Gross motor index and physical fitness among preschoolers: a cross-sectional study in Kuala Lumpur, Selangor, and Putrajaya

Índice de motricidad gruesa y aptitud física en niños preescolares: un estudio transversal en Kuala Lumpur, Selangor y Putrajaya

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Abstract

Introduction: Gross Motor Index is essential in children's physical development. However, there is limited evidence on the relationship of physical fitness with Gross Motor Index among preschool children in Malaysia.
Objective: This study aims to investigate the relationship of Gross Motor Index with physical fitness among preschool children in Kuala Lumpur, Selangor, and Putrajaya.
Methodology: This cross-sectional study involved 104 5 and 6-year-old preschool children who were assessed using the Test of Gross Motor Development – 3rd Edition (TGMD-3) to measure their Fundamental Movement Skills. Statistical analysis such as independent sample t-test, general linear model analysis, and Pearson product-moment correlation coefficients were used. Significant value was set as $p < 0.05$.
Result: Most of the preschool children were classified as borderline or delayed for the GMI (59.6%). Besides, girls had higher GMI scores than boys (76.06±6.82 vs 71.98±5.74, $p<0.001$). There was no significant association between GMI and physical fitness ($p>0.05$). Further analysis revealed that the 15-meter obstacle run demonstrated a significant correlation with locomotor skills ($r=-0.301$, $p=0.003$), whereas handgrip strength showed correlation with both locomotor skills ($r=0.207$, $p=0.043$), and ball control skills ($r=0.234$, $p=0.038$).
Discussion: This study showed that although there was no significant association of GMI with physical fitness overall, specific physical fitness, such as 15-meter obstacle run and handgrip strength, plays a crucial role in children's Fundamental Movement Skills.
Conclusion: In conclusion, future interventions should be focused on specific physical fitness development to support GMI development among preschool children.

Keywords

Fundamental movement skills; gross motor index.; muscle strength.; physical fitness.; preschool children.

Resumen

Introducción: El Índice Motor Grueso (GMI, por sus siglas en inglés) es esencial en el desarrollo físico infantil. Sin embargo, existe evidencia limitada sobre la relación entre la condición física y el Índice Motor Grueso en niños de edad preescolar en Malasia.
Objetivo: Este estudio tiene como objetivo investigar la relación entre el Índice Motor Grueso y la condición física en niños de edad preescolar en Kuala Lumpur, Selangor y Putrajaya.
Metodología: Este estudio transversal involucró a 104 niños preescolares de 5 y 6 años, quienes fueron evaluados mediante la Prueba de Desarrollo Motor Grueso - Tercera Edición (TGMD-3) para medir sus Habilidades Motrices Básicas. Se utilizaron análisis estadísticos como la prueba t de muestras independientes, el análisis de modelo lineal general y los coeficientes de correlación de Pearson. El valor de significancia se estableció en $p < 0.05$.
Resultado: La mayoría de los niños preescolares fueron clasificados en un nivel limítrofe o con retraso en el GMI (59.6%). Además, las niñas obtuvieron puntuaciones de GMI más altas que los niños (76.06±6.82 frente a 71.98±5.74, $p < 0.001$). No hubo una asociación significativa entre el GMI y la condición física ($p > 0.05$). Análisis posteriores revelaron que la carrera de obstáculos de 15 metros demostró una correlación significativa con las habilidades locomotoras ($r = -0.301$, $p = 0.003$), mientras que la fuerza de prensión manual (fuerza de agarre) mostró correlación tanto con las habilidades locomotoras ($r = 0.207$, $p = 0.043$) como con las habilidades de control de balón ($r = 0.234$, $p = 0.038$).
Discusión: Este estudio demostró que, aunque no hubo una asociación significativa del GMI con la condición física en general, componentes específicos de la condición física, como la carrera de obstáculos de 15 metros y la fuerza de prensión manual, desempeñan un papel crucial en las Habilidades Motrices Básicas de los niños.
Conclusión: En conclusión, las intervenciones futuras deberían centrarse en el desarrollo de componentes específicos de la condición física para apoyar el desarrollo del GMI en niños preescolares.

Palabras clave

Habilidades motoras fundamentales; índice motor grueso; fuerza muscular; condición física; niños en edad preescolar.

Introduction

The rising prevalence of obesity and physical fitness issues among children has become an escalating global concern in recent years (Phelps et al., 2024). The World Health Organization has identified childhood obesity as one of the most serious public health issues of the 21st century, affecting not only high-income countries but also low- and middle-income countries (World Health Organization (WHO), 2025). A study from the United States reported that only about one-quarter of children meet the minimum recommended levels of daily physical activity (Pfledderer et al., 2025). While research conducted in European countries also shows similar trends, with less than 30% of children achieving the recommended daily physical activity level (World Health Organization (WHO), 2022).

In Malaysia, the 2019 SEGAK report card showed that only 19.8% of adolescents aged 13 to 17 years old were physically active for at least 60 minutes per day on five or more days per week. However, the 2019 SEGAK report primarily focuses on adolescents, highlighting a gap in data for preschool children (Bahagian Pembangunan Kurikulum, 2016). In terms of physical fitness, data from the 2019 SEGAK indicate that Malaysian adolescents aged 10 to 17 years were ranked at the 67th percentile of flexibility. Nevertheless, there is a lack of national-level data on physical fitness among children aged 5 to 9 years, including preschool children (Universiti Kebangsaan Malaysia, 2022). This condition has received much attention in Putrajaya, as it is the administrative center of Malaysia. Although there is relatively good access to healthcare facilities, a systematic review and meta-analysis showed that Putrajaya had higher excess weight and obesity among children aged less than 18 years as compared to the overall national prevalence (Chua et al., 2024).

Studies have shown that low physical activity levels among children are associated with various health conditions, such as diabetes, cardiovascular disease, and psychological issues (Ahn & Fedewa, 2015; Gupta et al., 2012; Nga et al., 2019). In addition, reduced physical fitness among children not only negatively affects their ability to perform daily activities and increases their susceptibility to fatigue and physical injuries, but may also impair academic performance (Dapp et al., 2021; O'Hagan et al., 2022).

Fundamental movement skill is a motor activity that involves the use of large muscle groups within the body, often differentiated into three subsets: locomotor skills, ball skills, and stability skills (Logan et al., 2018). Gross Motor Index (GMI), a score calculated from the Test of Gross Motor Development – 3rd Edition (TGMD-3), is an index used to assess fundamental movement skill (Ulrich, 2019). Physical fitness, on the other hand, is conceptualized as either performance- or health-related fitness and is a set of attributes that people have or achieved (Campbell et al., 2013). Health-related fitness includes cardiorespiratory endurance, muscular endurance, muscular strength, body composition, and flexibility.

Motor competence, primarily reflected through fundamental movement skills (FMS), is a key determinant of physical activity, which can affect health status of children, such as health-related fitness and body weight status, particularly during early-to-middle childhood (Bremer & Cairney, 2018; Cairney et al., 2019; den Uil et al., 2023). A recent meta-analysis had identified the relationship between motor competence and physical fitness moderate to large, with $r = 0.43$, $p < 0.001$, after controlling for multiple effects (Utesch et al., 2019). This result supported the model from Stodden et al. (2008) where there is a positive relationship between motor competence and health-related fitness, and health-related fitness mediate the relationship between motor competence and physical activity. Children lacking motor skills may experience frustration and lower perceive competence, which reduces participation in physical activity, reduces health-related physical fitness, and increased the risk of obesity (Stodden et al., 2008).

Although there are several studies that have explored the relationship between FMS and physical fitness, there are two key research gaps that remain unexplored. Therefore, this study aims to address these gaps by identifying how FMS influences physical fitness among preschool children within the local context. The findings of this study are expected to contribute to the efforts in improving physical fitness and FMS among preschool children in Malaysia and to provide evidence-based strategies for tackling childhood obesity via enhancing physical fitness levels among preschool children.

There are three objectives of this study. Firstly, to determine the levels of FMS and physical fitness among 5 and 6-year-old children. Secondly, to identify the differences in the levels of FMS and physical fitness between sociodemographic factors among 5 and 6-year-old children. Thirdly, to determine the relationship between FMS and physical fitness among 5 and 6-year-old children.

Method

This study employed a quantitative cross-sectional design to assess the current level of Fundamental Movement Skills (FMS) among preschool children aged 5 and 6 years old. In addition, the study identified sociodemographic factors such as gender, age, height, weight, parental occupation, and residential location, including urban or rural, that may influence the development of these skills. This study also analyzed how FMS and physical fitness vary across demographic characteristics, as well as explored the correlation between FMS and physical fitness within this age group.

Participants

The study population consisted of preschool children aged 5 and 6 years old in the Central Zone of Malaysia, including Putrajaya, Kuala Lumpur, and Selangor. This zone was selected as it represents a mix of urban and rural areas, allowing for the inclusion of children from diverse sociodemographic backgrounds. The selection of this location also considered accessibility, the number of preschool institutions, and the feasibility in terms of cost and logistics.

The sample size was calculated using G*Power based on a correlation test, with a statistical power of 0.80, a significance level of 0.05, and a medium effect size of 0.30, which indicated a minimum requirement of 193 participants. To account for potential data loss or incomplete responses, a total of 200 participants were recruited for this study.

Procedure

Data collection was conducted using questionnaires and anthropometric assessment, with the assistance of enumerators. Enumerators were responsible for managing participant flow, administering the Fundamental Movement Skills (FMS) and Physical Fitness (PF) tests according to standardized procedures, accurately recording test results, and ensuring that all activities were conducted efficiently within the allocated time. All enumerators underwent prior training to ensure data consistency and quality. The use of enumerators was essential to minimize errors, facilitate the data collection process, and ensure that all participants were assessed systematically and in an organized manner.

Instrument

The Test of Gross Motor Development – 3rd Edition (TGMD-3) was used to assess the Fundamental Movement Skills (FMS). The TGMD-3 was an internationally recognized tool used to evaluate FMS among children aged 3 to 10 years old (Ulrich, 2019). It measured two primary domains: locomotor skills and ball skills, which are essential components of children's motor development. There were 5 components in locomotor skills. Run skill assessed the child's ability to move quickly. Jump skill evaluated the ability to jump using both feet. Hop skill measured the ability to jump on one foot. Horizontal jump skill assessed the ability to jump forward. Slide skill measured the ability to coordinate body movements while sliding. Next, there were 7 components in ball skills. The two-hand strike of a stationary ball skill assessed the ability to strike a stationary ball using both hands. One-hand strike of a bouncing ball skill measured the ability to strike a bouncing ball with one hand. Stationary dribble skill evaluated the ability to control and dribble a stationary ball. The catch with two hands skill measured the ability to catch a ball using both hands. Kicking a stationary ball skill assessed the ability to kick a stationary ball. Overhand throw skills measured the ability to throw a ball using an overhand technique. Underhand throw skills measured the ability to throw a ball using an underhand technique.

Physical fitness was assessed using the 2023 revised edition of the National Physical Fitness Measurement Standards Manual for Children Aged 3–6 Years. This manual was used to evaluate children's physical fitness and comprises two main components: physical form and physical quality. Physical form included anthropometric measurements, namely height, which was measured using a height and sitting height tester to ensure accuracy in both standing and sitting positions, and weight was recorded using a calibrated weight tester. Physical quality was evaluated using standardized field-based tests, including handgrip strength (upper body muscular strength), standing long jump (lower body explosive power), sit-and-reach test (flexibility of the lower back and hamstrings), continuous two-footed jumping (muscular endurance and coordination), a 15-meter obstacle run (agility and speed), and a balance beam walk (balance and postural control) (General Administration of Sport of China, 2023).

Data analysis

Statistical analysis was conducted using IBM SPSS Statistics version 30. Descriptive statistics, including means and standard deviation (SD), were used to describe the continuous variables, while frequency and percentage were used to describe the categorical variables. Tests of normality were performed to assess the distribution of continuous variables. Missing data was handled using the multiple imputation method.

Independent samples t-tests were conducted to examine the differences in Gross Motor Index (GMI) across gender. Differences in GMI by location were analyzed using the General Linear Model (GLM). Pearson's product-moment correlation coefficients were conducted to determine the association of physical fitness and Fundamental Movement Skills (FMS). Statistical significance was set at $p < 0.05$.

Ethical approval

Ethical approval had been obtained from Ethics Committee for Research Involving Human Subjects (JKEUPM) Universiti Putra Malaysia, Ref No: JKEUPM-2025-1199

Results

Table 1 presents the percentage of missing data for each study variable:

Table 1. Percentage of missing data

Variables	Missing (%)
Location	0.00
Gender	0.00
Age	0.00
Height (cm)	0.00
Body weight (kg)	0.00
Mid-Upper arm circumference (cm)	0.00
Waist circumference (cm)	0.00
Hip circumference (cm)	0.00
Continuous Two-Footed Forward Jump (s)	11.5
15-meter obstacle run (s)	0.96
Standing long jump (cm)	2.88
Sit-and-Reach (cm)	0.00
Grip strength (kg)	0.96
Locomotor run	22.12
Locomotor gallop	22.12
Locomotor hop	22.12
Locomotor skip	22.12
Locomotor horizontal jump	22.12
Locomotor slide	22.12
2-Hand strike of a stationary ball	22.12
1-Hand forehand strike of self-bounced ball	22.12
1-Hand stationary dribble	22.12
2-Hand catch	22.12
Kick a stationary ball	22.12
Overhand throw	22.12
Underhand throw	22.12

Multiple imputations were conducted to impute the missing data. Variables with missing data as shown in Table 1 were imputed. 5 Imputations were conducted. Imputations method was "Automatic", where SPSS automatically chose imputation method based on scan of the data.

Table 2. Descriptive results for sociodemographic variables (n = 104)

Variables	n (%)	Mean ± SD
Location		
Kuala Lumpur	46 (44.2)	
Selangor	22 (21.2)	
Putrajaya	36 (34.6)	
Gender		
Male	50 (48.1)	
Female	54 (51.9)	

Age (year)		
5	3 (2.9)	5.97 ± 0.17
6	101 (97.1)	

The sociodemographic characteristics of the study participants are presented in Table 2. Most children in this study are from Kuala Lumpur (44.2%), followed by Putrajaya and Selangor. The sample demonstrates a relatively balanced gender distribution, with 48.1% boys and 51.9% girls. For age, most of the children are 6 years old (97.1%).

Table 3. Descriptive results for anthropometric variables (n = 104)

Variables	Mean ± SD
Height (cm)	113.85 ± 4.99
Male	114.38 ± 4.37
Female	113.35 ± 5.50
Body weight (kg)	20.06 ± 4.66
Male	20.15 ± 4.12
Female	19.97 ± 5.14
Mid-Upper arm circumference (cm)	17.92 ± 4.05
Male	17.16 ± 3.48
Female	18.61 ± 4.44
Waist circumference (cm)	57.12 ± 10.41
Male	55.04 ± 12.65
Female	59.04 ± 7.41
Hip circumference (cm)	63.61 ± 9.43
Male	61.89 ± 11.44
Female	65.19 ± 6.83

Descriptive statistics for anthropometric variables are presented in Table 3. The mean height of the children is 113.85 ± 4.99 cm, while the mean body weight of the children is 20.06 ± 4.66 kg. For body circumference measurements, the mean mid-upper arm circumference (MUAC) is 17.92 ± 4.05 cm, and the mean waist circumference is 57.12 ± 10.41 cm. Finally, the mean hip circumference of the children in this study is 63.61 ± 9.43 cm.

Table 4. Descriptive results for physical fitness (n = 104)

Variables	Mean ± SD
Continuous Two-Footed Forward Jump (s)	5.41 ± 1.80
15-Meter Obstacle Run (s)	6.34 ± 1.26
Standing Long Jump (cm)	87.37 ± 18.34
Sit-and-Reach (cm)	26.58 ± 6.25
Handgrip strength (kg)	7.32 ± 1.74

Descriptive statistics for the physical fitness components are summarized in Table 4. The mean time for the continuous two-footed forward jump test is 5.41 ± 1.80 seconds, while the mean time for the 15-meter obstacle run is 6.34 ± 1.26 seconds. The mean distance achieved in the standing long jump is 87.37 ± 18.34 cm. For flexibility, the mean sit-and-reach score is 26.58 ± 6.25 cm. The mean handgrip strength recorded among the children is 7.32 ± 1.74 kg.

Table 5. Descriptive results for locomotor and ball skill raw score (n = 104)

Variables	Mean ± SD
Locomotor	
Run	2.91 ± 1.41
Gallop	2.86 ± 1.20
Hop	3.15 ± 1.11
Skip	2.33 ± 0.89
Horizontal jump	3.30 ± 0.95
Slide	3.65 ± 0.79
Ball	
2-Hand strike of a stationary ball	3.65 ± 1.36
1-Hand forehand strike of self-bounced ball	2.97 ± 1.61
1-Hand stationary dribble	2.02 ± 1.01
2-Hand catch	2.59 ± 0.74

Kick a stationary ball	3.25 ± 1.15
Overhand throw	3.08 ± 1.14
Underhand throw	3.07 ± 0.99

Descriptive statistics for the raw locomotor skill scores are summarized in Table 5. Overall, children demonstrate relatively higher proficiency in the slide skill, with a mean score of 3.65 ± 0.79. In contrast, the skip skill records the lowest level of performance among the locomotor skills, with a mean score of only 2.33 ± 0.89. Most children demonstrate good proficiency in the two-hand strike of a stationary ball, with a mean score of 3.65 ± 1.36. In contrast, the lowest performance was observed in the one-hand stationary dribble, with a mean score of 2.02 ± 1.01.

Table 6. Descriptive results for total locomotor skill score and total ball skill score (n = 104)

Variables	Mean ± SD	n (%)
Total locomotor skill score		
Raw score		
Scaled score		
1 – 3 (Impaired or delayed)		13 (12.5)
4 – 5 (Borderline impaired or delayed)	18.19 ± 3.51	48 (46.2)
6 – 7 (Below average)	5.04 ± 1.33	43 (41.3)
8 – 12 (Average)		0 (0.0)
13 – 14 (Above average)		0 (0.0)
15 – 16 (Superior)		0 (0.0)
17 – 20 (Gifted or very advanced)		0 (0.0)
Total ball skill score		
Raw score		
Scaled score		
1 – 3 (Impaired or delayed)		7 (6.7)
4 – 5 (Borderline impaired or delayed)	20.64 ± 4.85	28 (27.0)
6 – 7 (Below average)	6.20 ± 1.75	46 (44.2)
8 – 12 (Average)		23 (22.1)
13 – 14 (Above average)		0 (0.0)
15 – 16 (Superior)		0 (0.0)
17 – 20 (Gifted or very advanced)		0 (0.0)

Note: Frequencies are pooled estimates derived from multiple imputations and may be subject to rounding.

Descriptive statistics for the total locomotor and ball skill scores are summarized in Table 6. The mean locomotor raw score is 18.19 ± 3.51, with a corresponding scaled score of 5.04 ± 1.33. In terms of performance classification, 46.2% of the children are classified as being in the borderline or delayed category for locomotor skills.

For ball skills, the mean raw score is 20.64 ± 4.85, with a scaled score of 6.20 ± 1.75. A total of 44.2% of children were classified as below average in ball skill performance.

Table 7. Descriptive results for Gross Motor Index (n = 104)

Variables	Mean ± SD	n (%)
Gross Motor Index (GMI)	74.10 ± 6.64	
< 70 (Impaired or delayed)		24 (23.1)
70 – 79 (Borderline impaired or delayed)		62 (59.6)
80 – 89 (Below average)		17 (16.3)
90 – 109 (Average)		1 (1.0)
110 – 119 (Above average)		0 (0.0)
120 – 129 (Superior)		0 (0.0)
> 129 (Gifted or very advanced)		0 (0.0)

Note: Frequencies are pooled estimates derived from multiple imputations and may be subject to rounding.

Descriptive statistics for the Gross Motor Index (GMI) are summarized in Table 7. The mean GMI score among participants are 74.10 ± 6.64. Based on the classification of the scores, 59.6% of the children are classified as being in the borderline or delayed category.

Table 8. Differences in Gross Motor Index (GMI) based on sociodemographic factor

Variables	Mean ± SD	t	P value	95% CI
Gender				
Male	71.98 ± 5.74	-3.30	<0.001***	-6.50, -1.66
Female	76.06 ± 6.82			

***Significant differences, p< .001.

Differences in Gross Motor Index (GMI) across sociodemographic factor are presented in Table 8. Independent samples *t*-test are conducted to examine these differences. The results indicate that girls had significantly higher GMI scores as compared to boys, with mean scores of 76.06 ± 6.82 and 71.98 ± 5.74, respectively [t= -3.30, p < 0.001, 95% CI = -6.50, -1.66].

Table 9. Differences in Gross Motor Index (GMI) based on location

Variables	Mean ± SD
Location	
Kuala Lumpur	73.99 ± 6.86
Selangor	73.18 ± 6.34
Putrajaya	74.79 ± 6.57

Table 9a. Detailed analysis on the differences in Gross Motor Index (GMI) based on location

Variables	B	P value	95% CI
Location			
Putrajaya	Reference	Reference	Reference
Kuala Lumpur	-0.803	0.584	-3.679, 2.073
Selangor	-1.613	0.374	-5.166, 1.941

Differences in Gross Motor Index (GMI) across locations are presented in Table 9, with detailed analysis provided in Table 9a. Differences in GMI by location are analyzed using the General Linear Model (GLM) with pooled estimates following multiple imputations.

Descriptive statistics indicate that the mean GMI was highest among children in Putrajaya (74.79 ± 6.57), followed by Kuala Lumpur (73.99 ± 6.86) and Selangor (73.18 ± 6.34). However, GLM analysis indicates that the variation in GMI across locations was not statistically significant (p > 0.05), suggesting that geographical location did not have a meaningful effect on gross motor development among preschool children.

Table 10. Association of physical fitness with Gross Motor Index (GMI)

Variables	r	P value
Continuous Two-Footed Forward Jump (s)	-0.038	0.804
15-Meter Obstacle Run (s)	-0.131	0.197
Standing Long Jump (cm)	-0.052	0.662
Sit-and-Reach (cm)	0.101	0.350
Handgrip strength (kg)	0.109	0.336

Table 10a. Detailed analysis on the association of physical fitness with Gross Motor Index (GMI)

Variables	Locomotor skill		Ball skill	
	r	P value	r	P value
Continuous Two-Footed Forward Jump (s)	-0.189	0.081	0.003	0.983
15-Meter Obstacle Run (s)	-0.301	0.003**	-0.094	0.369
Standing Long Jump (cm)	0.111	0.366	0.085	0.476
Sit-and-Reach (cm)	0.033	0.748	0.070	0.509
Handgrip strength (kg)	0.207	0.043*	0.234	0.038*

*Significant differences, p< .05.
**Significant differences, p< .01.

The association of physical fitness with Gross Motor Index (GMI) is presented in Table 10. Pearson's product-moment correlation analysis is conducted to examine these associations. The results indicate that there is no significant association between any physical fitness variables and GMI.

Further analysis is conducted to examine the associations of specific components of GMI with physical fitness. As shown in Table 10a, a significant moderate negative association is observed between the 15-meter obstacle run and locomotor skills (r = -0.301, p = 0.003). In addition, a significant weak positive association is found between handgrip strength and locomotor skills (r = 0.207, p = 0.043), as well as between handgrip strength and ball skills (r = 0.234, p = 0.038).

Table 11 showed the association of physical fitness with GMI before and after adjusting for confounding effects. A hierarchical multiple linear regression was conducted across 5 multiply imputed datasets to evaluate the association of physical fitness on the GMI. The crude model, which included physical fitness indicators, explained a negligible portion of the variance (Mean adjusted R2 = 0.015). However, the addition of geographical locations, gender, and anthropometric confounders in adjusted model significantly improved model fit, accounting for approximately 16.7% of the total variance in the outcome (Mean adjusted R2 = 0.167).

Table 11. Multiple linear regression of the association between physical fitness and Gross Motor Index (GMI)

Variables	Crude Model		Adjusted Model	
	Unstandardized Beta-coefficient	95% CI	Unstandardized Beta-coefficient	95% CI
Continuous Two-Footed Forward Jump (s)	-0.135	-1.473, 1.203	0.108	-1.233, 1.449
15-Meter Obstacle Run (s)	-0.821	-2.005, 0.363	-2.039	-3.511, -0.567
Standing Long Jump (cm)	-0.054	-0.152, 0.044	-0.044	-0.145, 0.057
Sit-and-Reach (cm)	0.101	-0.121, 0.323	-0.004	-0.223, 0.216
Handgrip strength (kg)	0.372	-0.515, 1.260	0.812	-0.209, 1.833
Location				
Kuala Lumpur			Reference	Reference
Selangor			1.618	-2.739, 5.974
Putrajaya			5.172	1.362, 8.983
Gender			5.614	2.834, 8.394
Height (cm)			-0.084	-0.513, 0.344
Body weight (kg)			0.032	-0.728, 0.792
Mid-Upper arm circumference (cm)			-0.325	-1.056, 0.405
Waist circumference (cm)			0.048	-0.257, 0.353
Hip circumference (cm)			0.029	-0.267, 0.325

In the adjusted model, geographical location emerged as a significant independent predictor of Gross Motor Index. Specifically, children residing in Putrajaya exhibited significantly higher Gross Motor Index scores compared to those in the Kuala Lumpur reference group (B = 5.172, 95% CI = 1.362, 8.983), even when holding gender, physical fitness variables and body composition variables constant. No significant independent association was observed between children in Selangor and Kuala Lumpur (B = 1.618, 95% CI = -2.739, 5.974). Other primary independent predictors of the GMI included gender (B = 5.614, 95% CI = 2.834, 8.394) and 15-meter obstacle run (B = -2.039, 95% CI = -3.511, -0.567).

Discussion

The present study found that a substantial proportion of children were classified within the borderline or delayed category for Gross Motor Index (GMI) (59.6%), indicating a concerning level of suboptimal motor development. The present finding was supported by a study among 6 to 10 years old Columbia school children where 67.2% were below-average, poor or very poor motor development (Oyola et al., 2025). However. this finding contrasts with previous research conducted among seven-year-old children in Kuala Pilah, where the majority were reported to have average GMI levels (44.4%) (Mahinderjit Singh & Choon Lian, 2018). Several contextual factors may explain this discrepancy. Differences in environmental exposure, such as access to safe play spaces and opportunities for structured or unstructured physical activity, may influence motor skill development. Kuala Pilah is a town in Negeri Sembilan, Malaysia, which is not as developed as Putrajaya. Hence, children may have more leisure time to get involved in unstructured physical activity which improves their fundamental movement skills. Additionally, variations in daily activity patterns and sociodemographic characteristics could contribute to differences in motor competence across populations. For example, children who only walk on flat surfaces, such as school, shopping mall, and others in more developed area are developing differently from those who regularly navigate hills, sand, uneven terrain, or water. A wide variety of sensory-motor inputs build richer neural maps for movement control. Moreover, screen time may affect GMI too, where urban environments with high screen media access and less outdoor opportunity was highly associated with low GMI (Loureiro et al., 2026). The present study supports the importance of contextual and environmental influences in shaping preschool children's motor development. This highlights the importance of early intervention to enhance fundamental movement skills among preschool children, especially in urbanized areas.

The present study showed that there was a significant difference in GMI across gender, with girls outperforming boys. This finding suggests potential differences in motor development trajectories or engagement patterns between genders at preschool stage. However, the current findings are inconsistent with previous study conducted by Mahinderjit Singh & Choon Lian (2018), which revealed no significant differences across gender ($t = -1.53$, $p = 0.130$), as well as findings from China showed higher FMS levels among 3 to 6-year-old boys ($p < 0.010$) (Gao et al., 2024). These inconsistencies across studies may be attributed to several factors, such as differences in sample age, socio-cultural environments, levels of engagement in physical activity, and opportunities for participation in structured or unstructured play that affect the fundamental movement skills development. These findings highlight the need for gender-sensitive intervention strategies to ensure both genders develop fundamental movement skills during early life.

The absence of significant differences in GMI across locations may be explained by the similar socio-demographic characteristics shared by Putrajaya, Kuala Lumpur, and Selangor, including household educational levels, parental educational attainment, and access to preschool education, healthcare services, and adequate nutrition. These sociodemographic characteristics have been reported to be significantly associated with gross motor development in children (Kwon & O'neill, 2020). In addition, these regions are guided by the same national preschool curriculum, namely the Kurikulum Prasekolah 2026: Dokumen Kurikulum Prasekolah, which includes the learning area of Physical and Self-Well-being. This learning area emphasises physical development and health by strengthening basic movement, encouraging children's participation in physical activities, and promoting healthy and safe daily practices within preschool learning contexts (Bahagian Pembangunan Kurikulum, 2025). Consequently, similar exposure to learning experiences and opportunities for physical activity may contribute to the similarity of GMI among preschool children across these locations. This finding is also consistent with the motor development model proposed by Stodden et al. (2008), where individuals are influenced by environment in shaping children's fundamental movement skills through opportunities to be involved in physical activity. Therefore, the similar socioeconomic patterns and early childhood environment across these three locations contribute to the similar patterns of fundamental movement skills among preschool children.

The present study found no significant association between overall physical fitness and Gross Motor Index, suggesting that the overall measures of physical fitness may not directly affect overall motor competence among preschool children. However, further analysis revealed that specific components of physical fitness were significantly associated with specific motor skills. In particular, the 15-meter obstacle run, and handgrip strength were significantly associated with locomotor skills, while handgrip strength was also significantly associated with ball skills.

These findings are supported by study involving 7- to 8-year-old elementary school student, where strong association was found between locomotor skill and physical fitness ($r = 0.989$, $p < 0.05$) (Dewi et al., 2026). Moreover, another study involving 139 preschool children also supported the present findings where a weak but significant association between gross motor coordination and handgrip strength ($r = 0.178$, $p = 0.036$). In addition, the study identified a strong negative association between gross motor coordination and the 4 x 10 m shuttle run ($r = -0.742$, $p = 0.010$). However, the same study also reported different findings, including a moderate positive association between gross motor coordination and the sit-and-reach test ($r = 0.402$, $p = 0.010$), as well as a strong positive association with the standing long jump ($r = 0.601$, $p = 0.010$) (Stojiljković et al., 2024).

These inconsistencies may be attributed to differences in measurement approaches. The study by Stojiljković et al. (2024) utilized the Körperkoordinationstest für Kinder (KTK) to assess gross motor coordination, an instrument originally developed for European children that places greater emphasis on balance and locomotor coordination (Iivonen et al., 2015). Therefore, differences in assessment tools and the specific motor skill components measured may influence the strength of the relationships observed between physical fitness and gross motor skills across studies.

Overall, while no significant association was observed between overall physical fitness and the Gross Motor Index, specific components of physical fitness, such as agility and muscular strength, were found to be significantly associated with specific motor skills. Further hierarchical multiple linear regression showed that 15-meter obstacle run was significantly associated with GMI after controlling for gender, location, and anthropometry factors. These findings suggest that the development of specific physical fitness components may play a role in supporting gross motor skill development among children.

Locomotor skills, such as running, hopping, and horizontal jumping, involve coordinated movements of the lower limbs, balance, and movement efficiency, all of which are essential elements of agility. The 15-meter obstacle run, commonly used as a measure of agility, requires rapid changes in movement patterns, dynamic balance, and neuromuscular coordination. These abilities are fundamental components in the development of locomotor skills. This assertion is supported by a recent systematic review Liu et al. (2023), which reported a significant association between locomotor skills and muscular strength and endurance. The observed relationship may be explained by the execution of locomotor skills, which requires the generation and control of physical force during movement. These capabilities are closely associated with muscular strength and the functioning of the neuromuscular system that regulates muscle activity (Stodden et al., 2013). These findings are consistent with the motor competence model proposed by Stodden et al. (2008), which suggests a bidirectional relationship between motor competence and physical fitness, whereby both influence and reinforce each other throughout childhood. Consequently, children with higher levels of locomotor skill proficiency are likely to demonstrate more efficient movement mechanics and neuromuscular control. This, in turn, enhances their performance in agility-based tasks, such as obstacle run, enabling them to complete the test more effectively.

According to the conceptual model proposed by Stodden et al. (2008), motor skill competence is closely related to health-related physical fitness, including muscular strength, throughout child development. Children with higher levels of motor competence are more likely to perform better in physical activities that stimulate muscular development, thereby contributing to overall physical strength. Consistent with this framework, several studies have demonstrated that children with higher levels of fundamental movement skills also exhibit better physical fitness indicators, including handgrip strength (Liu et al., 2023). These findings suggest that the development of fundamental movement skills is not only essential for movement proficiency but also plays a critical role in supporting physical fitness development among children.

The non-significant relationship between the Gross Motor Index and physical fitness observed in this study may be attributed to the relative separation between fundamental movement skills and physical fitness during early childhood. At this development stage, these two domains often operate independently. Physical fitness among preschool children is largely influenced by biological maturation and volume of high-intensity free play, rather than the mechanical efficiency of their movements. At this stage, children may maintain adequate levels of physical fitness through high levels of activity alone, even if their fundamental movement skills are not yet fully developed. As children grow older and transition into more structured physical environments, physical fitness may become an important mediator in the relationship between fundamental movement skills and physical activity. This perspective aligns with the theoretical framework proposed by Stodden et al. (2008), which suggests that the synergy between these variables is a longitudinal process that strengthens over time, particularly as children progress beyond the "proficiency barrier".

This study has several strengths. First, it is among the earliest studies to examine the relationship between physical fitness and Gross Motor Index among preschool children in Kuala Lumpur, Selangor, and Putrajaya. As such, the findings provide important baseline information for the development of future interventions aimed at improving physical fitness and fundamental movement skills among children in these areas. However, this study also has several limitations. The cross-sectional design limits the ability to draw causal inferences regarding the relationship between physical fitness and GMI. Therefore, future research is recommended to adopt more robust study designs, such as randomized controlled trials (RCTs), to better understand the directional relationship between physical fitness and gross motor development. Such approaches would provide stronger evidence regarding the bidirectional relationship between physical fitness and motor development in children.

Conclusions

Overall, the findings of this study indicate that there is a significant relationship between 15-meter obstacle run and Gross Motor Index after controlling for confounders. In addition, specific components of physical fitness, such as agility and muscular strength, were associated with specific domains of gross motor skills, especially locomotor and ball skills. These results suggest that motor skills development and physical fitness are interrelated, consistent with the conceptual model proposed by Stodden et al. (2008), which emphasizes the dynamic relationship between motor competence and physical fitness throughout child development. However, due the weak and moderate association observed between physical fitness and GMI, the result needs to be interpreted cautiously, and future study is warranted with larger study population.

Therefore, interventions aimed at improving gross motor skills among children should also emphasize the development of specific physical fitness components, particularly muscular strength and agility. Such a comprehensive approach has the potential to enhance fundamental movement skills and support optimal physical development in children, thus reducing the prevalence of childhood obesity.

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