounting for cultural gender reality.

Taken together, these findings reinforce the need to systematically monitor MC alongside WS throughout development, guiding early and developmentally sensitive interventions that simultaneously promote HW trajectories and optimal motor development.

Data Availability Statement: The data that support the findings of this study are available on request from the corresponding author.

Ethics Committee Approval: Ethical committee approval was received from the Ethics Committee of the Polytechnic Institute of Castelo Branco (Approval No.: 184/CE-IPCB/2024; Date: 8 January 2025).

Informed Consent: Written informed consent was provided by parents or legal guardians, and verbal assent was obtained from the children and adolescents prior to participation

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – A.P., L.P.R.; Design – L.P.R., R.C.; Supervision – L.P.R.; Resources – A.P., C.L., R.C., G.A., L.P.R.; Materials – A.P., C.L., R.C., G.A., L.P.R.; Data Collection and/or Processing – A.P., C.L., R.C., G.A., L.P.R.; Analysis and/or Interpretation – A.P., C.L., L.P.R.; Literature Search – A.P., C.L., R.C., G.A., L.P.R., J.S., M.R.; Writing Manuscript – A.P., C.L., R.C., G.A., L.P.R., J.S., M.R.; Critical Review – A.P., C.L., R.C., G.A., L.P.R., J.S., M.R.

Declaration of Interests: The authors have no conflicts of interest to declare.

Funding: This research received financial support from FCT—Fundação para a Ciência e a Tecnologia (Foundation for Science and Technology, I.P., Portugal), within the scope of the SPRINT - Sport Physical Activity and Health Research & Innovation Center [UID/6185/2023].

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