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Gross motor coordination in relation to weight status and age in 5- to 12-year-old boys and girls: A cross-sectional study

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Abstract

Objective. The purpose of this study was to investigate differences in gross motor coordination in healthy-weight, overweight, and obese children of different ages. *Methods.* Using a cross-sectional design, data were collected in 954 Flemish primary school children (500 girls, 454 boys) stratified in consecutive age groups (5–7 years, 8–9 years, 10–12 years). Weight status (healthy-weight, overweight, obese) was defined according to the International Obesity Task Force body mass index (BMI) cut-off points for children. Gross motor coordination was assessed by means of the Körperkoordinationstest für Kinder (KTK). *Results.* Childhood overweight and particularly obesity were found to result in poorer KTK performances ($p < 0.001$), with the most apparent effect of BMI on items requiring physical properties next to dynamic body coordination. Expressed as an age-related Motor Quotient (MQ), overall KTK performance was featured by a BMI × AGE interaction ($p < 0.01$). Healthy-weight children displayed similar MQs across age groups ($p = 0.999$). Overweight and obese children in the 10–12-year-old group showed significantly poorer motor coordination performance compared with the corresponding 5–7-year-old group ($p < 0.01$). Less than 20% of the healthy-weight participants was identified as being motor impaired, while that proportion increased to 43.3% and up to 70.8% in children with overweight and obesity, respectively. *Conclusion.* Results indicate that BMI-related differences in gross motor coordination were more pronounced as children belonged to an older age group. Although this outcome needs to be confirmed in future longitudinal research, it emphasizes the need of an early focus on motor skill improvement to encourage overweight and obese children to be physically active.

Key words: *Age factor, body mass index, children, motor skills, obesity, overweight*

Introduction

Motor skill competence is an important determinant of children's general development (1–3). It is a prerequisite for everyday activities as well as an essential aspect underlying engagement in physical activities (4–7). Accordingly, children with movement difficulties are less likely to participate in movement situations (sports, physical activities, recess play, etc.) and spend a greater percentage of their time in sedentary activities, which may further impair motor skill development, social interaction, and health-related opportunities (8–11). This reciprocal relationship between motor competence, or lack thereof, and physical inactivity is very important, especially in children who are overweight or obese (9,12). Considering the exponentially increasing prevalence of childhood overweight and obesity across the world (13–15), along with the negative associations between habitual physical activities and body composition (16–19), great attention should be paid to motor competence and coordination level in children with an excessive body mass index (BMI).

Some previous studies have demonstrated an inverse relationship between increased body mass indices and gross motor coordination performance in children and young adolescents (20–26). Even at pre-school age, higher prevalence levels of impairment in gross motor skill have been established among obese versus non-obese children (27). Nevertheless, limited research has been done on the

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extent to which overweight and obesity are constraints to movement at different ages during childhood (20,25). Hence, it is not yet evident whether the reported deficiencies in overweight and obese children differ across developmental time. In addition, the available studies often lack the ability to discriminate between lower motor competence in children who are overweight and those who are obese. However, it is important to understand the impact of excess body mass on children's motor function according to the degree of overweight as the existence of a certain cut-off from which movement difficulties may appear has been recently suggested (28). Indicators of maturity are also rarely taken into account, even though children with increased BMI levels show advanced maturation (29–32). Given that maturational timing appears to be related to muscular strength and motor performance (33–35), some children may be (dis)advantaged in the performance of motor skill compared with peers depending on their maturity status and concomitant differences in body size (25,36).

Although there is a growing body of evidence, the relationship between motor skill and body composition in children has not yet been explored in depth. Therefore, the purpose of this cross-sectional study was to investigate differences in gross motor coordination in healthy-weight, overweight, and obese boys and girls across different age groups, taking into account maturity status as a potentially confounding characteristic. It was hypothesized that, even when adjusted for maturity dissimilarities, overweight and obese participants would display poorer performances compared with their healthy-weight peers. In addition, more pronounced differences were expected in the older children because of the continuous interrelationship between childhood overweight and obesity, physical (in)activity, and motor (in)competence. Furthermore, it was hypothesized that overweight children would outperform children in the obese group, given the different degree of excess body mass.

Methods

Participants

A large-scale project (the Flemish Sports Compass) was set up to investigate motor and physical abilities of Flemish children. To obtain a representative sample, a total of 30 primary schools for general education were randomly selected across the Flemish and Brussels-Capital region. Within the total group of 2932 participating children, 477 individuals were identified as being overweight or obese, based on international BMI cut-off points for children (37), and included in the present study. Randomly chosen classmates with the same gender and age (within the range of six months) represented the healthy-weight group, resulting in a final study sample comprising data of 954 primary school children aged 5–12 years (500 girls, 454 boys), stratified in three consecutive age groups (5–7 years, 8–9 years, 10–12 years). For all participants written informed consent was obtained from the parents or guardian. The study protocol was approved by the Ethics Committee of the Ghent University Hospital.

Measurements

Assessments were conducted by a group of trained examiners in the participating schools between September 2007 and February 2008. During the tests, all children wore light sportswear and were barefoot. First, anthropometric measurements were collected. Subsequently, participants accomplished the Body Coordination Test for Children (Körperkoordinationstest für Kinder [KTK]) to assess gross motor coordination (38,39).

Anthropometry

Date of examination and date of birth were used to obtain the exact chronological age of each child at the time of assessment (40). As an indicator of somatic maturity, age at peak height velocity (APHV) was predicted by means of a gender-specific regression equation since the number of years from peak height velocity can be estimated from chronological age and measurements of height, sitting height, and weight (41,42).

Height and sitting height were measured with 0.1 cm accuracy using portable stadiometers (Harpenden, Holtain Ltd., Crymych, UK). Body weight was determined to the nearest 0.1 kg by means of a digital balance scale (Tanita, BC-420 SMA, Weda B.V., Naarden, Holland). BMI was calculated from height and weight measures (kg/m^2). Overweight and obesity were defined by the age- and gender-specific BMI cut-off points for children of the International Obesity Task Force (IOTF). According to this definition of Cole and co-workers (37), participants were classified into a healthy-weight group (n = 477, 50.0%), an overweight group (n = 360, 37.7%), and an obese group (n = 117, 12.3%).

Gross motor coordination

Dynamic body coordination was evaluated by means of the KTK, a standardized product-oriented test, developed and recently revised by Kiphard and

Schilling (38,39). The KTK is a highly reliable and valid instrument and, therefore, frequently used to asses gross motor performance in children (38,39,43). The test is suitable for all children between 5 and 15 years of age. Given its focus on gross motor and dynamic balance skills, the KTK was also designed to identify children with motor problems in that area.

In this study, the KTK was administered and scored according to the manual guidelines. The test protocol consists of four test items, all involving the whole body to be well coordinated: (1) walking backwards along balance beams of decreasing width: 6.0 cm, 4.5 cm, and 3.0 cm (KTK_{BEAM}); (2) one-legged hopping over a foam obstacle with increasing height in consecutive steps of 5 cm (KTK_{HOP}); (3) moving sideways on wooden boards during 20 seconds (KTK_{BOARD}); and (4) two-legged jumping from side to side during 15 seconds (KTK_{JUMP}). Using normative data tables, based on the performance of a German standardization sample, the raw performance score of each test item can be converted into a standardized Motor Quotient (MQ) adjusted for age (all items) and gender (KTK_{HOP} and KTK_{JUMP}). Adding together all four item MQs results in a total KTK MQ that can be converted into a percentile score and allows classification in five gross motor coordination levels (Table I). A child with an overall performance equal or below the 15th percentile faces gross motor coordination problems and is in need of special attention (38,39).

Statistical methods

Data were analyzed using SPSS version 16.0 for Windows (SPSS Inc., Chicago, IL, USA). Significance level was set at $p < 0.05$. Descriptive statistics were calculated for both anthropometric and motor coordination variables, including the raw performance scores on all four KTK test item as well as total KTK MQ. Results are presented as means ± standard deviations (SDs). To explore the impact of gender, weight status (healthy-weight, overweight, obese), and age (5–7 years, 8–9 years, 10–12 years) on motor performance, data were implemented in 2 × 3 × 3 ANCOVAs with APHV included as a covariate to control for maturity dissimilarities. Three-way interactions were further analyzed by means of two-way ANCOVAs split by gender. In case of significant two-way interactions, analyses were digressed to single-factor ANCOVAs with the combination of both interacting factors as new groups (F-value obtained = $F_{INTERACTION}$). Significant group differences were further evaluated using post-hoc tests with Bonferroni correction for multiple comparisons. Finally, Pearson Chi-square values were calculated to investigate the relationship between weight status and motor impairment, using the 15th percentile as a cut-off point for total KTK performance.

Table I. Classification of gross motor coordination level based on total Motor Quotient (MQ) of the Körperkoordinationstest für Kinder (KTK), according to the revised and supplemented edition of the KTK manual [45].

Total KTK MQ	Percentile rank	Gross motor coordination level
≤70	<3rd percentile	Severe gross motor impairment
71–85	3rd – 15th percentile	Moderate gross motor impairment
86–115	16th – 84th percentile	Normal gross motor coordination
116–130	85th – 98th percentile	Good gross motor coordination
131–145	99th – 100th percentile	High gross motor coordination

Results

Descriptive statistics of the anthropometric characteristics are presented in Table II. Table III provides descriptive statistics of all four KTK test items (raw performance scores) and total KTK MQ. In all analyses, APHV was found to be a significant covariate (p-values < 0.05). Hence, three-factor ANCOVAs were executed from which F-values are displayed in Table IV.

BMI-related differences in gross motor coordination mainly varied according to age group (BMI × AGE interaction). A single-factor analysis for KTK_{BEAM} ($F_{INTERACTION} = 27.10$, $p < 0.001$) revealed no balance performance differences between healthy-weight, overweight, and obese children aged 5–7 years (p-values > 0.05). However, at the ages of 8–9 years and 10–12 years, healthy-weight participants outperformed both other BMI groups (p-values < 0.001), while overweight children recorded better balance performances compared with the obese group (p-values < 0.05). Although the older obese participants (aged 8–9 years or 10–12 years) obtained higher balance performance compared with 5–7-year-old children in absolute figures, these differences were not statistically significant (p-values > 0.05). So, no significant age-related progression in balance performance was found in the obese group (p-values > 0.05). For KTK_{HOP} ($F_{INTERACTION} = 61.69$, $p < 0.001$), the 5–7-year-old healthy-weight and overweight children achieved comparable scores ($p = 0.999$), both outperforming the 5–7-year-old obese children (p-values < 0.001). In the older age groups (8–9 years and 10–12 years), healthy-weight children hopped higher

Table II. Descriptive statistics (mean ± standard deviation) for healthy-weight (HW), overweight (OW), and obese (OB) boys and girls stratified by age.

		Boys n = 454			Girls n = 500		
Age group	Anthropometric characteristics	HW n = 227	OW n = 172	OB n = 55	HW n = 250	OW n = 188	OB n = 62
5–7 years	Height (cm)	123.2 ± 5.0	126.4 ± 6.6	128.9 ± 6.9	123.5 ± 6.4	125.1 ± 6.6	126.3 ± 4.4
	Weight (kg)	23.8 ± 2.7	30.1 ± 3.8	38.7 ± 6.7	23.4 ± 3.3	29.4 ± 3.8	36.7 ± 4.5
	BMI (kg/m²)	15.68 ± 1.11	18.79 ± 0.83	23.10 ± 2.51	15.29 ± 1.02	18.69 ± 0.78	23.00 ± 2.00
	APHV (years)	12.16 ± 0.29	11.94 ± 0.35	11.62 ± 0.23	11.10 ± 0.31	10.78 ± 0.31	10.51 ± 0.30
8–9 years	Height (cm)	135.0 ± 6.7	139.0 ± 7.2	139.6 ± 7.6	134.8 ± 6.2	136.5 ± 6.4	137.8 ± 7.3
	Weight (kg)	28.8 ± 3.8	39.6 ± 5.5	49.0 ± 7.1	29.2 ± 4.1	38.5 ± 4.8	47.1 ± 8.7
	BMI (kg/m²)	15.76 ± 1.28	20.41 ± 1.26	25.03 ± 1.60	16.00 ± 1.31	20.57 ± 1.25	24.60 ± 2.33
	APHV (years)	12.88 ± 0.35	12.50 ± 0.30	12.19 ± 0.42	11.57 ± 0.33	11.21 ± 0.29	10.77 ± 0.40
10–12 years	Height (cm)	146.3 ± 9.1	148.9 ± 7.4	147.7 ± 6.3	147.1 ± 7.3	148.7 ± 7.5	152.1 ± 7.2
	Weight (kg)	36.5 ± 6.6	49.4 ± 6.9	59.8 ± 8.5	36.0 ± 5.5	49.8 ± 6.9	64.4 ± 8.6
	BMI (kg/m²)	16.91 ± 1.54	22.19 ± 1.46	27.29 ± 2.30	16.56 ± 1.48	22.43 ± 1.49	27.76 ± 2.26
	APHV (years)	13.60 ± 0.50	13.29 ± 0.38	12.93 ± 0.38	12.01 ± 0.37	11.59 ± 0.39	11.30 ± 0.36

BMI: Body mass index; APHV: Age at peak height velocity.

than their overweight peers (p-values < 0.001), whose performance in turn exceeded that of the obese participants (p-values < 0.05). Within the obese group, no significant difference was found between hopping for height performances of 5–7-year-olds and 8–9-year-olds ($p = 0.999$). For KTK_{JUMP}, BMI × AGE interaction was affected by gender. In boys ($F_{BMI \times AGE} = 3.253$, $p = 0.012$), single-factor analysis ($F_{INTERACTION} = 5.71$, $p < 0.001$) revealed that healthy-weight boys executed more lateral jumps than overweight ($p = 0.014$) and obese peers ($p = 0.007$) at the age of 10–12 years. In the younger age groups (5–7 years and 8–9 years), the number of jumps was not significantly different according to weight status (p-values > 0.05). An age-related progression was only found in healthy-weight boys, with better scores for the older of two adjacent age groups (p-values < 0.001). In girls, on the other hand, no significant BMI × AGE interaction was observed ($F_{BMI \times AGE} = 0.987$, $p = 0.414$). A main effect of BMI ($F_{BMI} = 10.41$, $p < 0.001$) indicated that healthy-weight girls realized more lateral jumps than those in both other BMI groups (p-values <0.01), while overweight girls did better compared with their obese peers ($p = 0.024$). A main effect of age group ($F_{AGE} = 52.96$, $p < 0.001$) revealed that jumping performance significantly increased as girls belonged to an older age group (p-values < 0.001). For KTK_{BOARD}, no

Table III. KTK performances (mean ± standard deviation) in healthy-weight (HW), overweight (OW), and obese (OB) boys and girls stratified by age.

		Boys n = 454			Girls n = 500		
Age group	KTK variables	HW n = 227	OW n = 172	OB n = 55	HW n = 250	OW n = 188	OB n = 62
5–7 years	KTK_{BEAM}	25.18 ± 12.35	23.82 ± 14.11	19.50 ± 14.90	33.42 ± 11.41	31.98 ± 14.29	26.17 ± 7.63
	KTK_{HOP}	38.18 ± 10.58	34.14 ± 12.58	29.31 ± 13.20	37.87 ± 12.48	34.40 ± 11.91	19.58 ± 10.26
	KTK_{BOARD}	31.69 ± 5.99	29.65 ± 5.31	29.33 ± 6.06	32.17 ± 4.70	31.60 ± 6.08	26.92 ± 4.58
	KTK_{JUMP}	39.37 ± 10.05	38.78 ± 12.03	35.38 ± 8.79	42.00 ± 11.47	38.45 ± 11.07	29.23 ± 4.99
	Total KTK MQ	97.66 ± 12.39	95.31 ± 12.99	90.46 ± 12.17	98.34 ± 13.23	94.12 ± 13.56	77.00 ± 11.37
8–9 years	KTK_{BEAM}	39.38 ± 12.90	31.80 ± 12.92	21.72 ± 9.28	43.28 ± 13.37	35.58 ± 12.29	27.59 ± 10.29
	KTK_{HOP}	56.61 ± 11.93	44.39 ± 14.73	30.78 ± 8.73	54.43 ± 10.94	41.28 ± 13.33	30.66 ± 10.62
	KTK_{BOARD}	39.03 ± 7.41	35.39 ± 7.00	31.22 ± 5.26	38.82 ± 6.28	36.11 ± 5.29	32.79 ± 5.94
	KTK_{JUMP}	56.05 ± 11.20	49.17 ± 11.01	41.30 ± 9.07	56.06 ± 10.91	48.87 ± 11.84	45.30 ± 11.20
	Total KTK MQ	99.65 ± 14.05	87.65 ± 14.40	72.22 ± 11.46	98.08 ± 14.30	85.20 ± 15.47	76.59 ± 14.30
10–12 years	KTK_{BEAM}	44.84 ± 13.93	39.31 ± 14.93	32.06 ± 11.83	50.79 ± 13.05	41.47 ± 12.13	32.61 ± 13.89
	KTK_{HOP}	68.33 ± 9.40	53.66 ± 14.82	40.39 ± 15.47	64.09 ± 10.27	50.96 ± 11.46	42.47 ± 15.03
	KTK_{BOARD}	44.54 ± 6.18	39.67 ± 6.58	35.56 ± 7.76	44.48 ± 6.21	41.22 ± 6.75	36.61 ± 5.51
	KTK_{JUMP}	68.49 ± 9.60	59.59 ± 12.00	52.11 ± 12.91	64.38 ± 9.77	60.22 ± 10.93	55.61 ± 13.00
	Total KTK MQ	99.41 ± 12.98	83.94 ± 17.38	72.50 ± 17.92	94.95 ± 14.17	82.35 ± 15.39	67.06 ± 17.68

KTK: Körperkoordinationstest für Kinder.

Table IV. Main and interaction effects (F-values) on KTK performance according to weight status (BMI), age group, and gender.

KTK variables	F_{APHV} covariate	F_{BMI}	F_{AGE}	F_{GENDER}	$F_{BMI \times AGE}$	$F_{BMI \times GENDER}$	$F_{AGE \times GENDER}$	$F_{BMI \times AGE \times GENDER}$
KTK_{BEAM}	40.90*	12.49*	3.72‡	63.68*	2.56‡	0.16	0.12	0.49
KTK_{HOP}	10.73*	84.11*	44.69*	2.37	6.54*	0.08	0.94	1.56
KTK_{BOARD}	7.75‡	25.45*	42.02*	8.37†	2.16	1.34	0.81	0.69
KTK_{JUMP}	41.36*	15.62*	53.60*	29.31*	1.58	0.26	2.51	2.79‡
Total KTK MQ	8.28‡	61.89*	18.51*	1.33	4.99†	0.47	1.84	1.95

BMS: Body mass index. KTK: Körperkoordinationstest für Kinder.
$^{*}p < 0.001$.
$^{†}p < 0.01$.
$^{‡}p < 0.05$.

significant BMI × AGE interaction was found, but performances significantly differed between BMI groups ($F_{BMI} = 25.45$, $p < 0.001$) and age groups ($F_{AGE} = 42.02$, $p < 0.001$). KTK_{BOARD} scores were significantly lower in the obese children compared with the overweight participants ($p < 0.001$), with the latter performing worse than the healthy-weight group ($p < 0.001$). Significantly poorer performances were observed in the 5–7-year-old children relative to those belonging to an older age group (p-values < 0.001) and also in the 8–9-year-old children compared with participants aged 10–12 years ($p < 0.001$). Furthermore, a main effect of gender was observed for three KTK items. Boys achieved higher scores on KTK_{JUMP} ($F_{GENDER} = 53.60$, $p < 0.001$) and KTK_{BOARD} ($F_{GENDER} = 8.37$, $p = 0.004$), while girls demonstrated better performances on KTK_{BEAM} ($F_{GENDER} = 63.68$, $p < 0.001$).

Total KTK MQ was then again featured by a significant BMI × × AGE interaction, as depicted in Figure 1. Additional single-factor analysis ($F_{INTERACTION} = 37.34$, $p < 0.001$) established that the overall KTK performance in overweight children and healthy-weight children was comparable at the age of 5–7 years ($p = 0.999$), whereas obese peers obtained significantly lower total KTK MQs relative to the healthy-weight group ($p = 0.002$). However, in the subsequent age groups (8–9 years and 10–12 years), both overweight and obese children scored significantly worse, with the obese children achieving the lowest levels of motor coordination ($p < 0.01$). The single-factor analysis outcome also evidenced that healthy-weight children performed at a similar level over age groups ($p = 0.999$). In contrast, both overweight and obese children in the 10–12-year-old group showed significantly lower total KTK performance compared with their corresponding participants in the 5–7-year-old group (p-values < 0.01).

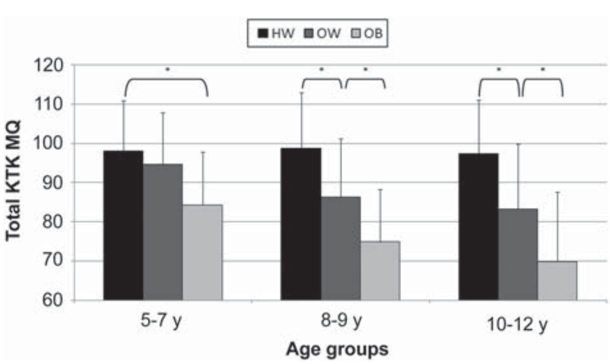

Figure 1. Mean values (vertical bars representing standard deviations) of total Motor Quotient (MQ) observed in healthy-weight (HW, black blocks), overweight (OW, dark gray blocks), and obese (OB, light gray blocks) participants stratified by age.

Using the 15th percentile as a cut-off point, the proportion of children who showed moderate to severe motor impairment was 18.9% in healthy-weight children, 43.3% in the overweight group, and 70.8% among the obese children ($\chi^2 = 120.9$, $p < 0.001$). The relationship between weight status and motor impairment for the distinguished age groups (χ^2-values between 14.49 and 61.85, p-values < 0.01) is presented in Figure 2. Regardless of age, it was shown that less than 20% of all healthy-weight children are facing gross motor difficulties. However, this ratio was considerably different for overweight and obese children, especially for those in the older age groups. About 50% of the overweight children aged 8–9 years or 10–12 years were scoring equal or below the 15th percentile. The proportion of obese children identified as being motor impaired even increased up to 72.3% (8–9 years) and 80.0% (10–12 years).

Discussion

The purpose of this cross-sectional study was to investigate differences in gross motor coordination in healthy-weight, overweight, and obese children of different ages. In addition, the proportion of children identified as being motor impaired was examined in relation to weight status for the distinguished age groups.

Childhood overweight and particularly obesity were found to result in poorer KTK performances. However, the extent to which excess body mass confined gross

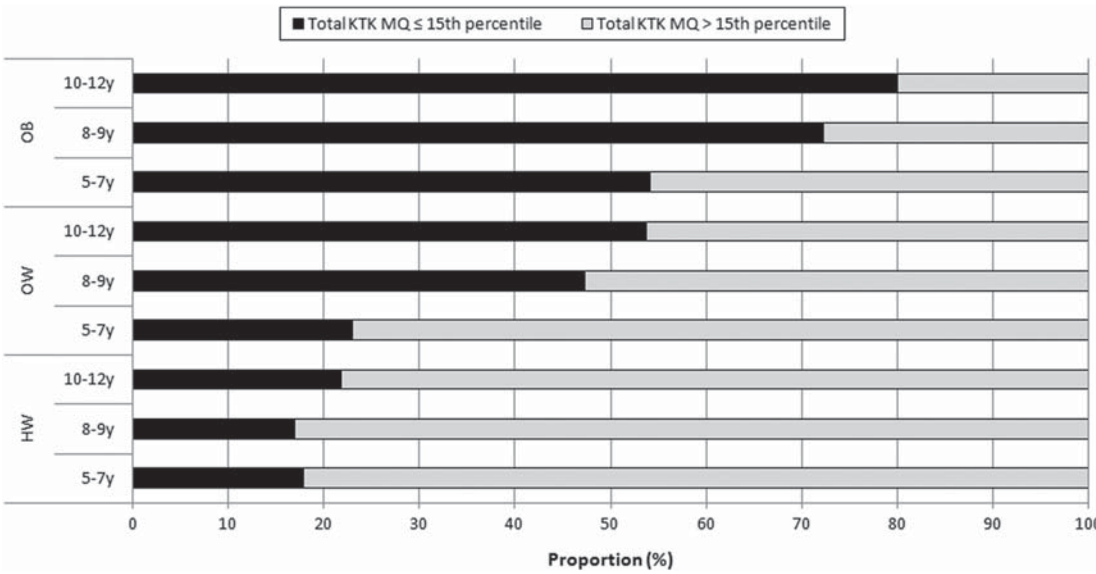

Figure 2. Proportion of children with a total Motor Quotient (MQ) below or equal to the 15th percentile (black blocks, impaired gross motor coordination) and above the 15th percentile (gray blocks, normal to high gross motor coordination) observed in healthy-weight (HW), overweight (OW), and obese (OB) participants stratified by age.

motor coordination differed according to the KTK item assessed. KTK_{BEAM} was featured by the least pronounced effect as compared with the other items, as it primarily measures balance coordination without the need for the body to be moved quickly (44–46). Stronger effects were found on KTK_{JUMP} and KTK_{BOARD}, both assessing coordination performance under time pressure and short-term endurance (44). The most pronounced effect of BMI on gross motor performance was observed for KTK_{HOP}. Next to dynamic coordination, hopping for height also requires additional physical properties, such as endurance, strength, and explosiveness (44,45,47). This interference with several aspects of physical fitness might explain the remarkable poorer scores in relation to weight status. In agreement with previous research (22,23,48–50), our results showed that the disadvantageous effect of excessive weight on children's motor coordination increases as a greater proportion of body mass is involved in the action and when the body needs to be moved under time constraints or against gravity.

A gradual improvement in gross motor coordination with increasing age is widely acknowledged as a general phenomenon during child development (46,47). In this cross-sectional study, such an age-related improvement in KTK raw performance scores was actually present in all children within the same BMI group according to the absolute figures. However, performances of consecutive age groups were not always found to be significantly different from one another, depending on the BMI group and the KTK item under study. For example, no significant age-related progression was established in the obese children's balance performances on KTK_{BEAM}. Overall KTK performance scores were determined using age- and gender-specific standards. Therefore, one could expect to find similar total KTK MQs for the distinguished age groups representing the gradual improvement with age (38,39). In our results, this was only shown to be true in healthy-weight children. The present study further demonstrated that differences between BMI groups in overall KTK performance were more pronounced as children belonged to an older age group. This finding was substantiated by the growing proportion of motor impairment in overweight and obese children across age groups. As hypothesized and previously suggested (25,51,52), the reported deficiencies associated with childhood overweight and obesity do not seem to be temporary. With increasing age, their gross motor coordination even appeared to deteriorate relative to the age- and gender-specific standards. Two earlier studies that examined the development of motor skill and coordination in relation to children's weight status found no relative decline in performance with increasing age (20,25). It should be noted, however, that Ahnert et al. (20) used different standards for BMI classification according to age, and KTK performances were analysed using a between-subjects design instead of a within-subjects design, although participants were followed longitudinally. Okely et al. (25), on the other hand, acknowledged that their process-oriented technique to assess fundamental movement skill proficiency could explain the greater inverse effect of BMI found in the lower school grades 4 and 6. More than likely, a ceiling effect occurred in the higher grades 8 and 10 due to the greater proportion of children showing advanced skills approaching expert performance levels. To the best of our knowledge, this cross-sectional study is thus the first to illustrate an increasingly detrimental effect of childhood overweight and obesity on gross motor coordination across developmental time.

The interrelationship between childhood overweight and obesity, physical (in)activity, and motor (in)competence is probably contributing to our findings. Regular involvement in physical activity provides crucial opportunities to learn and develop motor skills (24). Unfortunately, overweight and obese children display lower levels of physical activity and spend more time in sedentary behaviours compared with healthy-weight peers (16–19). As inactivity is associated with reduced movement experiences, overweight and obese children may encounter impaired motor skill development. Therefore, an accumulated lack of practice might be reflected in poorer motor functioning, especially in later childhood. Alternatively, children with motor difficulties are less likely to participate in physical activity and movement situations as they often experience constraints and negative affective outcomes (8,11,24). This avoidance strategy, however, may further aggravate their movement incompetence and increase adiposity levels (5,8,19). Considering the key role of motor competence in physical activity engagement, which in turn is health protective, our results emphasize the need for early identification of motor impairment, especially in overweight and obese children.

In line with Okely et al. (25) and Barnett et al. (53), we suggest that instruction and improvement of motor skill might be a key component in both prevention and management of childhood overweight and obesity. Next to intervention programs related to clinical practice, there is a crucial need for community- and school-based initiatives to provide various opportunities for motor skill development through physical activities. An appropriate workload is required for those children who are overweight or obese in order to maximize their enjoyment and experience of success. Improved motor skills may accordingly boost children's self-esteem and their motivation to be physically active (25). Therefore, enhanced motor competence and movement patterns may entail a healthy lifestyle in the long term (54). An increased focus on motor skill instruction should occur during primary school years, when children are still at an optimal age to develop their motor competence, to prevent from further reduction in motor coordination over time (24,25,54). As KTK performance between BMI groups also appeared to be considerably smaller at a younger age, overweight and obese children might still catch up their motor deficiency compared with the standard, although targeted initiatives are needed to reach that goal.

This study is not without limitations. The cross-sectional design precludes any statements on causality. Further, the reported relative decline of gross motor coordination in overweight and obese children across age groups cannot be considered truly developmental, given that developmental changes within individuals were not investigated (55). To control for individual differences in maturity status, APHV was included as a covariate in our analysis. However, by applying population specific regression equations to our sample, the prediction of this indicator of somatic maturity may have lost some of its accuracy (41,42). Caution should also be taken when estimating APHV in very young children as systematic errors may occur. In this study, however, such errors are reasonably supposed to be similar in children of different BMI groups. Finally, future research is warranted to investigate to what extent weight loss and decreased adiposity would improve overweight and obese children's gross motor skill competence. Future studies also need to include other factors that are thought to impact motor skill performance, such as the degree of physical activity (5–7), perceived motor competence (5,26), and environmental factors including socioeconomic status (28,56,57), in order to provide a more comprehensive understanding of the mechanisms underlying motor (in)competence in overweight and obese children.

In summary, the present cross-sectional study is innovative in that differences in gross motor coordination performance were investigated in a large sample of healthy-weight, overweight, and obese children across developmental time using a reliable test instrument with identical tests for all age groups. Even when maturity dissimilarities were taken into account, childhood overweight and particularly obesity in children were found to be detrimental to gross motor coordination performance. Most importantly, BMI-related differences appeared to become more pronounced as children belonged to an older age group. Although this relative decline in motor competence with increasing age needs to be confirmed in future longitudinal research, our study certainly highlights the need for an early focus on motor skill improvement in overweight and obese children in order to encourage them to be physically active.

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