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ORIGINAL ARTICLE

Association between motor coordination, body mass index, and sports participation in children 6–11 years old

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Abstract

Purpose To examine associations between motor coordination, body mass index (BMI), and sports participation in children 6–11 years old.

Methods 240 primary school children were enrolled in this cross-sectional study, divided into three age groups, each of which was subdivided into four weight classes: underweight (UW), normoweight (NW), overweight (OW), and obese (OB). The UW and NW groups were then compared to the OW and OB groups for differences in motor coordination ability and sports participation.

Results Motor coordination ability was observed to decrease and the proportion of OW/OB children to increase with age. A significant association between BMI and motor coordination ability was noted ($p < 0.01$), indicating that ability levels were lower in the OW and OB groups than in the UW and NW groups. Sports participation did not seem to depend on BMI status. Furthermore, a reduction of MC in both BMI groups according to the age-class stratification was observed.

Conclusion A significant decrease in motor coordination ability with increasing age, together with an increase in overweight/obesity status become actual. Moreover, a negative influence was observed on coordination skills according to the increment in BMI level. Since BMI status was not seen as a deterrent to physical activity, teachers, physicians, parents, and trainers should encourage children to take up sports and continue participation to better develop their motor coordination abilities.

Keywords Childhood · Physical level · BMI · KTK test

Introduction

Good motor coordination (MC) is essential for maintaining physical/psychological health in childhood through adulthood. Its positive effects extend along the entire lifespan [1] and across a variety of sports, daily living activities, and motor demands in both urban and rural environments [2, 3]. A strong cross-sectional association was already found in school-aged children between physical activity and health outcomes (i.e., reduced fatness and cardiovascular risk factors and increased bone cell turnover) [4]. Additionally Penendo and Dahn [1] and Bangsbo et al. [5] identified a connection between academic achievement and better mood state among the physically active.

Moreover, motor skills competence has been shown to affect a child's confidence and motivation to participate in physical activities and this is inversely related to sedentary habits [6, 7]. In point of this, there is some evidence for a relationship between overweight/obese status and lower conditional performance (i.e., cardiorespiratory fitness and body lifting action) and MC performance [8–15], the last of which was strongly associated with lower adherence to sports activity (< 7 h/week) [16].

Indeed, when the physical activity is not modulated by educators who define the proposal and alleviate the challenge between peers, the most heavy children are often excluded [17].

Consequently, a real observation in school or club context provides evidence whereas children with high value in

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BMI are scantly than normal weight peers enforcing the personal idea to leave the practice. In turn, the reduced physical activity (hours of practice per week) lead to an increment in weight (improvement of BMI) and then in critical body status to perform sport at the same level of normal weight peers [17, 18].

Thus, the aim of the present study was to identify associations between MC, BMI, and sports participation in children 6–11 years old. The research questions we asked were:

Is there an improvement or a reduction in MC level with increasing age?

What is the trend for BMI in young schoolchildren?

Does an improvement in BMI affect MC level and sports participation?

Materials and methods

Participants

A total of 240 primary school children aged 6–11 years (140 boys; 100 girls) were enrolled in the study. The children were evaluated for weight, height, MC level, and sports participation and then divided into three age groups: (I) 6–7 years; (II) 8–9 years; (III) 10–11 years. Inclusion criteria were: no history of illness considered likely to affect growth, no neurological, orthopaedic or cardiovascular diseases, and active participation in Physical Education (PE) classes.

Children found in good general health were deemed eligible. Table 1 shows the anthropometric characteristics of the study sample. The parents (or legal guardians) gave written, informed consent after having received a detailed explanation of the study procedure and possible risks. The study protocol was conducted in accordance with current national and international laws and regulations governing the use of human subjects (Declaration of Helsinki II).

Procedure

Data on medical history, age, height, BMI, MC, and extracurricular sports participation were collected during PE classes.

Anthropometric characteristics

Anthropometric measurements of height and weight were taken according to standard procedures of the International Society for the Advancement of Kinanthropometry [19]. Height was measured to the nearest 0.1 cm with a stadiometer, with the subject barefoot and standing upright with the head in the Frankfort plane. Weight was measured to the nearest 0.1 kg with an electronic scale, with the subject wearing minimal clothing. BMI was then calculated with the standard formula.

Motor coordination

MC ability was evaluated using the Körperkoordinationstest für Kinder (KTK) [2, 20] on 4 different days (1 week apart) during regular PE classes. The KTK is a reliable, validated test battery [2, 21–24] that comprises four subtests that evaluates balance, agility, speed, and power. For this study the trials consisted of:

Walking backwards three times along each of three balance beams (3 m long, 6, 4.5, 3 cm wide, respectively, 5 cm high) for a total of nine trials. A maximum of 24 steps (8 per trial) were counted for each performance; for a total of 72 steps.

Moving sideways across the floor in 20 s by stepping from one plate (25 cm × 25 cm × 5.7 cm) to the next, transferring the first plate, stepping on it, and repeating the same motion. The number of relocations was counted and summed over two trials.

Jumping with one leg over an increasingly higher pile of pillows (60 cm × 20 cm × 5 cm each) after a short run.

Jumping laterally (side to side) over a wooden bar (60 cm long × 4 cm wide × 2 cm high) in 15 s. The number of jumps performed in two trials were summed.

The subjects were thoroughly familiarized with the equipment and procedures before testing, as indicated in the literature [18]. In brief, 1 week before the test sessions all subjects followed the procedure explanation and performed only one trial per subtest [2, 21]. The same operator supervised all subtests for all subjects in the same order. The trials were administered (week by week) following the sequence indicated in our test description [20]. Administration and scoring (raw

Table 1 Anthropometric characteristics

Age group	Boys			Girls		
	No.	Weight (kg)	Height (cm)	No.	Weight (kg)	Height (cm)
I 6–7 years	50	25.2 ± 3.4	124 ± 5	40	24.5 ± 4.4	122 ± 5
II 8–9 years	41	31.6 ± 5.0	133 ± 6	34	33 ± 5.7	135 ± 5
III 10–11 years	49	41.0 ± 8.7	1.48 ± 6	36	39.1 ± 7.0	147 ± 6

Plus-minus values are the mean ± standard deviation (SD) score) of each subtest were performed following the current guidelines [2, 20, 22].

Sports participation

The parents or legal guardians were asked whether their child/children was/were involved in extracurricular sports or physical activity. The term “extracurricular physical activity” was defined as the amount of time (at least > 2 h/week) spent in formal training in a sports club [23].

Data analyses

The subjects were anonymously stratified into four BMI categories following the criteria proposed by Cole et al. [25, 26] (that involving percentiles every 6 months) for children and young underaged: (I) underweight (UW), (II) normal weight (NW), (III) overweight (OW), and (IV) obese (OB) [3]. The KTK-test results were normalized to age and gender according to the guideline [2, 20]. A single motor quotient was extrapolated to define the MC level for each child. Cutoff values for each MC level were: < 85 subnormal; 86–115 normal; 116–130 good; and 131–145 excellent [20]. The MC results were pooled in two groups: UW and NW (L group) and OW and OB (H group) separately for boys and girls [27].

Statistical analyses

Descriptive statistics [mean ± standard deviation (SD)] were calculated for outcome measures. Analysis of variance (ANOVA) was applied to verify between-group differences to evaluate changes in MC level with increasing age (separately for boys and girls), with Tukey’s multiple comparisons test to determine pair-wise differences. Glass’ Δ [28] was computed to verify the biological consistence of differences [effect size (ES)], where the reference group was group I, and 0.2, 0.5, and 0.8 were threshold values for small, moderate, and large effects, respectively.

The percentage of subjects in each BMI category was used to verify anthropometric status during growth, while differences in MC level between the L and the H group were verified using a *T* test (independent samples without separating boys and girls). Finally, the Chi square test was used to evaluate the relationship between BMI status and sports participation. The significance level was fixed at 5%. All data were analysed using SPSS ver. 22 (IBM-SPSS, Armonk, NY, USA).

Results

The MC level (pooled together for boys and girls) was 100, 90, and 85 for age groups I, II, and III, respectively, and fell within the normal-for-age range [20]. Figure 1 shows the trend for boys and girls, where a significant decline with age ($p < 0.05$) was observed. The post hoc analysis showed significant differences between age groups I and II (for boys and girls; $p = 0.04$ in both cases) and between age groups I and III ($p = 0.04$ and $p = 0.02$; for boys and girls, respectively), whereas the ES values were large in all cases. A significant decline was noted between age groups II and III for the boys ($p = 0.03$).

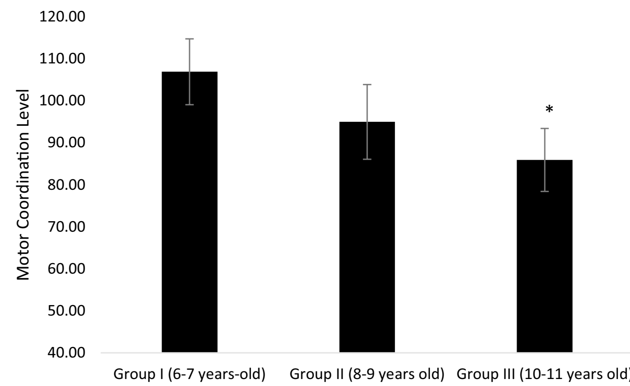

Fig. 1 Motor coordination level (error bars represent SD) in the three age groups. *Different from I group. $p < 0.05$

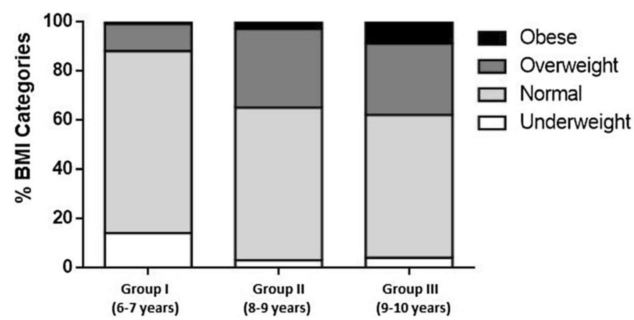

Fig. 2 Distribution of BMI categories

The percentage of OW and OB subjects increased with age, while the percentage of NW subjects decreased by about 20% (Fig. 2). There was a significant association between BMI and MC level ($p < 0.01$; Fig. 3), indicating that the MC level was higher for the L group, though both groups were classified as normal-for-age [20]. Finally, no significant correlation was found between BMI categories (L group and H group) and sports participation (χ^2 test; $p = 0.287$; Fig. 4).

Discussion

The KTK battery test has been used to define motor skills coordination in children with illnesses [29] or from different social backgrounds [30] and, more recently, the association between physical activity and motor coordination

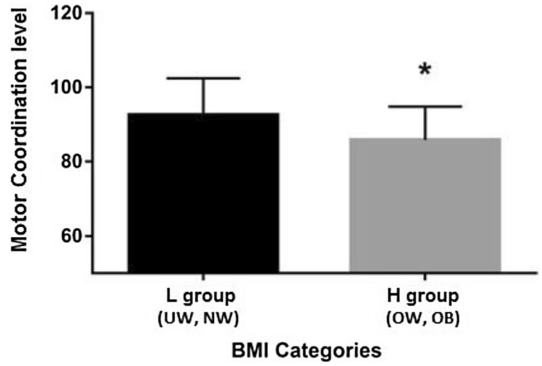

Fig. 3 Motor coordination level (error bars represent SD) in the light (L) (*UW* underweight, *NW* normal weight) and heavy (H) (*OW* overweight, *OB* obese) groups. *Significant difference, $p < 0.01$

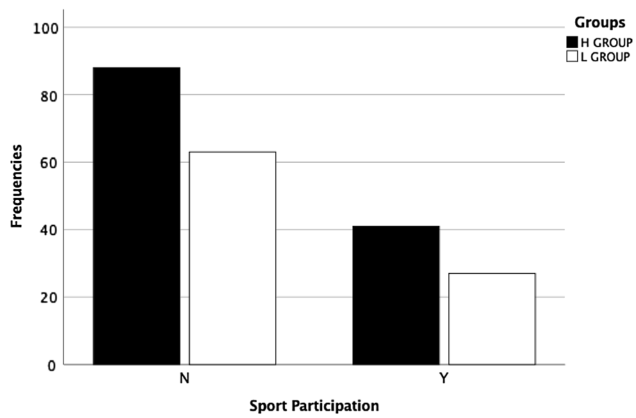

Fig. 4 Frequency of children within BMI categories according to their sport participation. Light (L) (*UW* underweight, *NW* normal weight) and the heavy (H) (*OW* overweight, *OB* obese) group

[10]. Coordination is a useful motor ability for performing daily living activities [27]; and its development depends on regular physical practice [31] and sports participation [6]. Conversely, successful outcomes in MC may encourage the practice of sports. This assumption is important for schoolchildren aged between 6 and 11 years because of the considerable growth changes they undergo during this stage of their development. Okely et al. [32] found a correlation between body weight and motor skills in which these changes may negatively affect MC and result in drop-out from sports participation.

Here we assessed the MC level in primary schoolchildren to determine whether it decreases or increases in relation to age and regular participation in sports. Moreover, the association with BMI status (a more complete anthropometric characteristic than body weight) was also considered. Our results are in line with previous data [2, 33] and show a decrease in MC with age (change in performance from age group I to III): this may be due to an improvement in conditional skills [21]. We observed that the boys that, usually, had better conditional status showed significant differences, also between consecutive age groups (II and III). No differences were found in female groups (II vs III) probably due to a low increment in anthropometric characteristics (about 6 kg and 7 cm along a range of 3 years) that usually negatively affect the MC [17, 18]. According to the first aim of this study we could assume that the regular growth path (without specific motor skill stimulation) negatively affects MC in favour of conditional outcomes. Our data suggest, and the ES confirmed, that MC levels decrease during growth and that the proportion of OB/OW children among the 11-year-olds increased threefold over age group I. This is a crucial issue in family education, because the increment in OB/OW is chiefly attributable to how parents manage their children's dietary habits [34, 35], with implications for skill coordination (that naturally decrease) and sports participation (often perseverated following the obtained success). Our data reflect the widespread public health problem of increasing childhood obesity in Western populations [36]. In fact, until age 11 years a child's independence is still largely under parental guidance, part of which is to educate children in adopting good dietary and sports habits.

The increase in BMI we observed corresponded to an improvement in body mass, which can affect all types of movement because human movement basically entails the displacement of centre of mass with speed and/or precision [37, 38]. We observed that the OW/OB children (H group) underperformed as compared to their aged-matched companions. This observation is shared by D'Hondt et al. [8] and Nervik et al. [11] who reported on the relationship between low MC levels and OW/OB status [8–12]. Differently, the NW children showed better levels of fundamental movement skills [39] (Fig. 3). Furthermore, the reduction of MC in the H-BMI vs. L-BMI group could be partly due to the concomitant increase in age [7–9] even if the performance (both conditional and coordinative) is affected by simultaneous phenomenon of growth (8, weight; 18, height; [40]), habits of diet, hormonal peaks and not only for a natural increment of age.

These findings should be viewed together with the results of the questionnaire on sports participation according to BMI categories (Fig. 4). The H group did not seem to avoid volunteer participation in sports activity any more than the NW and UW groups. In fact, we observed that, despite their lower MC level, the children with higher BMI participated in sports just as much as the NW and UW children. This observation holds vital importance for parents and educators who would continuously support this healthy attitude toward an active lifestyle in combination with counselling on proper dietary habits to reduce weight gain. Hesketh et al. [4] suggested that an active lifestyle of the mothers is strictly related to the lifestyle of their children. Moreover, PE teachers and/or trainers need to take into account the general decrease in MC skills and facilitate the socialization and acceptance of less skilled children, while avoiding discrimination based on body appearance or physical inefficacy. Spontaneous sport adherence, despite low MC levels, should be encouraged by parents, teachers, clinicians, and trainer as a way to promote an active lifestyle for long-term health promotion.

A limitation of this study is the sample size. Further studies are needed to investigate the relationship between MC and hours per week of PE classes or according to the presence of siblings in the family (especially older siblings). Future research could focus on the age-related increment of BMI in healthy and sedentary people keeping a close analysis of hormonal production, to verify, in turn, the MC reduction according to age.

Conclusion

Our results demonstrated a natural decrease in skill coordination during growth [2, 32] and a sour finding regarding the increment of body composition also in children. This combination of situation becomes important for a general control (parents, teacher and club) to reduce the negative experience of scantly performance and encourage the physical activity as lifestyle. In particular, this period (primary school frequency) is the most important because the children have not still abandoned the practice since their followed the family opportunity and the level of performance is not so high. Moreover, this kind of attention could be important for a inclusion process of OW–OB children.

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Compliance with ethical standards

Experiments comply with the current laws of the country in which they were performed.

Conflict of interest The authors have declared no conflict of interest.

Ethical approval All procedures were in accord with current national and international laws and regulations governing in line with the Declaration of Helsinki.

Informed consent Informed consent was obtained from all individual participants included in the study.

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