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Gender and grade-level differences in fundamental movement skills among Thai school children: The KIDDO protocol

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ABSTRACT

Background: Fundamental movement skills (FMS) are a core component of children's physical literacy. Proficiency in these skills is crucial for fostering lifelong participation in physical activity, enhancing confidence in motor abilities, and promoting overall healthy development. However, to date, no studies have employed the KIDDO-a standardized assessment tool with extensive international validation-to systematically evaluate the FMS of Thai children.

Objectives: This study aimed to compare FMS across different genders and grade levels among Thai primary school children aged 6-8 years. It was hypothesized that (a) boys would outperform girls in speed- and power-dependent tasks, (b) girls would outperform boys in flexibility-based tasks, and (c) physical fitness performance would improve progressively with increasing grade level across most measures.

Materials and methods: FMS were assessed in 138 Thai schoolchildren aged 6-8 years from three public primary schools in Khon Kaen province using the KIDDO protocols. The assessment included a range of physical tests, including height, weight, body mass index (BMI), and FMS, which consisted of a 50-meter sprint, a seated forward bend, and a one-minute rope-skipping exercise. All data were presented as descriptive statistics (means, standard deviations, and percentiles) and analyzed by gender and grade level for each measured variable.

Results: Results showed significant differences in performance by both gender and grade level ($p<0.05$). Specifically, boys outperformed girls in speed-based tasks, demonstrating greater sprinting abilities, while girls exhibited superior flexibility in the seated forward bending test. Additionally, it was found that physical attributes and motor performance generally improved as children progressed in age and grade level.

Conclusion: This study reveals a dual-patterned development of FMS in Thai children aged 6-8: a gender-specific divergence, with boys excelling in speed/power tasks and girls in flexibility, alongside a grade-sensitive critical period where Grade 2 students peak in multiple skills. These findings underscore the non-linear, phase-specific nature of early motor development. Consequently, physical education should evolve from a universal to a targeted, phase-adaptive approach, tailoring interventions to address gender gaps and leverage grade-specific developmental windows.

Introduction

A 2021 study reported that fewer than 30% of children and adolescents worldwide meet the recommended 60 minutes of daily moderate-to-vigorous physical activity (MVPA).[1] Before the COVID-19 pandemic, approximately 71% of children and adolescents globally and in Europe were not meeting the recommended PA levels. During the pandemic, only 19% of Thai adolescents (aged 6-17) met MVPA criteria, down from 20-28% between 2012 and 2019.[2] Overall, only 27% of children met the recommended daily 60-minute physical activity target, with a higher proportion of boys (31%) than girls (23%). Additionally, approximately 37% participated in organized sports (graded D+), and only 25% achieved the required standardized percentile benchmarks (graded D).[3] According to 2021 school health data, 89% of Thai children (aged 5-17) were classified as "normal weight" (Grade A), and 54% of the sample demonstrated "good" physical literacy (Grade C+).[2] In addition, the prevalence of childhood obesity in Khon Kaen ranged from 10.8% to 13.7%. Obesity was significantly more prevalent among boys than girls, with the largest differences in obesity rates observed across different types of schools.[4,5]

Early development of fundamental movement skills (FMS) is crucial for continued PA participation through childhood and adolescence.[6] Mastery of FMS during early childhood is pivotal, as it enables children to effectively participate in a variety of PA and sports, fostering lifelong retention of these. Proficiency in FMS allows adolescents to develop specialized movement patterns essential for engaging in diverse PA. In contrast, inadequate FMS can lead to negative psychosocial outcomes, including peer difficulties and low self-esteem, potentially affecting psychological well-being.[7] Furthermore, research has indicated that higher levels of FMS among school-aged children are associated with improved cognitive and academic performance.[6]

Interestingly, the KIDDO protocol has been shown to significantly improve children's movement skills, including running, jumping, balancing, and coordination, as well as strength, flexibility, and endurance. These improvements have been sustained over time, demonstrating the KIDDO intervention's efficacy. In contrast, no significant changes were observed in the control group. The findings suggest that systematic physical education and motor skill training, as implemented through the KIDDO protocol, have a long-term positive impact on children's physical literacy.[8] The KIDDO protocol supports the development of fundamental motor abilities in children, including running, jumping, balancing, and coordination, while also enhancing flexibility and overall physical competence. Enhancing PA and motor skill proficiency may help children manage body weight, reduce obesity risk, and improve self-confidence and social skills.

However, no previous research has examined FMS in Thai children, particularly using the KIDDO assessment. This study employed core modules of the

KIDDO assessment for children aged 6-8, focusing on three skill domains. Locomotor skills were evaluated through a 50-meter sprint run. Object control skills were assessed using a 1-minute rope-jumping test as a proxy for coordination and manipulation. Balance and stability skills were partially measured by the sit-and-reach test to assess flexibility related to postural control. Additionally, Thai primary school students aged 6 to 8 remain uncertain in terms of physical fitness levels. Currently, it is unclear how physical fitness components-such as strength, balance, and flexibility-manifest in this population, or what factors contribute to differences by gender and grade level. It was hypothesized that (a) boys would outperform girls in speed- and power-dependent tasks, (b) girls would outperform boys in flexibility-based tasks, and (c) physical fitness performance would improve progressively with increasing grade level across the majority of measures.

This study therefore aimed to investigate the FMS of Thai children, focusing on school-age children, such as physical posture, coordination, muscular strength, flexibility, explosiveness, and other related abilities. Based on the study's findings, this work aims to provide key information to inform effective strategies to increase moderate-to-vigorous physical activity and overall health among Thai children.

Materials and methods

Participants

This study employed a two-stage sampling approach for participant recruitment. First, three public primary schools in Khon Kaen province, Thailand, were purposively selected to represent rural, urban, and suburban settings. Second, stratified random sampling was conducted within each school to enroll children aged 6-8 years, with stratification by grade level and gender. Randomization was performed using computer-generated sequences until the predefined sample sizes were achieved.

Inclusion criteria required children to be aged 6-8 years, in good general health, and to provide written parental or guardian consent and child verbal assent, while exclusion criteria included engagement in long-term professional physical training (>5 hours/week), non-completion of assessments, or physical or mental disabilities. A total of 138 children (56 girls, 82 boys, six-year-olds in the first grade, seven-year-olds in the second grade, and eight-year-olds in the third grade) were recruited from government and demonstration schools in Khon Kaen. Ethical approval was obtained from the Ethics Committee of Khon Kaen University (No. HE672147) in accordance with the Declaration of Helsinki, with written informed consent from parents/guardians and verbal assent from children secured. To ensure methodological rigor, potential confounding variables, such as maturation, by restricting age ranges and conducting stratified analyses by age and grade. Assessors received standardized training, including protocol familiarization, equipment use, and delivery of uniform instructions during the pilot study. The pilot sample comprised 30 children aged 6-8 years (15 boys, 15 girls), recruited using the same inclusion/exclusion criteria as the main study. Intra-rater reliability was assessed using the ICC(2,1) with a 7-day interval between two rating sessions conducted by the same rater, yielding an ICC of 0.92 (95% CI: 0.86-0.96). Inter-rater reliability was evaluated using Pearson's correlation coefficient between two independent raters (r=0.94). Both values indicate excellent reliability. All data were anonymized immediately following collection.

Before full-scale implementation, comprehensive pilot testing and protocol validation were conducted for the Thai population to ensure cultural suitability, standardized procedures, and equipment familiarity. All test administrators received systematic training, and a pilot study with eligible children was conducted to optimize testing flow, confirm the clarity of instructions for children aged 6–8 years, and assess feasibility within school schedules.

Anthropometry and fundamental movement skills assessment

Age, height, weight, and body mass index

Participants were primarily grouped by school grade (Grades 1-3) for practical and educational reasons; however, chronological age (in years) was included as a continuous covariate in the statistical analyses to adjust for age-related variation in physical fitness outcomes. The procedures for height and weight measurement have been described in detail in a previous study.[9] Each participant was instructed to wear loose-fitting clothing and to remove their shoes prior to the measurement. Height was measured using a standard stadiometer, with participants standing upright, head in the horizontal plane, and back against the measuring board. It was ensured that the head, shoulders, hips, and heels all contacted the board, and that the eyes were parallel to the floor. The feet should face outward at a 60-degree angle. Participants were asked to remain still, with their bodies fully extended and not angled during the measurement. Height was recorded to the nearest 0.1 centimeter. Weight was measured using a calibrated digital scale. Participants stood still on the scale, and weight was recorded to the nearest 0.1 kilogram. Body Mass Index (BMI) was calculated using the formula: BMI = weight (kg) / height (m^2).

50-meter sprint test

The 50-meter run reflects neural adaptability, body coordination, joint and muscle flexibility, and muscular strength and endurance. It partially represents the comprehensive nature of movement and the fundamental physical attributes essential for sports participation and skill acquisition. In terms of validity, the 50-meter dash is a reliable indicator of speed and acceleration-key components of physical fitness in

children (ICC=0.904).[10]

Participants were asked to complete a proper warm-up and wear suitable athletic footwear. The test began with the participant standing behind the start line, and timing started at the signal and stopped at the finish line. The participants were instructed to sprint at maximal effort along a straight track. The 50-meter sprint test is typically conducted twice to allow participants to adapt and perform optimally, thereby ensuring data reliability. The time for each trial is recorded to the nearest 0.1 second, and the faster of the two times is taken as the final score. After each trial, a rest period of at least 10 minutes should be provided. After the evaluation, participants performed light stretching and jogging as part of a cool-down routine.

Sit-and-reach flexibility test

The seated forward bend test evaluates flexibility by measuring joint range of motion and the extensibility of muscles, tendons, ligaments, and surrounding tissues. Flexibility is a key component of physical fitness and is commonly assessed using the sit-and-reach test, which demonstrates moderate to excellent criterion-related validity for hamstring extensibility, with corrected correlation coefficients ranging from 0.46 to 0.67. Variations such as the back-saver and chair sit-and-reach tests have also been validated. The back-saver sit-and-reach, which assesses one leg at a time, has been confirmed as a reliable alternative to the traditional method.[11]

After completing a standardized warm-up and removing footwear, the participant sat on the floor with the legs fully extended and the soles of both feet placed flat against the testing board. The feet were positioned facing outward at a 60-degree angle. Then, while keeping the knees straight, the participant slowly used the middle fingers of both hands to slide the cursor forward to the farthest position and held for one second, with the best score being recorded. The core of this method was standardization to ensure the measurement reflected true joint and muscle flexibility, rather than values achieved through compensatory movements. Two consecutive measurements were taken, and the best score was recorded to the nearest 0.1 cm. The sit-and-reach test was administered to assess lower back and hamstring flexibility. Performance was measured in centimeters (cm). A positive value indicated that the participant reached beyond the toes, whereas a negative value indicated that the participant could not reach the toes.

One-minute jump rope

The 1-minute jump rope test is a reliable and valid assessment of physical agility, coordination, rhythmic movement, and lower limb strength, which reflects the participant's cardiorespiratory endurance and coordination. It demonstrates high inter-rater reliability (r=0.95) and has been shown to correlate strongly with established measures of physical fitness, including aerobic capacity and muscular endurance.[12] Before the test, the researcher ensured that the rope was appropriately sized-its ends reaching armpit level when the participant stood on the midpoint. During the test, participants held the rope handles with both hands and jumped continuously for one minute using either one foot, both feet alternately, or both feet simultaneously. A stopwatch was used to time the test, and the total number of successful jumps was counted. For the one-minute rope skipping test, participants are allowed two attempts, with the best score recorded.

Statistical analysis

Data were analyzed using SPSS version 28.0. Descriptive statistics, including means, standard deviations, and percentiles, were calculated for each variable by gender and grade level. Independent t-tests were conducted to compare mean differences in anthropometry and FMS assessment between boys and girls. Percentile analyses were used to examine the distribution of each variable across genders. One-way ANOVA was employed to assess differences in physical characteristics and FMS among the three grade levels. When significant differences were found, post hoc comparisons using Tukey's HSD test identified specific group differences. A $p<0.05$ was considered statistically significant. All significant between-group differences were further examined for their potential practical implications. The sample size was calculated using an independent samples t-test formula with parameters set at $\alpha=0.05$, power=0.80, and a large effect size (d=0.50), yielding an initial estimate of 116 subjects, which was then increased to 138 subjects after accounting for a 20% attrition rate.

Results

Figure 1 shows the results of the individual anthropometry and fundamental skill tests for each subject, by gender. Girls were taller than boys at the 95th percentile. Boys' heights were more evenly distributed, but girls' heights varied more. Girls were substantially heavier than boys at the 95th percentile, which could indicate a higher range in weight distribution among girls. Girls had a much higher BMI than boys at the percentile, which could be attributed to a greater weight difference. Boys showed a more concentrated BMI range, whereas girls showed more fluctuation at the higher end of BMI. Boys outperformed girls in the 50-meter run, finishing faster. Girls exhibited longer times in the top percentile, indicating a speed disparity. While girls outperformed boys in flexibility, particularly in the upper percentile. Boys had a relative concentration in flexibility, but girls displayed a significant difference in flexibility. Boys generally outperformed girls in the jump rope test, particularly in the upper percentile. Girls' jump rope performance was equivalent to girls at the 50th percentile, but there was a substantial difference at the highest percentile.

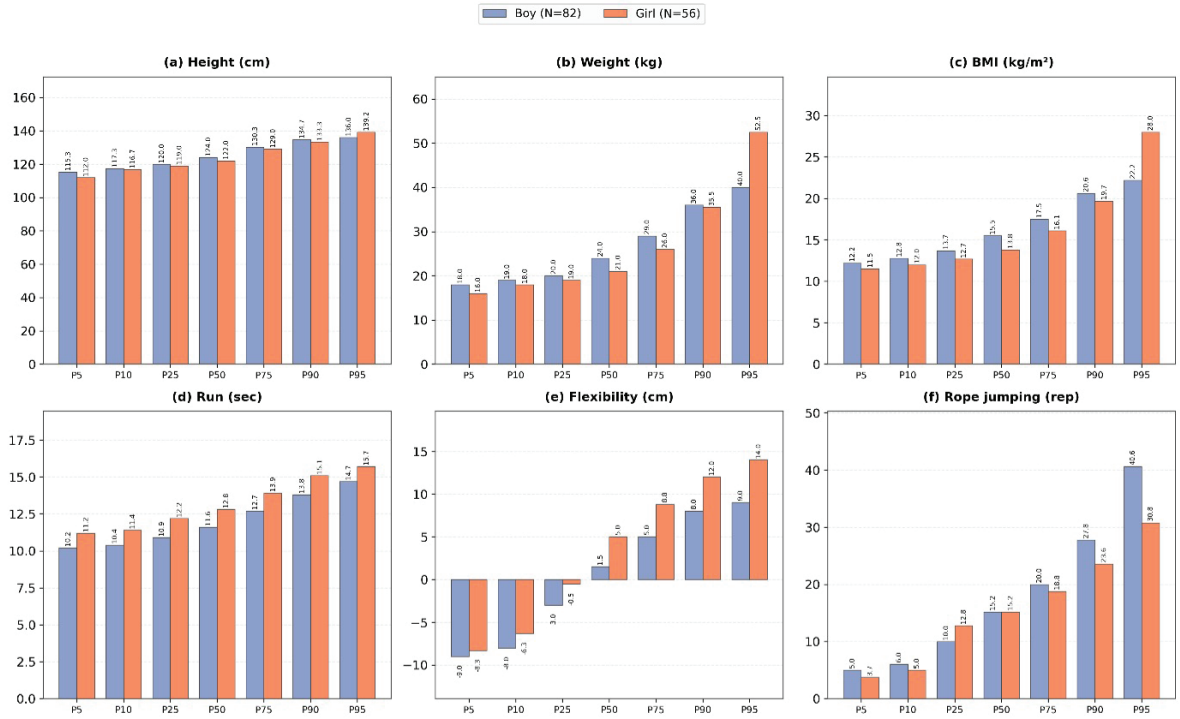


Figure 1. Percentiles of fundamental movement skill of boys and girls (N=138 children; 56 girls and 82 boys).

Figure 2 shows individual exercise test results by grade level. The findings showed that pupils' heights gradually increased from Grade 1 to Grade 3, indicating a considerable gain in height as they progressed through the grade levels. Grade 3 children had a wider range of heights, from 121 to 146.0 cm, indicating a larger height difference. Weight increased proportionally with grade, with Grade 3 having the biggest variance. At Grade 3, the 95th percentile body weight was 49.0 kg, substantially higher than the 5th percentile value of 24.0 kg, indicating pronounced weight variability among third-grade students. BMI increased with grade, with Grade 2 having the greatest range, particularly at 29.1 kg at the 95th percentile, indicating substantial weight gain at that grade.

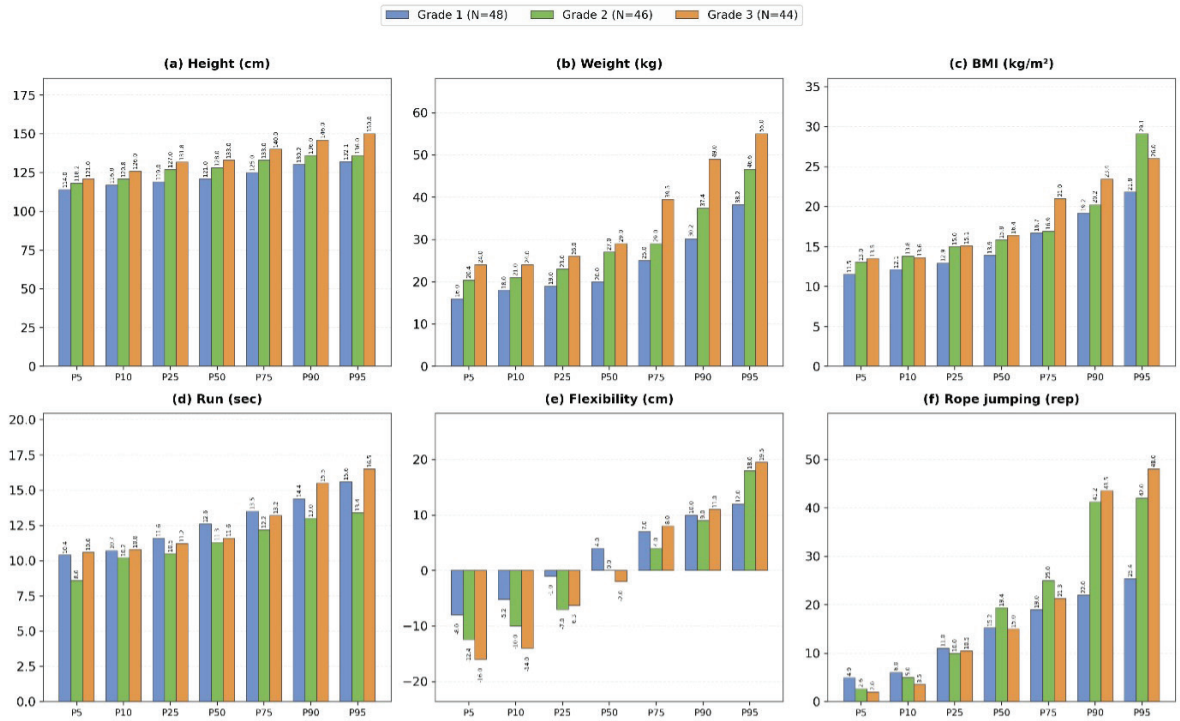


Figure 2. Percentiles of fundamental movement skills of children, Grade 1-Grade 3 (N=138).

As BMI is a ratio of weight to height, increases in both height and weight affect BMI values. The BMI data indicate normal physiological changes in student body size across grades but notably highlight a potential severe obesity issue among second graders (P95=29.1). Although the third-grade data remain elevated (P95=26.0), they suggest a trend of return toward normalcy. The 50-meter run was the best-performing event in Grade 2 (shortest time), indicating that Grade 2 students were faster. Students in Grades 1 and 3 did not do that well, particularly at the higher percentile times. In Grade 2, flexibility showed the strongest performance, particularly at the high percentile. Flexibility in Grade 3 was marginally less remarkable, particularly when compared to the 5th and 50th percentiles. Grade 2 showed the best jump rope performance, reaching 42.0 reps at the 95th percentile. The development of fundamental movement skills did not follow a uniform pattern across grades. So, Grade 2 showed the strongest overall performance in running and rope jumping. However, for high-percentile performance, third grade (G3) excelled in rope jumping and flexibility at the top end, while also showing the greatest individual variation. Furthermore, the performance range-the gap between the 5th and 95th percentiles-expanded with increasing grade levels for nearly all skills, with the differences being most pronounced in the third grade.

Table 1 presents the mean values for boys and girls across all measured variables. Height did not differ significantly between genders (p>0.05). A significant difference in body weight was observed between boys and girls (p<0.01). On average, boys weighed 23.83±3.98 kg, which was considerably higher than girls' average weight (21.8±4.1 kg). Boys had a considerably higher body weight than girls (p<0.05). The average weight of boys was 23.83±3.98 kg, and 21.8±4.1 kg for girls (p<0.01). Mean BMI differed significantly between boys and girls, with boys having a higher value (15.17 kg/m^2) than girls (14.15 kg/m^2) (p<0.05). Running ability differed significantly between genders (p<0.001), with girls outperforming boys on average. Flexibility differed considerably between genders, with girls exhibiting greater flexibility than boys (p=0.004). Boys' mean flexibility was 0.63 cm, while girls' mean flexibility was 3.71 cm (p=0.004). No significant difference was found in rope skipping performance between boys and girls (14.59±6.31 vs. 14.77±5.47, p>0.05).

Table 2 shows significant differences in height, weight, running time, and flexibility among grades (p<0.05). Height and weight increased significantly with grade level (p=0.001) for both genders. Running time was significantly faster for second graders (p=0.003), and flexibility was best in first grade, with flexibility decreasing in subsequent grades (p=0.004). However, BMI and number of rope jumps did not differ significantly between grades (p>0.05), indicating more consistent performance across grades on these two parameters. Overall, the data show that physical development increases as grade levels rise, and performance on certain core movement skill markers differs.

Table 1. The differences in fundamental movement skills between genders (N=138 children; 56 girls and 82 boys).

Variables	**Boy** (N=82)	**Girl** (N=56)	**t**	***p***
Height (cm)	125.12±6.17	123.91±7.16	1.06	0.291
Weight (kg)	23.83±3.98*	21.8±4.1	2.9	0.004*
BMI (kg/m^2)	15.17±1.93*	14.15±2.04	2.965	0.004*
Run (sec)	11.92±1.32*	12.89±1.16	-4.468	0.000*
Flexibility (cm)	0.63±5.72	3.71±6.67*	-2.901	0.004*
Rope jumping (rep)	14.59±6.31	14.77±5.47	-0.176	0.861

Note: *significant difference between boys and girls (p<0.05).

Table 2. Differences in fundamental movement skills across grade levels (N=138).

Variables	**Grade 1** (N=48)	**Grade 2** (N=46)	**Grade 3** (N=44)	**F**	***p***
Height (cm)	122.13±5.19^a	128.96±5.09^b	133.57±6^c	40.411	0.001
Weight (kg)	21.73±3.88^a	25.7±3.17^b	26.64±2.76^c	20.151	0.001
BMI (kg/m^2)	14.53±2.17	15.42±1.35	15±1.89	2.176	0.117
Run (sec)	12.53±1.33^a	11.53±0.96^b	12.31±1.58	6.219	0.003
Flexibility (cm)	3.03±5.59^a	-0.85±6.34^b	-0.79±8.55	5.811	0.004
Rope jumping (rep)	14.76±5.9	15±6.5	13.29±5.57	0.427	0.653

Note: ^{a,b,c} indicate statistically significant pairwise differences between grades (p<0.05). ^{a}Grade 1 vs Grade 2, ^{b}Grade 2 vs Grade 3, ^{c}Grade 1 vs Grade 3.

Discussion

Fundamental movement skills are considered a key health indicator in children. However, their diagnostic value in assessing children's health is often overlooked in schools and lower educational levels. The current study revealed significant differences between boys and girls in various FMS indicators, highlighting the role of gender in physical development and performance. Height and weight are crucial indicators of children's growth and health, particularly considering the increasing global prevalence of obesity. Proper growth in height and weight reflects good nutrition, overall health, and self-confidence.[13,14] This is consistent with previous studies, which show that prepubertal girls typically experience growth spurts earlier than boys at certain ages.[15] Girls' weight was also higher than boys' at the 95th percentile, indicating greater variability in the distribution of weight among girls. These weight differences may be attributed to gender-related variations in dietary habits, metabolic rate, and body fat distribution.[16]

Our results showed a significant increase in height and weight as grade increased. In addition, girls exhibited significantly higher BMI than boys at the 95th percentile, which may be attributed to differences in body weight. Girls with a high BMI may face increased health risks, including obesity.[17] The observed rise in BMI across grade levels suggests a faster rate of weight gain, particularly in the second grade, which may coincide with a period of accelerated growth in children.[18] While the increase in BMI reflects concurrent gains in both height and weight, it also highlights the need for vigilance regarding excessive weight gain in individual children. Based on the analysis of physical fitness and motor skill data among Thai school-aged children, this study identified several key findings: a notable obesity risk among second-grade students (with a BMI at the P95 percentile as high as 29.1) and a clear polarization trend in jump rope performance, where low-skilled students showed limited improvement while high-skilled students excelled. These findings indicate that FMS serve as a critical foundation for engaging in MVPA. Accordingly, it is recommended to strengthen FMS training within school curricula, design diverse and enjoyable activities, and establish a supportive family-school-community network. Such integrated efforts can effectively enhance children's MVPA levels, break the "low motor competence—low physical activity" cycle, and promote their overall health development.

The 50-meter run is a key indicator of motor skills, as well as lower-body muscle strength and endurance.[8,19] In our study, boys outperformed girls in the 50-meter run, particularly at the higher percentiles. This suggests that boys generally demonstrate superior speed and strength, which may be attributed to greater muscle mass and physiological differences.[20] These findings align with previous research indicating that boys typically outperform girls in measures of explosive power and speed. Notably, second-grade students performed best in the 50-meter run, possibly due to improved physical coordination and muscle development at this stage.[21] In contrast, the lower performance of first- and third-grade students at the higher percentiles may reflect inconsistent development of speed and endurance among some students in these age groups.

Improved flexibility enhances balance and coordination, thereby contributing to greater stability during physical activity.[22,23] In children aged 6–8 years, the body undergoes rapid physical development. Therefore, flexibility training should be age-appropriate-gentle, engaging, and incorporated through simple stretching games and activities. This study found that girls performed significantly better than boys on the seated forward bend test, particularly at the higher percentiles. This advantage may be attributed to physiological differences in tendon and ligament elasticity.[24] Among grade levels, second-grade students showed the highest flexibility scores, especially at the upper percentile ranks. In contrast, third-grade students demonstrated slightly lower flexibility, particularly at the 5th and 50th percentiles. These patterns may reflect developmental changes in flexibility across stages of physical growth.

Rope skipping, a stretch-shortening cycle (SSC) activity, enhances jumping ability and overall fitness by improving body mass index, cardiorespiratory endurance, motor coordination, agility, speed, strength, and balance.[25] In this study, boys outperformed girls in the jump rope test, particularly at the higher percentiles. However, no significant gender differences were observed at the 50th percentile. These variations may be attributed to differences in muscular strength, endurance, and coordination between genders.[26] Second-grade students achieved the highest scores, especially at the 95th percentile, suggesting better endurance and coordination development at this stage. In contrast, the lower performance of first- and third-grade students may reflect developmental variability across age groups.

In summary, FMS among the sampled group of Thai children varied significantly by gender and grade level. These findings suggest implications for developing tailored exercise and PA programs in similar contexts. However, the study's sample size and limited geographic scope limit the generalizability of the results to all Thai children, as participants were drawn from only three schools in Khon Kaen province. Workout programs, for example, can be tailored to target flexibility and coordination in girls while emphasizing strength and speed in boys. Children with high BMIs or rapid weight growth should receive early intervention and health education to avoid obesity and related health problems. Schools should conduct regular assessments of fundamental movement abilities to evaluate student performance and adjust physical education curricula and training techniques as needed. Further research is needed

to investigate the correlations between various core movement skill indicators and how specific activities can help youngsters develop their overall movement skills. Furthermore, it is critical to explore how FMS differ among children from various socioeconomic backgrounds and cultural contexts.

Limitations

This study has several limitations. First, the relatively small sample size (n = 138) and recruitment from only three public schools in Khon Kaen province may limit the generalizability of the findings to the wider Thai child population. Second, the inclusion of children aged 6–8 years restricts the applicability of the results to other developmental stages. Third, the assessment focused on three physical performance tests, which may not comprehensively represent all domains of fundamental movement skills. Furthermore, potential confounding factors, including biological maturation, socioeconomic status, and habitual physical activity, were not directly assessed or controlled. These limitations should be considered when interpreting the findings.

Conclusion

The findings of the present study revealed that, within this specific group of subjects, gender and grade level significantly influenced children's FMS and physical characteristics. Girls demonstrated superior flexibility, while boys excelled in the 50-meter run and jump rope tests. First graders exhibited the highest flexibility, second graders were the fastest runners, and second graders also performed best in the jump rope test. However, despite the considerable differences across grades, BMI and jump rope performance remained relatively consistent across grades. Therefore, our findings emphasize the importance of considering both gender and grade-level differences when designing physical education curricula and training programs.

Ethical approval

The study was approved by the Ethics Committee of Khon Kaen University (HE672147).

Declaration of generative AI and AI-assisted technologies

The authors declare used Google Gemini generative AI for only preparing the graphical abstract. The authors have reviewed and edited the contents and took full responsibility for the accuracy and originality. The AI tool was not used to generate novel concepts, analyze data, conduct literature retrieval, or draw scientific conclusions. All edits were critically evaluated, verified, and finalized by the author(s), who retain full accountability for the integrity and accuracy of the entire manuscript.

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Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

CRediT authorship contribution statement

Xueliang Zou: conceptualization, methodology, data collection, data curation, formal analysis, writing-original draft, review and edit; **Kurusart Konharn**: conceptualization, methodology, formal analysis, interpretation, supervision, writing-review and edit; **Wichai Eungpinichpong**: review and edit; **Changai Zhang:** review and edit; **Michael Rosenberg**: resources, methodology and supervision.

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