2024, Retos, 57, 72-79

Motor coordination in relation to weight status and age in primary school children in Indonesia
Coordinación motora en relación con el peso y la edad en niños de primaria de Indonesia

[*]Arischo Mardiansyah, [*]Syahrial Bakhtiar, [*]Syafruddin, [*]Risky Syahputra, [*]Lucy Pratama Putri, [*]Atradinal, [*]Romi Mardela, [*]Heru Afrian, [**]Johan Pion
[*]Universitas Negeri Padang (Indonesia), [**]Ghent University (Belgium)

Resumen. Pocos estudios han evaluado la relación entre la coordinación motora y la composición corporal en niños. Este estudio investigó la relación entre la obesidad, el peso normal y el bajo peso en niños de 7 a 12 años de edad en Indonesia. En este estudio, se evaluó la idoneidad del Körperkoordinationstest Für Kinder (KTK3+) como herramienta de evaluación de la coordinación motora en 986 niños de primaria (485 niñas, 501 niños) de la provincia de Riau, Indonesia. Todos los niños realizaron cuatro subpruebas: barra de equilibrio (BB), salto lateral (JS), desplazamiento lateral (MS) y coordinación ojo-mano (EHC). El estado ponderal (bajo peso, peso normal, obesidad) se clasificó según los criterios de la OMS en niños de 5 a 19 años de edad. Se ha demostrado que la obesidad infantil influye negativamente en el rendimiento del KTK3+ (p = 0,001), con algunas influencias causadas por las características físicas, además de las necesidades de coordinación del cuerpo que causan los efectos más pronunciados del IMC. El cociente motor (MQ) está fuertemente relacionado con la edad. En los niños de peso normal se observó el mismo MQ en todos los grupos de edad (p = 0,400). Mientras tanto, el rendimiento de la coordinación motora de los niños obesos del grupo de mayor edad (de 10 a 12 años) era mucho mejor que el del grupo de menor edad (de 7 a 9 años) (p = 0,001). El estudio descubrió que las deficiencias motoras estaban presentes en el 17% de los niños con peso normal, pero aumentaban hasta el 28,1% en los niños obesos. Nuestros resultados mostraron que las diferencias en la coordinación motora asociadas al índice de masa corporal eran más pronunciadas en los niños mayores. Aunque se necesitan estudios longitudinales para consolidar estos hallazgos, se subraya la importancia de priorizar el desarrollo temprano de las habilidades motoras en los niños obesos para promover su compromiso con la actividad física.
Palabras clave: índice de masa corporal, coordinación motora, niños, obesidad, factor de edad

Abstract. Few studies have assessed the relationship between motor coordination (MC) and body composition in children. This study investigated the relationships among obesity, normal weight, and underweight in 7- to 12-year-old children in Indonesia. The suitability of the Körperkoordinationstest Für Kinder (KTK3+) as a MC assessment tool was evaluated in 986 primary school children (485 girls, 501 boys) from Riau Province, Indonesia. All children performed four subtests: balance beam, jumping sideways, moving sideways, and eye–hand coordination. Weight status (underweight, normal weight, or obese) was classified according to WHO criteria for children 5–19 years old. Childhood obesity was shown to negatively impact KTK3+ performance ($p = 0.001$), with some tests affected by physical characteristics and the body's coordination needs causing the most pronounced body mass index (BMI) effects. Motor quotient (MQ) was strongly related to age. The same MQ was seen in normal-weight children across age groups ($p = 0.400$). Meanwhile, the MC performance of obese children in the older age group (10–12 years old) was much better than that of the lower age group (7–9 years old) ($p = 0.001$). We found that motor impairments were present in 17% of normal-weight children and 28.1% of obese children. Our results showed that the differences in MC associated with BMI were more pronounced in older children. While longitudinal studies are needed to solidify these findings, they underscore the importance of prioritizing early motor skill development in obese children to promote their engagement in physical activity.
Keywords: body mass index, motor coordination, children, obesity, age factor

Fecha recepción: 21-02-24. Fecha de aceptación: 06-05-24
Arischo Mardiansyah
arischo@student.unp.ac.id

Introduction

A downward trend in children's participation in physical activity (PA) is unfolding in Indonesia, with national data showing that 57% of children fail to engage in the 60 minutes of daily moderate-to-vigorous PA that is critical for optimal health and development (Hanifah et al., 2023). The high prevalence of overweight (20%) and obese (9.2%) children aged 5–12 in Indonesia highlights the impact of insufficient PA on childhood obesity rates (Sulistiadi et al., 2023). In particular, socioeconomic disadvantage (specifically being from a low-income family) is a significant risk factor for reduced quality of PA, increased prevalence of obesity, and long-term health disparities (Brian et al., 2019). Thus, in many low- and middle-income countries, including Indonesia with its population of 280 million, there has been an increase in overweight and obesity (Abay et al., 2022). Motor coordination (MC) skills are crucial for reducing negative health trends and increasing engagement in PA, fitness development, and healthy weight management (Lima et al., 2019). Early childhood presents a unique window of opportunity for strengthening core motor skills, which include the fluidity of locomotor movements (e.g., running, jumping, hopping, galloping) and object control (e.g., catching, throwing, hitting, kicking) (Clark & Metcalfe, 2002). These skills enable every child to enjoy play and PA, making this critical period ideal for strengthening the foundation for MC that will benefit children throughout their lives. MC is also essential for a wide range of functional and goal-directed daily tasks, sports, and leisure activities (Lima et al., 2019). MC reflects the cooperation of the central nervous and musculoskeletal systems in addition to strength and power (Brian et al., 2018). Recent research suggests that MC potentially affects children's health, with solid evidence of an association between MC and PA, cardiorespiratory fitness, and weight status (Schmutz et al., 2020). The association between MC and weight status should begin to be observed in early childhood

(5 years of age) and continue through early adulthood (Eldiasty et al., 2023; Tsuda et al., 2020). The relationship between gross MC and weight status in children aged 6–14 years and 5–12 years was examined cross-sectionally by Lopes et al. (2014) and D'Hondt et al. (2011), respectively, who concluded that children with higher MC scores had lower body mass index (BMI) at ages 5 and 6 years.

The interrelationship between poor MC and physical inactivity is crucial and especially noticeable in overweight or obese children. An important aspect of engagement in PA is participation in daily exercise. Children with movement difficulties (MD) show a paradoxical association between decreased participation in movement-based activities (e.g., sports, PA, recreation) and increased engagement in sedentary behaviours. This pattern may potentially increase pre-existing MD by negatively impacting motor skill development, social interaction, and health outcomes (Chen et al., 2018; D'Hondt et al., 2011). Given the increasing worldwide prevalence of childhood obesity and the association between sedentary lifestyles and body composition, it is essential to focus on enhancing MC levels in children with obesity indicated by BMI (Lopes et al., 2018; Mardiansyah et al., 2023; Wälti et al., 2022).

The ability to differentiate between reduced motor skills in obese children is often lacking in available studies (D'Hondt et al., 2011). Some studies report an effect of increasing BMI on reduced quality of MC in children and adolescents (Lopes et al., 2018; Sgro et al., 2019). There is also some evidence from longitudinal studies that the level of MC during childhood influences the level of PA in later years (Lopes et al., 2011). However, there is still limited research on the issue of obesity as a barrier to PA across age groups during childhood in Indonesia (Bakhtiar et al., 2019). It is still unclear whether reported barriers for obese children differ across developmental periods. Moreover, body composition in relation to MC for children has not yet been studied in depth in Indonesia. In this study, we assessed MC during childhood using the modified Körperkoordinationstest Für Kinder (KTK3+) (Coppens et al., 2021). This is a standardized normative product-oriented test battery used to assess motor development in children aged 5–15 years. A product-oriented test is a method from the motor development literature that tests the outcome or product of a motor skill, such as the number of jumps or ability to catch a ball (Bardid, 2016).

Thus, the present study aimed to examine the differences in MC performance of underweight, normal-weight, and obese children and the differences between boys and girls and children of different ages. We hypothesized that children with obesity might have lower motor skills than children of normal weight, which prompted us to examine this potential association. Furthermore, differences were also expected between younger and older children due to the relationships among motor (in)competence, obesity, and physical (in)activity.

Materials and Methods

Participants

A large-scale project (Yayasan Sekora) was established to analyze the motor and physical performance problems of primary school children in Indonesia. The study was approved by the local ethics committee and by the first author's institution, Universitas Negeri Padang. Participants were 7-to 12-year-old children (n = 986), 485 girls and 501 boys, from Riau Province, Indonesia. Written informed consent was obtained from the parents of each child.

Measurements

Accurate measurements of participants' height and weight were obtained using standardized procedures. Heights were obtained using a microtoise/stadiometer with an accuracy of 0.1 cm, while weights were collected using calibrated scales with an accuracy of 100 g. To evaluate the weight status of all participants, BMI was calculated (BMI = weight (kg)/height $(m)^2$). The children in this study were then categorized according to WHO guidelines for children 5–19 years old, allowing further analysis of weight-related trends within this age group.

The KTK3+ is a modified version of the KTK developed by Kiphard and Schilling (1974) with 1,228 German children aged 5–15 years. The original KTK consisted of jumping sideways (JS), moving sideways (MS), balance beam (BB), and hopping for height (HH). The objective was to examine data from children without motor and/or health-related problems. The reason for modifying the original KTK to KTK3+ was that the HH test is often omitted from the original KTK test protocol in more recent studies due to time constraints and/or safety reasons, particularly when applied to children and adolescents (Coppens et al., 2021).

In this study, KTK3+ consisted of four test items, all of which required good coordination of the whole body: (1) walking backwards on three BBs of decreasing width: 6 cm, 4.5 cm, and 3 cm; (2) MS on a wooden board for 20 seconds twice; (3) JS with two feet from one side to the other for 15 seconds twice; and (4) testing eye–hand coordination (EHC) by measuring the total number of ball catches over two attempts of 30 seconds each.

Data Analysis

Statistical analysis was conducted using IBM SPSS software version 24 for Windows. A significance level of $p < 0.05$ was adopted to standardize all analyses. Furthermore, the anthropometric variables, MC, raw KTK3+ and motor quotient (MQ) scores were analyzed descriptively (Mardiansyah et al., 2023). MANOVA for MC measures was conducted to investigate the effects of age (7–9 and 10-12 years old), body weight status (underweight, normal weight, or obese), and gender. The significant interactions and main effects were further analyzed using Bonferroni *post hoc* tests or pairwise comparisons. A group's effect size was assessed

using partial eta squared (ηp^2) with standardized interpretation guidelines (0.01 for a small effect, 0.06 for a medium effect, and 0.14 for a large effect).

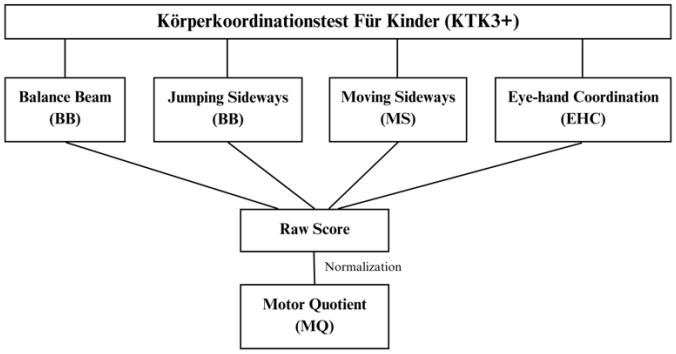

Figure 1. KTK3+ test including four items (Mardiansyah et al., 2023).

Table 1.
Motor coordination of the children based on KTK3+ was categorized based on the total raw data score to Motor Quotient (MQ) (Coppens et al., 2021; D'Hondt et al., 2011; Pion, 2015)

Total MQ KTK3+	Percentile rank	Motor coordination level
≤ 70	< 3rd percentile	Severe motor coordination impairment
71 – 85	3rd – 15th percentile	Moderate motor coordination impairment
86 – 115	16th – 84th percentile	Normal motor coordination
116 – 130	85th – 98th percentile	Good motor coordination
131 – 145	99th – 100th percentile	High motor coordination

Results

Descriptive statistics of the anthropometric characteristics for underweight, normal-weight, and obese children are presented in Table 2. Table 3 provides the descriptive statistics of the raw performance scores of the $KTK3+_{BB}$, $KTK3+_{JS}$, $KTK3+_{MS}$, and $KTK3+_{EHC}$, as well as the $_{TOTAL}$MQ KTK3+. Meanwhile, Table 4 shows the *F*-values based on the MANOVA. The differences in MC related to BMI were mainly by age group (BMI × AGE interaction). A multivariate interaction effect for $KTK3+_{BB}$ ($F_{INTERACTION} = 4.24$, $p < 0.05$) showed no differences in balance performance among underweight, normal-weight, and obese children aged 7–9 years ($p > 0.05$). Furthermore, underweight participants scored higher than other BMI groups at ages 10–12 years ($p < 0.05$), while balance skills were more dominant in normal-weight than obese children ($p < 0.05$). Despite exceeding the absolute balance performance scores of 10- to 12-year-olds, the scores of younger obese children (7–9 years) were not statistically significantly better ($p > 0.05$). In addition, obese children in both age groups (7–9 and 10–12 years) showed similar balance abilities, as assessed by $KTK3+_{BB}$, with no statistically significant differences detected ($p > 0.05$).

Table 2.
Descriptive statistics of age and gender of children with mean and standard deviation of body mass index (BMI)

Age group	Antropometric characteristics	Boys n = 501			Girls n = 485		
		UW n = 369	NW n = 94	OB n = 20	UW n = 378	NW n = 88	OB n = 8
7-9 years	Height (cm)	131.5 ± 8.2	132.8 ± 6.4	134.3 ± 5.4	131.6 ± 9.4	128.9 ± 6.4	125.5 ± 2.5
	Weight (kg)	25.2 ± 4.7	36.8 ± 4.5	48.4 ± 2.3	25.6 ± 4.5	33.6 ± 5.0	40.6 ± 2.5
	BMI (kg/m²)	14.5 ± 2.0	20.8 ± 1.3	26.9 ± 1.8	14.7 ± 1.7	20.1 ± 1.4	25.8 ± 2.6
10-12 years	Height (cm)	141.4 ± 8.0	143.9 ± 8.9	148.9 ± 7.8	142.1 ± 9.0	146.7 ± 6.0	147.2 ± 7.1
	Weight (kg)	29.8 ± 5.3	42.2 ± 6.3	57.2 ± 8.4	39.9 ± 5.7	43.7 ± 4.0	55.7 ± 7.4
	BMI (kg/m²)	14.9 ± 2.0	20.3 ± 1.3	25.7 ± 2.3	14.7 ± 2.1	20.3 ± 1.2	25.7 ± 3.1

BMI: Body mass index

For $KTK3+_{JS}$ ($F_{INTERACTION} = 0.41$, $p = 0.946$), no statistically significant differences were found among underweight, normal-weight, and obese children. Furthermore, no significant BMI × AGE interaction was found in girls or boys ($F_{BMI \times AGE} = 1.092$, $p = 0.319$). The main effect of BMI ($F_{BMI} = 3.00$, $p < 0.001$) showed that normal-weight girls performed better on side jumps than their obese peers ($p = 0.009$), while underweight girls performed better than the other two BMI groups ($p < 0.05$). In addition, another main effect was observed in the age group ($F_{AGE} = 2.90$, $p < 0.001$): a significant increase in lateral jumping was seen in the older age group of girls ($p < 0.001$). Furthermore, no statistically significant BMI × AGE interaction was found in $KTK3+_{MS}$, but there were significant differences among groups for BMI ($F_{BMI} = 2.92$, $p < 0.05$), gender ($F_{GENDER} = 10.51$, $p < 0.001$), and age ($F_{AGE} = 3.43$, $p < 0.05$). However, $KTK3+_{MS}$ scores were similar between underweight and normal-weight children ($p = 0.104$).

Table 3.
KTK3+ performances (mean ± standard deviation) in underweight (UW), normal weight (NW), and obese (OB) boys and girls stratified by age

Age group	KTK3+ variables	Boys n = 501			Girls n = 485		
		UW n = 369	NW n = 94	OB n = 20	UW n = 378	NW n = 88	OB n = 8
7-9 years	$KTK3+_{BB}$	61.0 ± 11.3	57.8 ± 10.6	53.0 ± 7.0	60.7 ± 11.0	62.6 ± 10.2	59.0 ± 18.3
	$KTK3+_{JS}$	48.8 ± 13.9	49.5 ± 10.0	46.7 ± 12.7	45.5 ± 12.1	38.7 ± 12.5	35.0 ± 12.7
	$KTK3+_{MS}$	38.2 ± 7.2	36.2 ± 8.1	30.7 ± 8.3	34.3 ± 7.5	33.9 ± 10.1	33.0 ± 4.2
	$KTK3+_{EHC}$	8.4 ± 6.6	11.8 ± 6.6	11.0 ± 5.3	4.5 ± 4.9	7.0 ± 7.4	6.5 ± 3.5
	$_{TOTAL}$ MQ KTK3+	99.99 ± 15.03	100.01 ± 14.98	100.02 ± 15.03	99.98 ± 15.01	100.01 ± 15.03	100.0 ± 15.0
10-12 years	$KTK3+_{BB}$	64.5 ± 9.7	60.5 ± 13.0	54.3 ± 14.9	62.7 ± 11.3	56.6 ± 14.3	48.3 ± 16.7
	$KTK3+_{JS}$	56.9 ± 12.9	51.6 ± 12.8	49.5 ± 12.6	52.8 ± 11.5	51.1 ± 11.9	45.7 ± 11.5
	$KTK3+_{MS}$	44.4 ± 10.7	41.7 ± 7.7	40.9 ± 7.2	38.3 ± 10.0	37.6 ± 6.1	31.6 ± 10.8
	$KTK3+_{EHC}$	16.0 ± 6.7	14.4 ± 6.2	17.7 ± 6.8	10.2 ± 6.6	10.0 ± 6.7	12.0 ± 5.7
	$_{TOTAL}$ MQ KTK3+	100.0 ± 15.0	100.01 ± 15.01	100.0 ± 15.0	100.02 ± 15.01	100.0 ± 15.02	100.0 ± 15.02

KTK3+: Körperkoordinationstest für Kinder (3+)

Both the underweight and normal-weight groups performed better than the obese group ($p < 0.05$). A significantly lower performance was found in children between the ages of 7–9 years compared with the older age group ($p < 0.001$). For $KTK+_{EHC}$, no significant BMI × AGE interaction was observed, but performance was significantly different among the BMI groups ($F_{GENDER} = 18.43$, $p < 0.001$) and between the age groups ($F_{AGE} = 8.46$, $p < 0.001$). At older ages, obese children performed better at throwing and catching than the other two groups ($p = 0.003$). In addition, a main effect of gender was found for the three items of the KTK3+. Boys scored higher on $KTK3+_{JS}$ ($F_{GENDER} = 6.89$, $p < 0.010$), $KTK3+_{MS}$ ($F_{GENDER} = 14.52$, $p < 0.001$), and $KTK3+_{EHC}$ ($F_{GENDER} = 22.94$, $p < 0.001$). In contrast, girls scored higher on $KTK3+_{BB}$ ($F_{GENDER} = 18.87$, $p < 0.001$).

Table 4.
Main and interaction effects on KTK3+ according to age, body mass index, and gender

KTK variabels	F_{BMI}	F_{AGE}	F_{GENDER}	$F_{BMI \times AGE}$	$F_{BMI \times GENDER}$	$F_{AGE \times GENDER}$	$F_{BMI \times AGE \times GENDER}$
$KTK3+_{BB}$	4.24^{**}	1.34^{*}	19.36^{****}	2.12^{**}	0.01^{*}	1.76^{*}	0.88^{*}
$KTK3+_{JS}$	3.89^{**}	4.37^{***}	6.26^{***}	0.41^{*}	0.49^{*}	1.42^{*}	1.19^{*}
$KTK3+_{MS}$	2.92^{**}	3.43^{***}	10.51^{****}	0.98^{*}	0.11^{*}	1.01^{*}	0.87^{*}
$KTK3+_{EHC}$	0.63^{*}	8.46^{****}	18.43^{****}	1.75^{*}	0.08^{*}	0.16^{*}	0.15^{*}
$_{TOTAL}$ MQ KTK3+	6.17^{**}	5.84^{****}	0.05^{*}	1.05^{*}	0.13^{*}	0.24^{*}	0.85^{*}

BMI: Body mass index. KTK3+: Körperkoordinationstest für Kinder (3+)
$^{*}p \geq 0.05$, $^{**}p \leq 0.05$ $^{***}p < 0.01$, $^{****}p < 0.001$

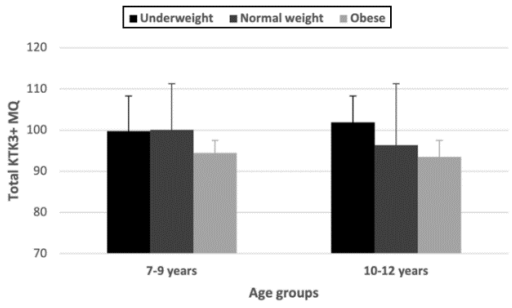

Figure 2. Mean values (vertical bars represent standard deviations) of total motor quotient (MQ) observed in normal-weight (black blocks), underweight (dark gray blocks), and obese (light gray blocks) participants stratified by age.

Significant differences were also observed for age ($p < 0.001$) and BMI ($p = 0.002$) in $_{TOTAL}$MQ KTK3+. Statistical analysis indicated that $_{TOTAL}$MQ KTK3+ was similar in underweight and normal-weight children aged 7–12 years ($p = 0.946$), whereas obese children showed significantly lower $_{TOTAL}$MQ KTK3+ when compared to the normal-weight group ($p = 0.006$). In addition, older obese children (10–12 years old) had significantly lower MC abilities ($p < 0.001$) (see Fig. 2).

Discussion

This study investigated age and gender differences in the MC test among underweight, normal-weight, and obese children. In summary, raw scores for $KTK3+_{MS}$ and $KTK3+_{EHC}$ increased with age, and boys performed better than girls. In addition, underweight children outperformed their normal-weight and obese peers on the $KTK3+_{BB}$, $KTK3+_{JS}$, and $KTK3+_{MS}$ tests. However, overweight children also outperformed their peers on $KTK3+_{EHC}$.

Overweight and, especially, obesity in childhood have been found to lead to poorer performance on gross MC using the KTK (D'Hondt et al., 2011). The $KTK3+_{BB}$ score was weakly related to those of the other items because it is designed to measure balance skills without the need to complete tasks quickly (Coppens et al., 2021; Mardiansyah et al., 2023; Moreira et al., 2019). However, a greater effect of gender was found on $KTK3+_{JS}$ and $KTK3+_{MS}$, in which the children completed the tasks quickly within a limited time period and required short-term endurance (Niet et al., 2021). A notable effect on gross motor performance was observed for $KTK3+_{EHC}$ (Mardiansyah et al., 2023).

The $KTK3+_{EHC}$ task involves controlling a tennis ball while performing repetitive movements (e.g., left-hand throw and right-hand catch followed by right-hand throw and left-hand catch), which is also affected by PA and anthropometric measures (i.e., hand size and arm length) that can make it difficult to catch and throw the ball (Coppens et al., 2021). This impairment in some of these aspects of physical fitness may explain the lower scores associated with weight status. Lopes et al. (2018) and D'Hondt et al. (2011) discussed in their research the adverse effects of obesity on children's MC. In contrast, our results show that the unexpected effect of obesity on children's MC was greater

in children aged 10–12 years. Although there is not much evidence to explain that excess weight greatly affects the quality of MC, this finding could be due to several reasons, such as specific types of motor skills, including good EHC and endurance.

Gradual age-related differences in MC are generally recognized as a common phenomenon during child development. This study found age-related improvements in specific KTK3+ test items and BMI groups rather than in general. For instance, there was no significant age-related improvement in balance ability for obese children on the $KTK3+_{BB}$.

In general, the MQ values in our dataset were low compared to the original KTK reference values (collected approximately 48 years ago) (Kiphard & Schilling, 1974). An important point to consider is the possibility of a changing culture of PA among children. Children's MQ and BMI may be lower in our study as in recent normative data showing a downward trend in PA and fitness levels and an increase in BMI over the past few decades (Giuriato et al., 2021).

Overall, the tasks in the KTK3+ strongly predict the quality of motor competence during child development. Our results also showed significant interactions among MC level, gender, and age in predicting the prevalence of obesity. Boys and girls with lower MC levels showed a higher prevalence of obesity across age groups. These findings align with existing research showing that obese children show deficits in motor skill development, especially for tasks requiring manipulation of the entire body mass (Castetbon & Andreyeva, 2012; Ružbarská, 2020). The difference between children's BMI scores on the $_{TOTAL}$MQ KTK3+ increased gradually between the ages of 7 and 9 and sharpened between the ages of 10 and 11. Consistent with the present findings, D'Hondt et al. (2011) reported that obese children aged 10–12 years in a Flemish study performed significantly worse on MC tasks compared to their younger obese peers. In addition, longitudinal data from D'Hondt et al. (2013) highlighted the influence of weight status on MC development, with normal-weight children consistently outperforming their obese counterparts, leading to progressively more significant MC discrepancies between groups over time.

The difference between the BMI of normal-weight and obese 12-year-old children was greater with higher $_{TOTAL}$MQ- KTK3+ scores. In particular, the mean difference in $_{TOTAL}$MQ KTK3+ between 12-year-old boys and girls was greater than for younger children. The relatively smaller sample size for 12-year-old boys and girls may also have influenced this drastic increase in the difference. However, in the younger age group (7–9 years), the mean $_{TOTAL}$MQ KTK3+ values for normal-weight and obese children were not significantly different (see Table 3). Overall, these results align with previous longitudinal and cross-sectional studies showing an increasing association between MC and weight status with age (D'Hondt et al., 2013; D'Hondt et al., 2011; Lopes et al., 2014). Our findings also reveal the contribution of the interrelationship among physical (in)activity, motor (in)competence, and obesity in children. Participating in regular PA provides important benefits for developing and learning motor skills (Nobre et al., 2023). Unfortunately, obese children have lower PA levels and often spend more time sedentary than their normal-weight peers (Laukkanen et al., 2020; Lopes et al., 2018; Rezaei et al., 2023). As the effects of inactivity are related to less movement experience, obese children may have impaired motor skill development (D'Hondt et al., 2011). Thus, the lack of structured and supervised training by a child movement expert during childhood can reduce the quality of MC function. Additionally, motor-impaired children avoid participating in PA and exercise because they often experience obstacles to every activity (Giuriato et al., 2021; Ruiz-Pérez, 2018). However, limiting their movement activities and differentiating activities can increase their movement disabilities and decrease their health levels (Lopes et al., 2021). Given the established relationships among MC, PA levels, and health status, our findings highlight the crucial role of early intervention and detection of motor impairments, particularly in children with obesity, to minimize potential adverse effects.

Consistent with Barnett et al. (2019) and Wälti et al. (2022), we propose that improving motor skills might be important in preventing childhood obesity. Besides clinical practice–based intervention programs, there is an important need in the community and in schools to provide a wide variety of opportunities for motor skill development through PA and play-based activities during childhood (Famelia et al., 2018). Motivating and working with children to help them develop motor competence from an early age by engaging children in sports, PA, and free play will lead to better fitness outcomes (Luz et al., 2017). Appropriate activity levels are needed for obese children to maximize their engagement in and enjoyment of PA (Bakhtiar et al., 2023). Improving the quality of motor skills from an early age can positively impact children's confidence and motivation to be physically active (Luz et al., 2017). Therefore, it is essential to help children improve their motor skills and active movement patterns to promote a healthy lifestyle. The primary school age is critical for optimizing motor skill development and prioritizing interventions. Interventions during this period can effectively prevent declines in motor competence and the associated consequences (D'Hondt et al., 2011; Goodway et al., 2017; Mardiansyah et al., 2023; Ružbarská, 2020). In addition, as KTK3+ performance does not appear to differ much among BMI groups at younger ages, obese children might still be able to improve their motor skills relative to the standard. However, special attention will be needed to achieve this goal.

This study had several limitations. Its design did not provide definitive evidence of causality regarding the relationship between MC and other variables. A thorough longitudinal and interventional study is needed to provide more

information about the direction of this relationship. Another limitation is the lack of information on maturity (e.g., sexual maturity, bone maturity), sedentary time, PA level, and abdominal circumference. Future research should include other factors influencing MC skills, such as PA level; perceived motor ability; and environmental factors, including socioeconomic status, to provide a complete understanding. Lastly, direct comparisons of the KTK3+ among provinces are not possible due to the lack of representative data for all provinces in Indonesia.

Conclusion

This study was innovative because it assessed differences in the MC of underweight, normal-weight, and obese children during the developmental period with a reliable instrument (KTK3+) using the same test for children 7–12 years old and of and both genders. In our study, BMI-related differences in children seemed more pronounced in the early age group (7–9 years). Sedentary behavior and physical inactivity are now major concerns for children. Although our findings highlight the potential for age-related improvements in motor skill development, further validation is needed through longitudinal studies in Indonesia. Despite this limitation, our study emphasizes the importance of interventions to facilitate early motor skill development, especially in obese children, to encourage engagement in PA and to prevent potential decline in motor competence later in life. Future research should develop specific KTK3+ benchmarks for children in Indonesia, and this study can serve as a pilot study for this process. Researchers should also examine the structures within motor development programs in Indonesian primary schools. There is a need to further investigate the content, age-appropriateness, exposure levels, and learning outcomes of physical education in primary schools, as well as the level of knowledge and training of primary school teachers, especially in terms of motor development.

Acknowledgements

With financial support of the PMDSU scholarship program, the Ministry of Education and Culture of Indonesia.

Conflict of interest

Arischo Mardiansyah, Syahrial Bakhtiar, Syafruddin, Risky Syahputra, Lucy Pratama Putri, Atradinal, Romi Mardela, Heru Afrian, and Johan Pion declare no conflicts of interest regarding the content of this research.

References

Abay, K. A., Ibrahim, H., & Breisinger, C. (2022). Food policies and obesity in low- and middle-income countries. *World Development*, *151*, 105775. https://doi.org/10.1016/j.worlddev.2021.105775

Bakhtiar, S., Famelia, R., & Goodway, J. D. (2019). Developing a Motor Skill-Based Curriculum for Preschools and Kindergartens as a Preventive Plan of Children Obesity in Indonesia. *Advances in Social Science, Education and Humanities Research*, *21*(Icsshpe 2019), 106–110.

Bakhtiar, S., Syahputra, R., Putri, L. P., Mardiansyah, A., Atradinal, Hendrayana, A. A., Afrian, H., Mardela, R., & Pion, J. (2023). Sports talent profile of 7-12 years old : Preliminary study of talent identification in Indonesia. *Journal of Physical Education and Sport*, *23*(12), 3167–3177. https://doi.org/10.7752/jpes.2023.12361

Bardid, F. (2016). Early childhood motor development: Measuring, understanding and promoting motor competence. Ghent University.

Barnett, L. M., Hnatiuk, J. A., Salmon, J., & Hesketh, K. D. (2019). Modifiable factors which predict children's gross motor competence: A prospective cohort study. *International Journal of Behavioral Nutrition and Physical Activity*, *16*(1), 1–11. https://doi.org/10.1186/s12966-019-0888-0

Brian, A., Bardid, F., Barnett, L. M., Deconinck, F. J. A., Lenoir, M., & Goodway, J. D. (2018). Actual and Perceived Motor Competence Levels of Belgian and United States Preschool Children. *Journal of Motor Learning and Development*, *6*(s2), S320–S336. https://doi.org/10.1123/jmld.2016-0071

Brian, A., Pennell, A., Taunton, S., Starrett, A., Howard-Shaughnessy, C., Goodway, J. D., Wadsworth, D., Rudisill, M., & Stodden, D. (2019). Motor Competence Levels and Developmental Delay in Early Childhood: A Multicenter Cross-Sectional Study Conducted in the USA. *Sports Medicine*, *49*(10), 1609–1618. https://doi.org/10.1007/s40279-019-01150-5

Castetbon, K., & Andreyeva, T. (2012). Obesity and motor skills among 4 to 6-year-old children in the united states: Nationally-representative surveys. *BMC Pediatrics*, *12*(1), 28. https://doi.org/10.1186/1471-2431-12-28

Clark, J. E., & Metcalfe, J. S. (2002). The Mountain of Motor Development: A Metaphor. *Motor Development: Research and Reviews*, *2*, 163–190.

Coppens, E., Laureys, F., Mostaert, M., D'Hondt, E., Deconinck, F. J. A., & Lenoir, M. (2021). Validation of a Motor Competence Assessment Tool for Children and Adolescents (KTK3+) With Normative Values for 6- to 19-Year-Olds. *Frontiers in Physiology*, *12*(June). https://doi.org/10.3389/fphys.2021.652952

D'Hondt, E., Deforche, B., Gentier, I., De Bourdeaudhuij, I., Vaeyens, R., Philippaerts, R., & Lenoir, M. (2013). A longitudinal analysis of gross motor coordination in overweight and obese children versus normal-weight peers. *International Journal of Obesity*, *37*(1), 61–67. https://doi.org/10.1038/ijo.2012.55

D'Hondt, Eva, Deforche, B., Vaeyens, R., Vandorpe, B., Vandendriessche, J., Pion, J., Philippaerts, R., de Bourdeaudhuij, I., & Lenoir, M. (2011). Gross motor

coordination in relation to weight status and age in 5- to 12-year-old boys and girls: A cross-sectional study. *International Journal of Pediatric Obesity*, *6*(2–2), e556–e564. https://doi.org/10.3109/17477166.2010.500388

de Niet, M., Platvoet, S. W. J., Hoeboer, J. J. A. A. M., de Witte, A. M. H., de Vries, S. I., & Pion, J. (2021). Agreement Between the KTK3+ Test and the Athletic Skills Track for Classifying the Fundamental Movement Skills Proficiency of 6- to 12-Year-Old Children. *Frontiers in Education*, *6*(March), 1–8. https://doi.org/10.3389/feduc.2021.571018

Eldiasty, H. A. E. S., Hassan, A. K., Elhakim, B. E. H. A., & Ahmed, Y. A. R. S. (2023). Impact of a dexterity programme on motor skills and inventiveness in 5–6-year-old children. *Journal of Physical Education and Sport*, *23*(8), 2041–2050. https://doi.org/10.7752/jpes.2023.08235

Famelia, R., Tsuda, E., Bakhtiar, S., & Goodway, J. D. (2018). Relationships among perceived and actual motor skill competence and physical activity in Indonesian preschoolers. *Journal of Motor Learning and Development*, *6*, S403–S423. https://doi.org/10.1123/jmld.2016-0072

Giuriato, M., Biino, V., Bellafiore, M., Battaglia, G., Palma, A., Baldari, C., Guidetti, L., Gallotta, M. C., Schena, F., & Lanza, M. (2021). Gross Motor Coordination: We Have a Problem! A Study With the Körperkoordinations Test für Kinder in Youth (6–13 Years). *Frontiers in Pediatrics*, *9*(December), 1–12. https://doi.org/10.3389/fped.2021.785990

Goodway, J. D., Famelia, R., & Bakhtiar, S. (2017). Future Directions in Physical Education & Sport: Developing Fundamental Motor Competence in the Early Years Is Paramount to Lifelong Physical Activity. *Asian Social Science*, 44–54. https://doi.org/10.5539/ass.v10n5p44

Hanifah, L., Nasrulloh, N., & Sufyan, D. L. (2023). Sedentary Behavior and Lack of Physical Activity among Children in Indonesia. *Children,* https://doi.org/10.3390/children10081283

Kiphard, E. J., & Schilling, F. (1974). *Körperkoordinationstest für Kinder : KTK*.

Laukkanen, A., Bardid, F., Lenoir, M., Lopes, V. P., Vasankari, T., Husu, P., & Sääkslahti, A. (2020). Comparison of motor competence in children aged 6-9 years across northern, central, and southern European regions. *Scandinavian Journal of Medicine and Science in Sports*, *30*(2), 349–360. https://doi.org/10.1111/sms.13578

Lima, R. A., Bugge, A., Ersbøll, A. K., Stodden, D. F., & Andersen, L. B. (2019). The longitudinal relationship between motor competence and measures of fatness and fitness from childhood into adolescence. *Jornal de Pediatria*, *95*(4), 482–488. https://doi.org/10.1016/j.jped.2018.02.010

Lopes, L., Santos, R., Coelho-E-Silva, M., Draper, C., Mota, J., Jidovtseff, B., Clark, C., Schmidt, M., Morgan, P., Duncan, M., O'Brien, W., Bentsen, P., D'Hondt, E., Houwen, S., Stratton, G., De Martelaer, K., Scheuer, C., Herrmann, C., García-Hermoso, A., Agostinis-Sobrinho, C. (2021). A narrative review of motor competence in children and adolescents: What we know and what we need to find out. *International Journal of Environmental Research and Public Health*, *18*(1), 1–20. https://doi.org/10.3390/ijerph18010018

Lopes, V. P., Malina, R. M., Maia, J. A. R., & Rodrigues, L. P. (2018). Body mass index and motor coordination: Non-linear relationships in children 6–10 years. *Child: Care, Health and Development*, *44*(3), 443–451. https://doi.org/10.1111/cch.12557

Lopes, V. P., Stodden, D. F., & Rodrigues, L. P. (2014). Weight status is associated with cross-sectional trajectories of motor co-ordination across childhood. *Child: Care, Health and Development*, *40*(6), 891–899. https://doi.org/10.1111/cch.12127

Lopes, Vítor Pires, Rodrigues, L. P., Maia, J. A. R., & Malina, R. M. (2011). Motor coordination as predictor of physical activity in childhood. *Scandinavian Journal of Medicine and Science in Sports*, *21*(5), 663–669. https://doi.org/10.1111/j.1600-0838.2009.01027.x

Luz, C., Rodrigues, L. P., De Meester, A., & Cordovil, R. (2017). The relationship between motor competence and health-related fitness in children and adolescents. *PLoS ONE*, *12*(6), 1–11. https://doi.org/10.1371/journal.pone.0179993

Mardiansyah, A., Syafruddin, M., & Bakhtiar, S. (2023). Assessment of motor competence in Indonesian elementary school children using the Körperkoordinationstest Für Kinder (KTK3+). *Journal of Physical Education & Sport*, *23*(10), 2632–2641. https://doi.org/10.7752/jpes.2023.10301

Moreira, J. P. A., Lopes, M. C., Miranda-Júnior, M. V., Valentini, N. C., Lage, G. M., & Albuquerque, M. R. (2019). Körperkoordinationstest Für Kinder (KTK) for Brazilian Children and Adolescents: Factor Analysis, Invariance and Factor Score. *Frontiers in Psychology*, *10*(November), 1–11. https://doi.org/10.3389/fpsyg.2019.02524

Nobre, J. N. P., Morais, R. L. D. S., Viegas, Â. A., Fernandes, A. C., Scheidt Figueiredo, P. H., Costa, H. S., Peixoto, M. F. D., de Alcântara, M. A., Mendonça, V. A., & Lacerda, A. C. R. (2023). Factors Associated with Motor Competence in Preschoolers from a Brazilian Urban Area. *Child & Youth Care Forum*, *52*(3), 721–736. https://doi.org/10.1007/s10566-022-09708-7

Pion, J. (2015). *The Flemish Sports Compass From sports orientation to elite performance prediction*. Ghent University, Department of Movement and Sports Sciences (*Dissertation*)

Rezaei, F., Askari, R., Hamedinia, M., & Pusceddu, M. (2023). Impact of combined aerobic–resistance exercise

training without dietary intervention on irisin serum levels in overweight and obese girls. *Journal of Physical Education and Sport*, *23*(10), 2853–2861. https://doi.org/10.7752/jpes.2023.10326

Ruiz-Pérez, L. M. (2018). Low Competence and Developmental Motor Coordination Problems in Physical Education [Baja competencia y problemas evolutivos de coordinación motriz en Educación Física]. *RICYDE. Revista Internacional de Ciencias Del Deporte*, *14*(52), 97–100. https://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=129220095&site=ehost-live

Ružbarská, I. (2020). Gross motor coordination in relation to weight status in 7- to 9-year-old children. *Acta Gymnica*, *50*(3), 105–112. https://search.ebscohost.com/login.aspx?direct=true&db=s3h&AN=147376611&site=ehost-live

Schmutz, E. A., Leeger-Aschmann, C. S., Kakebeeke, T. H., Zysset, A. E., Messerli-Bürgy, N., Stülb, K., Arhab, A., Meyer, A. H., Munsch, S., Puder, J. J., Jenni, O. G., & Kriemler, S. (2020). Motor Competence and Physical Activity in Early Childhood: Stability and Relationship. *Frontiers in Public Health*, *8*(February), 1–8. https://doi.org/10.3389/fpubh.2020.00039

Sgro, F., Quinto, A., Platania, F., & Lipoma, M. (2019). Assessing the impact of a physical education project based on games approach on the actual motor competence of primary school children. *Journal of Physical Education and Sport*, *19*(3), 781–786. https://doi.org/10.7752/jpes.2019.s3111

Sulistiadi, W., Kusuma, D., Amir, V., Tjandrarini, D. H., & Nurjana, M. A. (2023). Growing Up Unequal: Disparities of Childhood Overweight and Obesity in Indonesia's 514 Districts. *Healthcare (Switzerland)*, *11*(9), 1–13. https://doi.org/10.3390/healthcare11091322

Tsuda, E., Goodway, J. D., Famelia, R., & Brian, A. (2020). Relationship Between Fundamental Motor Skill Competence, Perceived Physical Competence and Free-Play Physical Activity in Children. *Research Quarterly for Exercise and Sport*, *91*(1), 55–63. https://doi.org/10.1080/02701367.2019.1646851

Wälti, M., Sallen, J., Adamakis, M., Ennigkeit, F., Gerlach, E., Heim, C., Jidovtseff, B., Kossyva, I., Labudová, J., Masaryková, D., Mombarg, R., De Sousa Morgado, L., Niederkofler, B., Niehues, M., Onofre, M., Pühse, U., Quitério, A., Scheuer, C., Seelig, H., … Herrmann, C. (2022). Basic Motor Competencies of 6- to 8-Year-Old Primary School Children in 10 European Countries: A Cross-Sectional Study on Associations With Age, Sex, Body Mass Index, and Physical Activity. *Frontiers in Psychology*, *13*(April), 1–12. https://doi.org/10.3389/fpsyg.2022.804753

Datos de los/as autores/as y traductor/a:

Arischo Mardiansyah	arischo@student.unp.ac.id	Autor/a
Syahrial Bakhtiar	syahrial@fik.unp.ac.id	Autor/a
Syafruddin	syafruddin5619@gmail.com	Autor/a
Risky Syahputra	riskys@fik.unp.ac.id	Autor/a
Lucy Pratama Putri	lucy.pratamaputri@gmail.com	Autor/a
Atradinal	atradinal99@fik.unp.ac.id	Autor/a
Romi Mardela	mardela@fik.unp.ac.id	Autor/a
Heru Afrian	heruafrian@gmail.com	Autor/a
Johan Pion	johan.pion@ugent.be	Autor/a
M. Smith, PhD	info@cambridgeproofreading.com	Traductor/a