Original research

Correlation between BMI and motor coordination in children

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Abstract

Objectives: To analyze the association between motor coordination (MC) and body mass index (BMI) across childhood and early adolescence. *Design*: This study is cross-sectional. *Methods*: Data were collected in 7175 children (boys $n = 3616$, girls $n = 3559$), ages 6–14 years. BMI was calculated from measured height and weight [body mass (kg)/height (m^2)]. Motor coordination was evaluated using Kiphard-Schilling's body coordination test (KTK). Spearman's rank correlation was used to study the association between BMI and MC. A Kruskal–Wallis test was used to analyze the differences in MC between children of normal weight, overweight and obese children. *Results*: Correlations between MC and BMI were negative and varied between 0.05 and 0.49. The highest negative correlations for both boys and girls was at 11 years of age. There was a general pattern of increasing negative correlations in both genders from 6 to 11 years of age and then a decrease in correlation strengths through 14 years of age. In both boys ($\chi^2_{(2)} = 324.01$; $p < 0.001$) and girls ($\chi^2_{(2)} = 291.20$; $p < 0.001$) there were significant differences in MC between the three groups' weight status. Normal weight children of both sexes demonstrated significantly higher MC scores than overweight. Obese children in both sexes had the lowest MC scores among all three groups. *Conclusion*: Motor coordination demonstrated an inverse relationship with BMI across childhood and into early adolescence. The strength of the inverse relation increased during childhood, but decreased through early adolescence. Overweight and obese children of both sexes demonstrated significantly lower MC than normal weight children.

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1. Introduction

The prevalence of childhood obesity is increasing worldwide. In Europe, the percentage of overweight and obesity in adolescents ranges from 3% to almost 35% in 13-year-olds and from 5% to 28% in 15-year-olds. In Portugal 32% of children between seven to nine years of age are overweight or obese.[1]

Although several studies have shown that obese children and adolescents are less physically active than their non-obese peers, relationships between physical activity (PA),

sedentary activity, and obesity in children and adolescents has not been clearly established.[2] Overall, many studies examining PA and/or weight status in children have only provided data on psychological and environmental correlates.[3] Recent studies have focused on understanding the relationships among motor coordination (MC) and health-related behaviors and attributes. A recent review on the relationships among MC and health benefits in children and adolescents[4] indicated MC levels are inversely correlated with weight status, but positively correlated with PA, and perceived physical competence in cross-sectional and longitudinal data. Weight status was negatively correlated with MC in six of nine studies, with the remaining three demonstrating no relationship. This review of associations of MC and aspects of physical and

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psychological attributes provides indirect evidence that MC may be an important antecedent/consequent mechanism for promoting to healthy lifestyles related behaviors, including weight status.

Despite the fact that a large number of children do not achieve PA recommendations[5] children are naturally drawn to be active and, if provided the opportunity, often engage in active play[6] Inherent pleasure associated with movement,[7] as well as the psychological benefits associated with MC[8] may be important contributors to children's PA.

Stodden et al.[9] proposed a developmental and recursive model suggesting that obesity trajectories may be triggered by the cumulative effects that lower levels of MC has on reducing movement opportunities (PA), physical fitness, and perceived physical competence during childhood. Overall, low MC will result in unsuccessful participation in movement play activities and/or sports in middle to late childhood, thus leading to a negative spiral of disengagement from an active lifestyle. Accordingly, the model predicts that MC levels will eventually lead to positive or negative obesity trajectories over time as the recursive nature of the model effects compound over time. To our knowledge, no studies have specifically examined the relationship between MC and weight status over time.

It is important to note that the term "motor coordination," used in this study is a general term that encompasses various aspects of movement competency. There are many different test batteries that assess movement in a variety of ways using different movement tests. Specifically, process and product oriented movement assessments are used to examine differences in levels of MC. For example, the aforementioned review article[4] reported data from many studies that assessed "fundamental movement skills" (i.e., object control and locomotor skills) from a subjective, process-oriented perspective. That is, actual movements, and not the product of the movements, were subjectively assessed to differentiate skill levels. Alternatively, other studies not used in the Lubans et al. review have used product-oriented movement assessments.[10–12] These types

of assessments examine objective outcomes of movements (e.g., distance, speed). While it is outside the scope of this study to explain the differences and limitations in how movement and/or movement outcomes are assessed,[9] we used the term "motor coordination" in this study as it specifically aligns with the language used in the assessment implemented for this study (Kiphard-Schilling body coordination test) and with previous literature that has used the same assessment.

The purpose of this study was to examine the association between MC (as defined by the Kiphard-Schilling body coordination test) and weight status (BMI) across childhood and early adolescence. This is the first study to specifically address the possible changing relationships between weight status and MC across a wide range of ages.

2. Methods

Data were collected from 7175 children (boys $n = 3616$ – girls $n = 3,559$), between 6 and 14 years of age (see Table 1 in supplementary material). These data were combined from several research projects[13–15] conducted by the authors in four regions of Portugal (Azores Islands, Madeira Islands, northeast and central regions of continental area) between 2003 and 2009. All children were attending public schools selected according to the general characteristics of each region. Despite the fact that Madeira and Azores are two archipelagos in Atlantic Ocean, there are not marked differences between the regions in terms of social economic development. Parents and children gave their informed consent. The results of children with any diagnosed physical or mental disability were excluded from the data. This study was approved by the ethics committee of Polytechnic Institute of Bragança.

Stature and body mass were measured using a stadiometer and a scale according to standardized procedures. Values were recorded to the nearest 0.1 cm and 100 g, respectively. Body mass index (BMI) was calculated [BMI = weight

Table 1
Descriptive statistic (mean ± standard deviation) for the assessed variables by sex and age.

Age (y)	Girls				Boys			
	BMI (kg m^{-1})	Weight (kg)	Height (cm)	MC (# points)	BMI (kg m^{-1})	Weight (kg)	Height (cm)	MC (# points)
6	17.0 ± 2.6	24.6 ± 5.0	119.7 ± 5.6	78.8 ± 13.9	17.0 ± 2.5	24.9 ± 4.9	120.6 ± 6.1	87.8 ± 13.5 *
7	17.4 ± 3.1	27.4 ± 6.6	124.7 ± 6.2	81.1 ± 15.1	17.4 ± 2.8	27.6 ± 6.1	125.5 ± 6.4	88.0 ± 15.3*
8	17.9 ± 3.0	30.7 ± 6.9	130.6 ± 6.7	81.9 ± 15.8	18.0 ± 3.4	31.4 ± 8.0	131.1 ± 6.7	86.5 ± 16.3*
9	18.6 ± 3.3	34.5 ± 8.3	135.5 ± 8.3	77.4 ± 15.4	18.5 ± 3.5	34.3 ± 8.6	135.6 ± 6.6	85.3 ± 15.2*
10	18.7 ± 3.5	36.7 ± 9.0	139.4 ± 7.6	78.4 ± 15.1	18.7 ± 3.5	36.7 ± 9.2	139.1 ± 7.5	87.5 ± 15.1*
11	19.7 ± 3.8	42.9 ± 10.0	147.2 ± 7.8	82.7 ± 14.4	19.4 ± 3.7	41.7 ± 10.6	145.9 ± 7.8	88.3 ± 17.3*
12	19.4 ± 3.5	46.3 ± 10.2	153.8 ± 6.5	82.9 ± 15.9	20.6 ± 3.9	48.8 ± 12.3	153.3 ± 8.4	91.2 ± 14.8*
13	21.1 ± 3.5	52.4 ± 9.9	157.5 ± 6.2	78.5 ± 15.6	20.2 ± 3.8	52.2 ± 11.9	160.3 ± 9.5	94.5 ± 16.3*
14	21.3 ± 2.7	54.7 ± 8.0	160.3 ± 6.6	83.5 ± 16.6	20.5 ± 3.2	57.4 ± 11.3	166.7 ± 9.4	100.8 ± 11.8*

BMI: body mass índex; MC: motor coordination [MC categories: 'not possible' (MQ < 56), 'severe motor disorder' (MQ 56–70), 'moderate motor disorder' (MQ 71–85), 'normal' (MQ 86–115), 'good' (MQ 116–130) and 'high' (MQ 131–145)].
* Significant differences ($p < 0.05$) between boys and girls.

(kg)/height (m^2)]. Weight status was classified according to International Obesity Task Force (IOTF) cut-values for BMI.[16]

Motor coordination was evaluated with the Kiphard-Schilling body coordination test, Körperkoordination-Test-für-Kinder (KTK), developed and validated on German children[17] The KTK includes the assessment of the following items:

- Balance – child walks backward on a balance beam 3 m in length, but of decreasing widths: 6 cm, 4.5 cm, 3 cm.
- Jumping laterally – child makes consecutive jumps from side to side over a small beam (60 cm × 4 cm × 2 cm) as fast as possible for 15 s.
- Hopping on one leg over an obstacle – the child is instructed to hop on one foot at a time over a stack of foam squares. After a successful hop with each foot, the height is increased by adding a square (50 cm × 20 cm × 5 cm).
- Shifting platforms – child begins by standing with both feet on one platform (25 cm × 25 cm × 2 cm supported on four legs 3.7 cm high); places the second platform alongside the first and steps on to it; the first platform is then placed alongside the second and the child steps on to it; the sequence continues for 20 s.

The "motor quotient" (MQ), a global indicator of MC adjusted for age and gender, was calculated using the four items and used as indicator of MC. The MQ allows an assessment of the gross motor development in the following categories: 'not possible' (MQ < 56), 'severe motor disorder' (MQ 56–70, percentile 0–2), 'moderate motor disorder' (MQ 71–85, percentile 3–16), 'normal' (MQ 86–115, percentile 17–84), 'good' (MQ 116–130, percentile 85–98) and 'high' (MQ 131–145, percentile 99–100).

The psychometric characteristics of the KTK have been documented[17] with a test–retest reliability coefficient for the raw score on the total test battery of 0.97, while corresponding coefficients for individual tests range from 0.80 to 0.96. Validity was further determined through differentiation of "normal" and "disabled" children. The KTK test differentiated 91% of children with brain damage compared to normal children. It is important to note that the KTK items measured in this study represent movement product scores that generally assess locomotor and balance outcomes.

The sample was split by gender and age and all analyses were conducted accordingly. Descriptive statistics (mean and standard deviation) were calculated for height, weight, BMI and MC variables. Kolmogorov-Smirnov with Lilliefors significance correction was used to test BMI and MC variables for normality. Since BMI in all age groups and gender and MC in some of the age groups did not demonstrate a normal distribution, Spearman's rank correlation coefficient was used to examine the association between BMI and MC. A Kruskal–Wallis test was used to analyze the differences in MC between children among the three weight status categories (i.e., normal weight, overweight and obese). The

Table 2
Spearman's rank correlation between BMI and MC in boys and girls by age.

Age (years)	Girls	Boys
6	−0.16**	−0.18**
7	−0.28**	−0.23**
8	−0.26**	−0.26**
9	−0.29**	−0.20**
10	−0.30**	−0.28**
11	−0.44**	−0.49**
12	−0.29**	−0.43**
13	−0.26*	−0.19
14	−0.20	−0.05

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Mann–Whitney Test was used to test the differences between boys and girls in MC.

3. Results

Table 1 provides descriptive statistics for weight, height, BMI and MQ for boys and girls of different age groups.

Motor coordination results show clear MC gender differences with boys outperforming girls at every age. According to normative values of KTK test battery,[17] results indicated low to moderate MC, especially for girls, across all ages. The results for girls were indicative of "moderate motor disorder". For boys the results were at the lower ranges of "normal coordination", except for 9 years olds, which indicated "moderate motor disorder".

Table 3 (in supplementary material) provides data on the percentage of boys and girls in normal weight, overweight and obesity categories by age. The prevalence of overweight and obesity, respectively, for the entire sample was 22% and 11% for girls and 18% and 10% for boys, which is consistent with recent data on Portuguese children of the same age.[1]

Spearman's rank correlations between BMI and MC in boys and girls by age are shown in Table 2. All correlations between BMI and MC were negative and varied between 0.05 and 0.49. That is, higher MC was associated with lower BMI. Correlation values were similar in boys and girls, except at 14 years of age, where boys demonstrated a lower correlation than girls. Overall, there was a general pattern of correlation strengths increasing across time from 6 to 11 years of age. The highest correlation for both boys and girls was at 11 years of age. Only eight year old girls' and nine year old boys' correlations did not follow this pattern. There was a decrease in correlation strengths from 12 through 14 years of age with correlation strengths in boys decreasing more than girls. Specifically, correlations were not significant in either boys or girls at age 14.

In both boys ($\chi^2_{(2)} = 324.01$; $p < 0.001$) and girls ($\chi^2_{(2)} = 291.20$; $p < 0.001$) there were significant differences in MC between the three groups weight status. Normal weight children had significantly higher MC scores than overweight children, and obese children had significantly lower scores
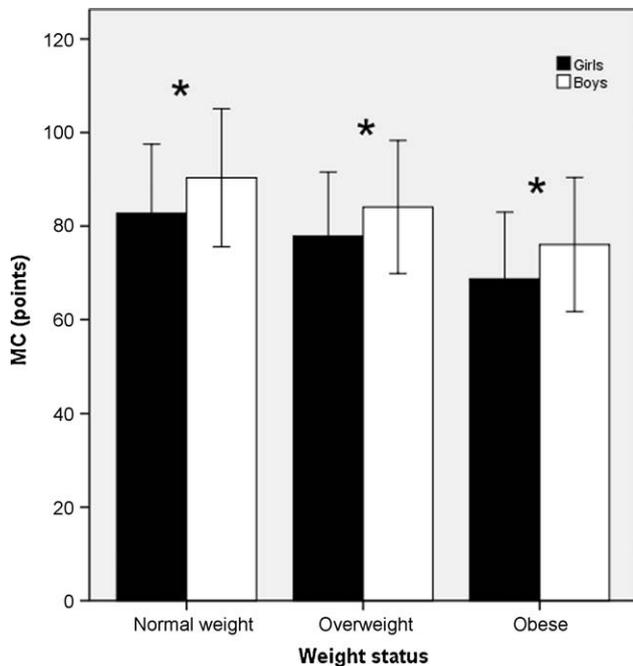
Fig. 1. Motor coordination levels (mean ± standard deviation) by weight status in boys and girls [* indicates significant differences ($p < 0.05$) between boys and girls].

than overweight children. Boys significantly outperformed girls in MC in all weight categories (Fig. 1).

4. Discussion

The purpose of this study was to analyze the association between BMI and MC (as measured by the KTK assessment) in children, ages 6–14 years. The present study demonstrated low to moderate negative correlations between MC and BMI across age. Data also indicate markedly poorer MC for overweight and obese children of both sexes compared to normal weight children. Overall, these data agree with most other data that demonstrate an inverse relationship between childhood body weight status and various measures of MC (i.e., process and product movement assessments).[4,18,19] Most studies that have demonstrated a relationship between BMI and MC have examined it within a small age range (i.e., 1–3 yrs). Only one study has examined the relationship between measures of body composition and MC across multiple ages. Okely et al.[19] examined both BMI and waist circumference and their associations to object control and locomotor MC in late childhood/adolescence across four age groups (i.e., approximately 10, 12, 14 and 16 yrs). Their results indicated that, despite a general inverse relationship between body composition and overall MC, there were virtually no associations with object-control coordination. That is, the correlation occurred only with locomotor coordination. Thus, the MC tests assessed in this study generally align with the types of locomotor tests used in Okely et al.[19] study. In addition, the strongest inverse relationships were found in the youngest

age groups (i.e., 10 and 12 yrs), which generally agrees with the data reported in this study.

The strengths of the negative correlations between MC and BMI for both boys and girls in this study generally increased up to age 11, and then began to decline. D'Hondt et al.[20] also found an inverse correlation between MC (i.e., Movement ABC test) and BMI in children of 5–10 years between balance ($r = 0.20$) (static and dynamic) and ball skills ($r = 0.46$) with BMI z-score adjusted for age and sex. These correlation strengths are in line with the correlations found in the present study. Although Hume et al.[21] found a very low correlation ($r = 0.01$–0.08) between MC (object control and locomotor) and BMI in 9–12 year old boys and girls, their data was not analyzed by age. Thus, it is rather difficult to compare and contrast the data from the Hume et al. data to our study as the onset of puberty may occur for many children, particularly for girls, during this time frame. This should be considered in a statistical analysis across such a wide age range, specifically in this time of developmental transition.

The clear tendency for strengthening of the inverse correlations between MC and BMI up to age 11, presumably result from the reciprocal effects between the two variables.[9] These data indirectly support the Stodden et al.[9] hypothesis that children's weight status across time may be indirectly affected (from the direct result of PA and fitness levels) via the development of MC throughout childhood. Children who continue to develop higher levels of MC throughout childhood will be able to successfully engage in and enjoy more movement opportunities. Thus, this will reinforce the development of MC, perceived physical competence, PA, physical fitness, and consequently promote a healthy weight status (i.e., lower BMI). The opposite is to be expected for children with low initial MC and who do not continue to develop MC. Additive effects of increased weight on MC may also affect the relationship between MC and BMI at any age, but this hypothesis needs to be adequately tested. These hypothesized positive or negative spirals of reinforcement of MC, which may indirectly lead to long-term adaptations in body composition, parallels the increased strength of negative correlation values across childhood observed in our data.

Other longitudinal studies examining MC, PA, cardiorespiratory fitness and perceived physical competence provide further support for these hypothesized reciprocal pathways as they indicate MC is both a predictor of PA and/or cardiorespiratory fitness[10,22] and a product of continued development of PA and fitness.[23] Overall, these factors may have been associated to long-term changes in body composition status. Unfortunately, body composition was not assessed.

In general, there are consistent negative correlations among weight status and MC.[18,20,24] However, decreases in negative correlation strengths between BMI and MC occurred (more markedly on boys) from 12 to 14 years of age. During the beginning years of adolescence, inverse correlation strengths tended to decrease, which may be explained by

the appearance of rapid and differentiated individual growth (i.e., differential growth spurt and growth intensity) typical during this period.[25] In fact, during pubertal years it is expected that the relationship between MC and BMI can be dramatically altered by the rapid and individualized changes in somatic growth that result in changes in muscle mass (boys) and adipose tissue (girls).[25–27] The occurrence of puberty may explain not only the decrease in the negative correlation values, but also the sex biased heterocronicity of the event.[2] Accordingly, girls have an earlier decrease of correlation strengths at 12 years of age, with boys following a year later. Furthermore, boys show a more dramatic decrease in negative correlation strengths from 12 to 14 years, perhaps related to the more meaningful changes in muscle mass over the growth spurt. In order to fully clarify this phenomenon, longitudinal data and post-pubertal information is needed. In addition, the documented differences in how object control and locomotor MC levels relate to weight status are rather perplexing and may be related to specific cultural and environmental differences among the populations studied. Future research is needed to better understand the possible differing movement constructs that various testing batteries measure and how they may relate to weight status across age.

The strength of this study lies in the large age-span distribution of BMI and MC data that allows comparison across time. However, the cross-sectional nature of the data does not allow us to make causal inferences regarding the relationships between BMI and MC. In addition, BMI is not the most accurate predictor of body fat percentages. Furthermore, a more comprehensive MC assessment (e.g., developmentally valid product and process MC assessments) may provide a clearer picture of the relationship between MC and body composition trajectories across time. Examining other variables (e.g., energy balance, fitness, social and psychological variables) that influence weight status across time also is necessary to fully understand the nature of this relationship. Although our sample sizes were smaller in older age groups (12–14 years) (Table 1 in supplementary material), the decreasing negative correlation strengths from ages 12 to 14 do fit with traditional views of pubertal transitions of adipose and muscle mass in girls and boys respectively. In addition, these data compare favorably with the data from Okely et al.[19] in that inverse relationship strengths seem to decrease during adolescence.

5. Conclusion

These data support the majority of cross-sectional data that indicate MC is inversely associated with BMI, and that the strength of the inverse relation increases during childhood in both genders. Overweight and obese children showed markedly worse MC levels. Despite the limitation of the cross-sectional design, MC showed to be an important, yet dynamic, correlate of weight status.

6. Practical implications

- Observations from this study highlight the potential importance of promoting motor coordination in children to alleviate increasing obesity trajectories across childhood.
- The increasing negative correlations between motor coordination and body mass index across childhood suggests there is a need to allocate appropriate time for play and directed learning experiences that will allow for the development of motor coordination. Providing adequate directed learning experiences, time for play and a developmentally appropriate environment for children may assist in promoting a healthy weight status across childhood.
- These data also suggest that it may be beneficial to target young children with low motor coordination for early screening and intervention.
- The development of motor coordination should be a key strategy in childhood interventions aiming to promote long-term obesity prevention and physical activity promotion.

Acknowledgments

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jsams.2011.07.005.

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