©Journal of Sports Science and Medicine (2026) **25**, 291-302
http://www.jssm.org DOI: https://doi.org/10.52082/jssm.2026.291

Research article

Is Higher Frequency Always Better? The Dose-Response Relationship Between Structured Physical Activity Frequency and Physical Fitness Improvement in Preschool Children

Fang Ren, Xing Zhao ✉ and Sha Qu
Beijing Sport University, School of Sport Science, Beijing 100000, China

Abstract

This study investigated the dose–response relationship between structured physical activity frequency and improvements in physical fitness in preschool children. Sixty-three children (3 - 6 years) were divided according to weekly participation frequency in a 12-week structured physical training program (60 min/session): low frequency (L, ≤1 session/week), moderate frequency (M, 1 - 2 sessions/week), moderate-to-high frequency (MH, 2 - 3 sessions/week), and high frequency (H, ≥3 sessions/week). Physical fitness was assessed before and after the intervention using six standardized motor tests. These tests included walking the balance beam, 10 m × 2 shuttle run, tennis throwing, continuous jumping with both feet, standing long jump, and sit-and-reach. A 2 (Time: pre- vs post-intervention) × 4 (Group: L/M/MH/H) repeated-measures ANOVA was used to analyze changes within and between groups.Significant time × group interactions were found for walking the balance beam, 10 m × 2 shuttle run, tennis throwing, continuous jumping with both feet, and standing long jump ($p < 0.05$), but not for sit-and-reach flexibility. Post-hoc analyses revealed that the H group performed better than L across all five indicators and outperformed M in the 10 m × 2 shuttle run, tennis throwing, and standing long jump ($p < 0.05$). The MH group demonstrated better performance than the L group in the balance beam walk, 10 m × 2 shuttle run, and tennis throwing. However, no significant differences were observed between the MH and H groups at post-test. These findings indicate that participating in structured physical activity fewer than two sessions per week is insufficient to enhance preschool children's physical fitness. In contrast, engagement at least twice per week significantly improves key indicators of strength, coordination, and agility. However, performance reach a performance plateau when frequency exceeds three sessions per week, suggesting diminishing marginal returns. Incorporating moderate-to-high frequency structured physical activity into preschool curricula may thus be an efficient strategy for optimizing fitness development in early childhood. Taken together, these findings emphasize the need for at least two weekly sessions of structured physical activity to effectively enhance physical fitness in preschool children.

Key words: Preschool children, Physical fitness, Frequency, Physical training activities.

Introduction

Early childhood is a critical period for physical, cognitive, and social development. Physical fitness serves as a key indicator of children's overall health and developmental status (Ortega et al., 2008). Good physical fitness contributes to prevent health problems such as obesity (Latorre Román et al., 2017) and improves children's subjective health-related quality of life (Gu et al., 2016). It is also associated with cognitive development (Latorre-Román et al., 2016) and contributes to better academic performance in adolescence (García-Hermoso et al., 2021). The ages of 3 - 6 years constitute a critical period of childhood growth and development, during which elements of physical fitness such as speed, strength, endurance, flexibility, coordination, and balance develop rapidly, laying the foundation for lifelong health (Fernandez, 2014). A key question in pediatric exercise science is how to effectively promote improvements in preschool children's physical fitness during this sensitive period, given the lack of evidence on optimal intervention strategies.

Studies have shown that physical activity interventions can effectively improve preschool children's physical fitness (Hui et al., 2024; Wang et al., 2023). The FITT principle of exercise (Frequency, Intensity, Time, and Type) provides a theoretical framework for designing effective exercise interventions. Among these factors, exercise frequency is one of the key determinants of intervention efficacy. Research on exercise frequency in adolescents has shown positive effects on mental health (Li et al., 2024), working memory and cognitive flexibility (Xu et al., 2022), physical fitness and health status (Shi et al., 2022), and health-related quality of life (Calzada- Rodríguez et al., 2021; Finne et al., 2013). Generally, a higher frequency of exercise leads to better outcomes. However, in the preschool population, systematic evidence on how different activity frequencies affect physical fitness is still lacking (Carson et al., 2017). Although some public health guidelines recommend that preschool children engage in at least a certain amount of moderate-to-vigorous physical activity every day (Tremblay et al., 2017), these recommendations are mainly based on total activity volume and lack specific guidance on the independent role of frequency of activity. Therefore, it is necessary to investigate the independent effect of activity frequency in early childhood, to provide a basis for developing more refined exercise prescriptions for preschool children.

Among various physical activities to improve preschool children's physical fitness, structured physical activity is an important proactive intervention due to its organized and goal-oriented nature. Structured physical activity refers to goal-oriented, organized exercise conducted under adult (teacher) guidance. Compared with unstructured free play, organized exercise programs more effectively enhance preschoolers' fundamental movement skills and key physical fitness components—such as strength, agility,

Received: 20 October 2025 / Accepted: 08 January 2026 / Published (online): 01 February 2026

balance, and cardiorespiratory endurance (Wang et al., 2023). For example, previous studies have shown that well-designed exercise programs produce greater improvements in preschool children's physical fitness than free play(Tan et al., 2017; Wick et al., 2021). In addition, structured exercise training interventions have been found to more effectively enhance preschool children's motor skills and physical fitness levels compared to routine physical activity controls (Quan et al., 2024). Teacher-led programs in kindergarten have also been confirmed to have positive health effects in preschoolers (Kobel et al., 2020). This evidence suggests that, relative to unstructured play, structured physical activities have clear advantages in boosting preschool children's physical fitness and can be considered an effective means of intervention.

In preschool physical education, "physical training" activities are a typical form of structured physical activity. Physical training activities refer to structured physical activity involving a variety of basic movement exercises. These include running, jumping, throwing, climbing, and balancing, all of which aim to develop children's overall physical fitness and fundamental motor skills. Research has found that compared to exercise programs focusing on a single activity or movement, a comprehensive physical training program composed of diverse movements is more beneficial for improving the overall physical fitness of preschoolers (Wang et al., 2023). Physical training activities have well-defined instructional goals and a systematic curriculum, making them a fundamental component of structured physical activity for preschool children. They serve as an ideal model for studying the effect of exercise frequency on preschoolers' physical fitness.

Given the current lack of empirical evidence on the dose–response relationship between the frequency of structured physical activity and improvements in preschool children's physical fitness, this study aimed to examine this relationship by comparing changes in physical fitness indicators before and after 12 weeks of physical training interventions conducted at different frequencies.

This study included multiple frequency groups (low, moderate, moderately high, and high), allowing for a more nuanced analysis compared to the commonly used intervention-versus-control group designs in previous research. The findings of this research will provide a theoretical basis for determining appropriate frequencies of structured physical activity for preschool children, and offer practical guidance for preschools and child exercise programs to optimize their curriculum—thereby more effectively promoting the development of physical fitness and healthy growth in preschool children.

Methods

Trial design

This study employed a 12-week intervention with four parallel groups of different exercise frequencies. Physical fitness testing was conducted one week before the intervention and immediately after the 12-week intervention, to evaluate the effects of different intervention frequencies on preschoolers' physical fitness development. The study protocol was approved by the Ethics Committee of Beijing Sport University (Approval No. 2024192H) and conformed to the requirements of the Declaration of Helsinki. In addition, informed consent for their children's participation was obtained from all parents or legal guardians.

Participants

An a priori power analysis was performed using G*Power (version 3.1) for a repeated-measures ANOVA with four groups and two time points. Assuming a medium effect size ($f = 0.25$), $\alpha = 0.05$, and statistical power ($1-\beta$) = 0.80, the analysis indicated that at least 48 participants would be required.

Strict eligibility criteria were applied to reduce potential confounding and enhance comparability across groups. Children were included if they were 3 - 6 years old, physically healthy, enrolled in non-sports-specialized kindergartens where physical activity primarily consisted of unstructured free play, and had not received structured sports training prior to the study. Children were excluded if they had medical conditions contraindicating physical activity (e.g., chronic illness, musculoskeletal problems), sensory or cognitive impairments (e.g., vision, hearing, or learning disabilities), or were concurrently engaged in other structured extracurricular sports programs during the study period, as participation in additional organized activities would make it difficult to determine whether improvements in physical fitness were attributable to the frequency of the intervention or to other exercise exposure.

Preschool children who met these criteria were recruited through open enrollment at an integrated sports training institution in Shenzhen, China, with parents voluntarily registering their children after receiving detailed information about the study's objectives and procedures. A total of 76 children expressed interest in participation. After screening against the eligibility criteria, 5 were excluded because they were concurrently engaged in other structured sports programs at different institutions. Thus, 71 children were formally enrolled in the study. During the 12-week intervention, 8 children withdrew due to illness, family emergencies, or other personal reasons, leaving 63 participants who completed the intervention and were included in the final analysis, meeting the required sample size to achieve adequate statistical power (0.80). The participant flow is summarized in Figure 1.

Prior to the intervention, the study objectives and the basic procedures of the training courses were explained in detail to parents and legal guardians. Informed consent was subsequently obtained, and permission was granted by the training institution. Participants were allocated to four groups according to weekly training frequency: L (at most 1 session/week, intermittent participation; $n = 16$), M (fixed 1 session/week, occasionally 2; $n = 15$), MH (fixed 2 sessions/week, occasionally 3; $n = 18$), and H (fixed ≥ 3 sessions/week; $n = 14$). For children attending ≥ 1 session/week, at least one day was required between consecutive sessions to ensure adequate recovery. Baseline demographic and anthropometric characteristics are presented in Table 1.

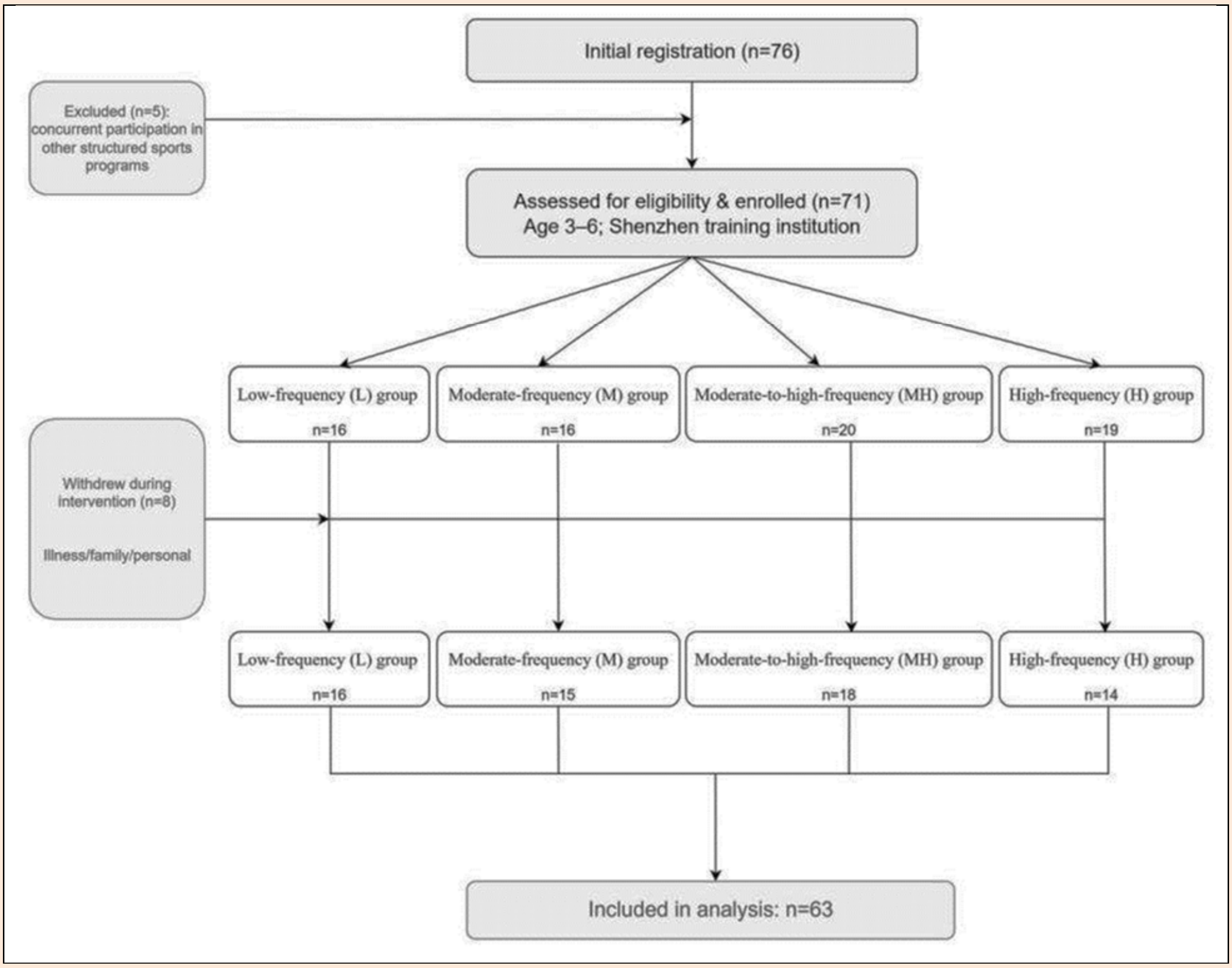

Figure1. Participant flow diagram.

Table 1. Basic information of preschool children participating in physical training activities at different frequencies (Mean ± SD).

Group	Age (years)	Height (cm)	Weight (kg)	n
H	4.4 ± 0.6	106.4 ± 5	17.7 ± 4.1	14
MH	4.1 ± 0.7	107.3 ± 6.2	18.0 ± 2.3	18
M	4.3 ± 1.1	106.7 ± 8.5	18.1 ± 3.1	15
L	4.2 ± 0.9	106.8 ± 8.3	17.3 ± 2.8	16

Intervention

Each group of children participated in a 12-week program of structured physical training classes at their designated weekly frequency. Each session lasted 60 minutes. Throughout the study period, the training center offered multiple class time slots each week for the different groups to attend as scheduled, but the content and intensity of all classes were kept identical. Exercise intensity was standardized through instructor supervision, unified pacing and movement demonstrations, and monitoring children's observable exertion levels to maintain a consistent moderate-intensity workload across all sessions. Each session consisted of approximately 15 minutes of warm-up games, 40 minutes of basic skill practice, and 5 minutes of cool-down and relaxation (see Table 2 for details). Both the warm-up and cool-down phases followed fixed, predefined activity sequences that were identical across all sessions. Session duration was strictly maintained at 60 minutes with no deviations permitted. The warm-up phase involved games incorporating running and jumping to activate the children's neuromuscular system. The basic practice phase primarily used a series of circuit challenges, with several activity circuits set up that included movements such as crawling, jumping, throwing, walking the balance beam, and running along an S-shaped path. The circuit challenges used fixed station arrangements, and the order of movement tasks was not randomized, ensuring equal exposure and training load across groups. These activities were designed to develop the children's strength, speed, agility, and coordination in a comprehensive way. Specifically, strength was developed through jumping and throwing tasks; speed was trained through running segments embedded within the activities; agility was enhanced through rapid directional changes such as S-shaped running; coordination was promoted through crawling tasks and various combined movement sequences requiring upper– and lower–limb integration; balance was trained through walking on the balance beam; and flexibility was addressed in the closing phase through a standardized static stretching routine. The closing phase involved static stretching to help the children relax their muscles and recover. The stretching routine also followed a standardized sequence across all groups. To ensure intervention quality and consistency, each class was a standardized sequence across all groups.

Table 2. Settings of the content of preschool children's physical training activities.

Activity Sections	Activity Content and Duration
Preparation Part	Warm-up games (15 min), including: • Running • Jumping • Crawling These activities aim to activate the nerves and muscles in preparation for more intensive movement.
Basic Part	Circular challenge activities (40 min): • Three circular routes, each with 3–4 checkpoints • Practice includes: - Crawling - Jumping - Throwing - Kicking - Hitting - Dodging - Balance beam walking - S-shaped running • Each route: 10–15 min
Closing Part	Static stretching and relaxation (5 min): • Help children relax muscles • Restore heart rate • Reduce excitement

To ensure intervention quality and consistency, each class was limited to 4 - 8 children and led by one head coach with one assistant instructor. The same instructors remained assigned to each group throughout the 12-week intervention to minimize instructor-related variability. All teachers held qualifications in early childhood physical education and underwent standardized training before the intervention to ensure the curriculum was delivered according to the predefined lesson plans. During the intervention, researchers closely monitored each group's attendance and class implementation to ensure that, aside from the intended variation in weekly session frequency, all other aspects—including program content, activity order, session duration, instructor assignment, and intensity—were strictly standardized across groups. This ensured that physical activity frequency functioned as the only independent variable.

Each child underwent a physical fitness test battery once in the week before the intervention and once immediately after completing the 12-week intervention. The test indices were selected from the National Physical Fitness Measurement Standards Handbook for Preschool Children (Zhang et al., 2017)(Appendix A), and included walking the balance beam, 10 m×2 shuttle run, tennis throwing, continuous jumping with both feet, standing long jump, and sit-and-reach. Each test was administered by two trained testers following standard protocols: one tester guided the child through the movements while the other recorded the performance. All tests were administered in a fixed order for every participant, and all testing sessions for both pre- and post-intervention were conducted at the same time of day to minimize diurnal variation. To improve accuracy, each test was performed twice with a standardized rest interval between attempts, and the best result was used for analysis. All pre- and post-tests were conducted by the same team of testers to further reduce procedural variability and minimize human error.

Statistical analysis

Data were entered into Excel 2019, double-checked by a second researcher to ensure accuracy, and subsequently analyzed in SPSS 26.0 and visualized in Prism 10.0. Data are presented as mean ± standard deviation (M ± SD). Preliminary checks indicated no missing values or outliers. Normality was assessed with Q - Q plots and homogeneity of variances with Levene's and Brown–Forsythe tests. Baseline equivalence among groups was tested using one-way ANOVA on pre-test scores. On this basis, a 2 (Time: pre vs. post) × 4 (Group: L/M/MH/ H) repeated-measures ANOVA was conducted for each physical fitness measure to examine the effect of intervention frequency. When a significant interaction effect was observed, simple effect analyses were performed using LSD-adjusted pairwise comparisons to examine both group differences at each time point and within-group changes across time. Effect sizes for interactions were reported as partial η^2. According to Cohen's guidelines, values of 0.01, 0.06, and 0.14 represent small, medium, and large effects, respectively (Cohen, 2013). The significance level α was set at 0.05 (two-tailed). In the results, $p < 0.05$ was considered statistically significant, and $p < 0.01$ was considered highly significant.

Results

Data summary, baseline comparisons, and ANOVA results

Basic descriptive statistics of preschool children's physical fitness test results before and after intervention for each group are shown in Table 3; a comparison of baseline physical fitness test results is shown in Table 4; the results of the repeated-measures ANOVA are shown in Table 5.

Baseline data comparison

As shown in Table 4, no significant differences were observed among the four groups in any of the baseline physical fitness indicators ($p > 0.05$). This suggests that the groups were comparable prior to the intervention, thereby reducing potential bias attributable to pre-existing disparities in physical fitness levels and ensuring that subsequent changes can be more confidently attributed to the intervention.

Table 3. Descriptive statistics (Mean ± SD) for physical fitness test results by group and time.

Test items	L		M		MH		H	
	pre-test	post-test	pre-test	post-test	pre-test	post-test	pre-test	post-test
Walking the balance beam(s)	11.11 ± 1.34	9.79 ± 1.01	8.59 ± 1.39	6.51 ± 1.05	11.41 ± 1.26	5.39 ± 0.96	10.50 ± 1.43	5.59 ± 1.08
10 m×2 shuttle run(s)	8.58 ± 1.64	8.27 ± 1.78	8.36 ± 1.27	7.95 ± 1.08	8.75 ± 1.21	7.41 ± 1.08	8.42 ± 1.27	7.00 ± 0.65
Tennis throwing (m)	3.94 ± 1.47	4.13 ± 1.60	4.51 ± 1.42	4.96 ± 1.57	3.64 ± 1.01	5.62 ± 1.50	4.41 ± 1.67	6.36 ± 1.73
Continuous jumping with both feet (s)	7.94 ± 3.25	7.19 ± 2.81	6.50 ± 1.35	5.92 ± 1.46	8.44 ± 3.47	5.92 ± 1.66	7.76 ± 2.74	5.27 ± 1.25
Standing long jump (cm)	89.69 ± 24.35	94.81 ± 24.65	87.53 ± 18.57	95.40 ± 16.43	77.50 ± 15.81	101.72 ± 16.46	81.50 ± 12.98	111.07 ± 13.75
Sit-and-reach (cm)	7.41 ± 4.05	7.21 ± 4.42	8.33 ± 4.96	9.25 ± 4.77	8.36 ± 3.84	8.68 ± 3.56	8.64 ± 4.13	8.79 ± 4.73

Table 4. Comparison of baseline physical fitness test results across groups.

Test Items	L (mean ± SD)	M (mean ± SD)	MH (mean ± SD)	H (mean ± SD)	Baseline comparison	
					F	*P*
Walking the balance beam(s)	11.11 ± 1.34	8.59 ± 1.39	11.41 ± 1.26	10.50 ± 1.43	0.88	0.459
10 m×2 shuttle run(s)	8.58 ± 1.64	8.36 ± 1.27	8.75 ± 1.21	8.42 ± 1.27	0.27	0.844
Tennis throwing (m)	3.94 ± 1.47	4.51 ± 1.42	3.64 ± 1.01	4.41 ± 1.67	1.41	0.250
Continuous jumping with both feet (s)	7.94 ± 3.25	6.50 ± 1.35	8.44 ± 3.47	7.76 ± 2.74	1.32	0.278
Standing long jump (cm)	89.69 ± 24.35	87.53 ± 18.57	77.50 ± 15.81	81.50 ± 12.98	1.51	0.220
Sit-and-reach (cm)	7.41 ± 4.05	8.33 ± 4.96	8.36 ± 3.84	8.64 ± 4.13	0.25	0.864

Table 5. Main effects and interaction effects of physical fitness test indicators among different groups of preschool.

Test items	Time		Group		Time × Group		
	F	P	F	P	*F*	*P*	η^2_p
Walking the balance beam(s)	87.56	0.000	1.31	0.302	10.49	**0.000**	0.329
10 m×2 shuttle run(s)	71.29	0.000	0.86	0.469	8.17	**0.000**	0.293
Tennis throwing (m)	89.78	0.000	2.27	0.090	16.05	**0.000**	0.449
Continuous jumping with both feet (s)	42.83	0.000	1.18	0.325	4.88	**0.004**	0.199
Standing long jump (cm)	560.16	0.000	0.36	0.779	71.33	**0.000**	0.784
Sit-and-reach (cm)	0.91	0.343	0.44	0.723	0.55	0.651	

Bold values indicate statistically significant differences in the corresponding physical fitness indicators.

Overall changes in physical fitness after interventions of different frequencies

A repeated-measures ANOVA was conducted on the physical fitness test data to examine changes over time and differences between frequency groups. The results showed that after 12 weeks of intervention, five of the six test indicators — walking the balance beam, 10 m×2 shuttle run, tennis throwing, continuous jumping with both feet, and standing long jump — demonstrated a significant Time × Group interaction effect (p <0.05; see Tables 5). Based on the significant interactions, we further analyzed simple effects for each group. The sit-and-reach flexibility test showed no significant effects for time or group, so results for that measure are not described further.

Effects of Different-Frequency Training on Each Physical Fitness Indicator

Walking the balance beam

There was a significant interaction effect for walking the balance beam performance ($F_{3,59} = 10.49$, $p < 0.001$, $\eta^2_p = 0.329$; Table 5). The M, MH, and H groups all improved their balance beam walking times significantly from pre- to post-test ($p < 0.01$; Figure 2a). At baseline, there were no significant differences among the groups. By the post-test, the H and MH groups performed significantly better (faster times) than the L group ($p < 0.01$), and the M group was significantly better than the L group ($p < 0.05$; Figure 2b).

10 m×2 shuttle run

The 10 m×2 shuttle run also showed a significant interaction effect ($F_{3,59} = 8.17$, $p < 0.001$, $\eta^2_p = 0.293$; Table 5). The MH and H groups significantly improved their shuttle run times (p <0.01; Figure 3a). There were no significant group differences at pre-test. At post-test, the H group was significantly faster than the L group ($p < 0.01$) and M group ($p < 0.05$), the MH group was faster than the L group ($p < 0.05$; Figure 3b).

Tennis throwing

For the tennis throwing test, a significant interaction effect was found ($F_{3,59} = 16.05$, $p < 0.001$, $\eta^2_p = 0.449$; Table 5). The MH and H groups showed highly significant improvements in tennis ball throw distance ($p < 0.01$; Figure 4a). There were no significant group differences at pre-test. By post-test, the H group's throwing distance was significantly greater than those of the M and L groups ($p < 0.01$), and the MH group's was significantly greater than that of the L group ($p < 0.01$; Figure 4b).

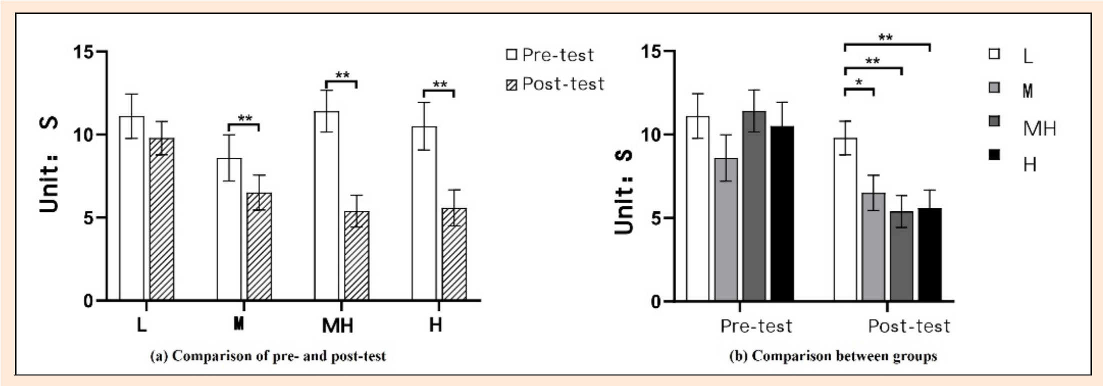

Figure 2. Interaction analysis for the walking the balance beam performance (*indicates $p < 0.05$, ** indicates $p < 0.01$).

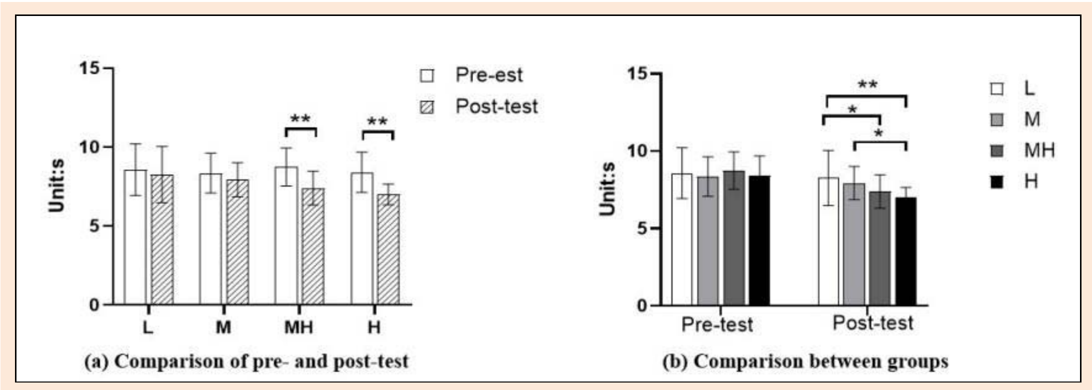

Figure 3. Interaction analysis for the 10 m×2 shuttle run performance (*indicates $p < 0.05$, ** indicates $p < 0.01$).

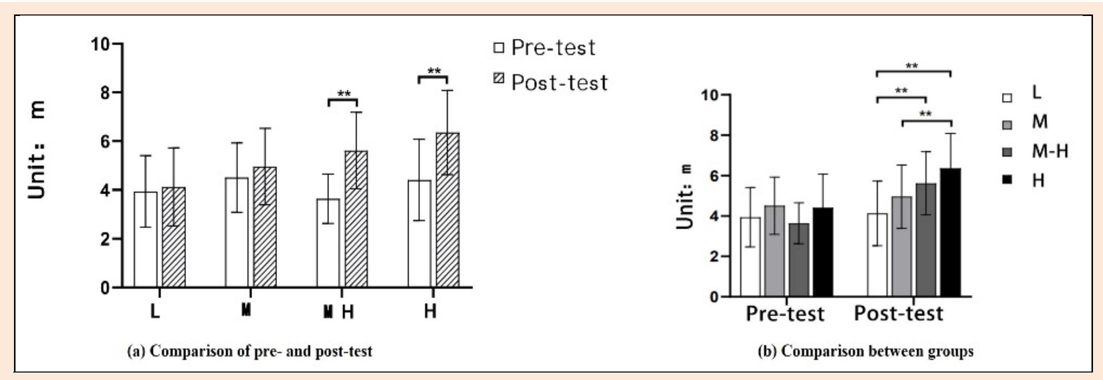

Figure 4. Interaction analysis for the tennis throwing performance (* indicates $p < 0.05$, ** indicates $p < 0.01$).

Standing long jump

Standing long jump performance also exhibited a significant interaction ($F_{3,59} = 71.33$, $p < 0.001$, $\eta^2_p = 0.784$; Table 5). All frequency groups, including L, showed highly significant improvements in standing long jump distance from pre- to post-test ($p < 0.01$; Figure 5a). There were no differences among groups at pre-test; at post-test, the H group jumped significantly farther than the L and M group ($p < 0.05$; Figure 5b).

Continuous jumping with both feet

The continuous jumping with both feet test showed a significant interaction effect ($F_{3,59} = 4.88$, $p = 0.004$, $\eta^2_p = 0.199$; Table 5). The MH and H groups demonstrated significant improvements in preschool children's performance on the continuous jumping with both feet test ($p < 0.01$; Figure 6a). There were no baseline differences among groups; at post-test, the H group performed significantly better than the L group ($p < 0.01$; Figure 6b).

Discussion

This study, using physical training activities as an example, explored the effects of different frequencies of structured physical activity on the physical fitness of preschool children. We found that when the frequency of structured physical activity was at a lower level, improvements in the preschool children's physical fitness were quite limited. With structured physical training less than twice a week, preschoolers showed little progress in speed, agility, coordination, and upper-body strength; the low-frequency (L) group only improved in the standing long jump, and the medium-frequency (M) group improved in balance (beam walking) and standing long jump. In contrast, when the

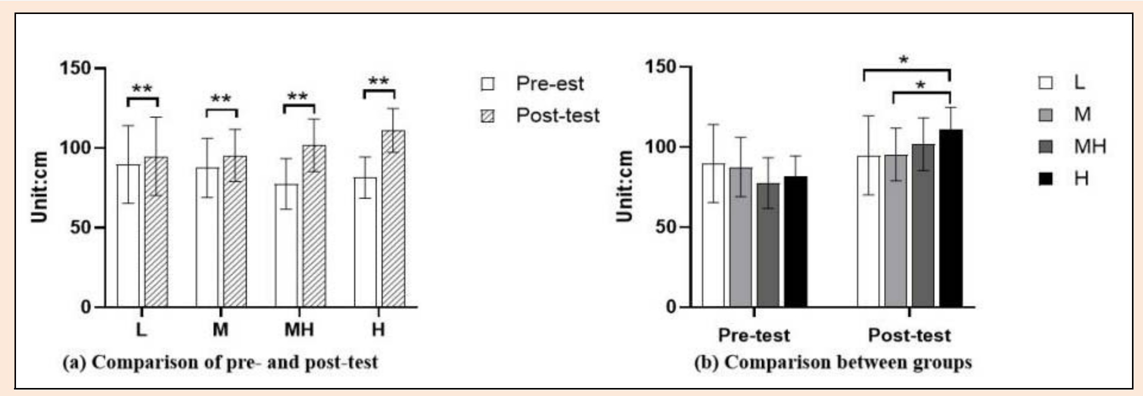

Figure 5. **Interaction analysis for the standing long jump performance (* indicates $p < 0.05$, ** indicates $p < 0.01$).**

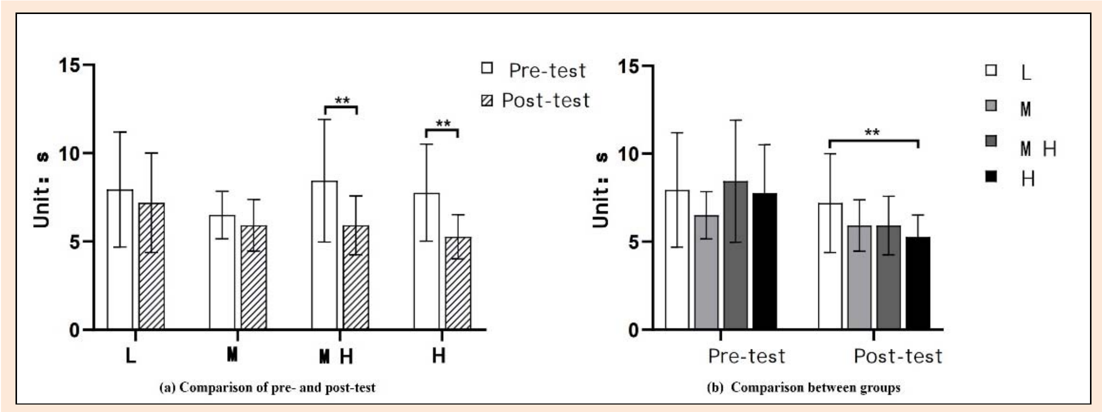

Figure 6. **Interaction analysis for the continuous jumping with both feet performance (* indicates $p < 0.05$, ** indicates $p < 0.01$).**

frequency reached two or more sessions per week, all aspects of physical fitness except flexibility showed improvement.

Firstly, from the perspective of physiological load and adaptation, a higher training frequency can provide frequent stimuli to children's muscles, bones, and cardiorespiratory system, leading to positive physiological adaptations (Ara et al., 2004). Regularly applied exercise stimuli help increase bone density and strength (Bailey et al., 1999), promote muscle growth and strength gains (Detter et al., 2014), and repeated aerobic activity gradually improves children's cardiorespiratory endurance and circulatory function (Bjelica et al., 2020; Xia et al., 2024). Conversely, with low-frequency exercise (fewer than two sessions per week), the stimulus may be insufficient to elicit notable physiological changes. The child might almost fully revert to baseline between sessions, resulting in limited cumulative effects.

Secondly, high-frequency structured activity has greater advantages for comprehensive improvements in physical fitness through neuromuscular adaptation and fundamental motor skill development. Frequent practice helps strengthen preschool children's neuromuscular pathways and increases the excitability and responsiveness of the motor nervous system(Buzescu et al., 2021). Early childhood is a critical period for the development of the nervous system. Sustained high-frequency physical activity can optimize neural signal transmission between the brain and muscles, facilitating the effective recruitment of additional motor units. This process enhances motor coordination and reaction speed, thereby improving key physical attributes in preschool children such as coordination and agility. Research has shown that children who engage in more frequent physical activity exhibit faster responses in both simple and complex reaction time tests, reflecting improved neural processing speed(Reigal et al., 2019). In contrast, with low-frequency training, the long intervals between practice sessions make it difficult to retain the neural adaptations gained from the previous session; children struggle to consolidate improvements in coordination and agility. Additionally, a high frequency of targeted structured activities provides children with repeated opportunities to practice fundamental motor skills, allowing them to correct their movements promptly and reinforce motor memory, thereby more effectively improving gross motor skill proficiency (Wang and Zhou, 2024). Preschool children's fundamental motor skill levels are closely related to their physical fitness development (Vlahov et al., 2014). This linkage is not merely correlative but reflects an underlying developmental interdependence: enhanced FMS competence facilitates more efficient neuromuscular recruitment, energy expenditure, and movement quality, which in turn support gains in physical performance metrics. For instance, improvements in skills such as hopping, throwing, and balancing enhance muscular coordination and biomechanical efficiency, enabling children to better engage in structured and spontaneous physical activities of moderate-to-vigorous intensity. On the one hand, successfully performing fundamental movements requires the coordinated operation of multiple neural pathways and relies on sensory-motor integration; this neural integration mechanism is also a key physiological basis for developing physical fitness components like speed, agility, and coordination(Kellis and Hatzitaki, 2013). On the other hand, there is an indirect effect: research suggests that children with better motor skills tend to participate more actively in physical activities, which in turn leads to improvements in physical fitness (Dobell et al., 2023; Vandorpe et al., 2012). Taken together, these mechanisms underscore the mediating role of motor competence in the frequency–fitness relationship observed in this study. Future research could further explore this pathway using combined assessments of both skill acquisition and physiological adaptation to more precisely characterize how frequent FMS practice drives gains in specific fitness domains. In summary, higher-frequency training appears to produce more robust neuromuscular adaptations and motor skill gains, which translate into greater improvements in related physical fitness components.

Finally, an appropriate frequency of intervention helps cultivate preschool children's positive interest in exercise and good exercise habits, forming a virtuous cycle for physical fitness improvement from psychological and behavioral perspectives. Having structured activities two or more times per week means children frequently experience the fun of movement. The enjoyment gained from playing and competing with peers can increase their love of physical activity and their level of engagement. When children see themselves improving through frequent activity (for example, jumping farther or running faster than before), their self-confidence in physical tasks grows, making them more willing to challenge new movements and attempt higher-intensity exercises. This sense of achievement creates a positive psychological experience that further motivates them to participate in exercise. Indeed, studies have found that children who participate in physical activity more often show better mental health in terms of social-emotional and cognitive development (Christian et al., 2021; Zeng et al., 2017). In our observations, children in the MH and H groups, after repeatedly succeeding in physical challenges, displayed strong feelings of accomplishment and enthusiasm for participation, supporting the mechanism that frequent intervention can enhance interest and confidence, thereby promoting physical fitness development. In contrast, too infrequent activity fails to help children form a regular exercise habit and leads to lower motivation to participate, which directly impacts their engagement and effort during the sessions.

Our findings align in part with previous research and also offer some new insights. We confirmed that "structured physical activity at least twice per week can significantly improve preschool children's physical fitness," which is consistent with many intervention studies. For example, a 9-month intervention of structured activities twice weekly found that, compared to a no-intervention control, preschoolers achieved significantly greater improvements in 4×10 m shuttle run, standing long jump, sit-ups, bent-arm hang, grip strength, and sit-and-reach tests (Popović et al., 2020). Another study of a 6-month program with three sessions per week also reported that structured physical activity more effectively enhanced preschool children's motor coordination, agility, and running speed (Kojić et al., 2024). Through our intervention, we found that physical training twice a week or more can effectively improve preschoolers' physical fitness, further supporting the positive role of a ≥2 times/week structured activity frequency in developing physical fitness. However, regarding low-frequency structured activity (around once weekly), previous studies have shown mixed results compared to our findings. One 10-week intervention reported that even one structured activity session per week significantly improved preschoolers' physical fitness(Tortella et al., 2023), whereas our findings suggest that less than two sessions per week may be insufficient to achieve meaningful gains. The discrepancy may be due to differences in experimental conditions: in that study, the intervention took place in a large outdoor playground (~2500 m²) equipped with abundant apparatus, providing a spacious and stimulating environment that likely elicited high-intensity spontaneous activity from children. Even with a lower frequency, each session may have provided a high total amount of movement and high-quality stimuli. Previous research has indicated that playgrounds furnished with extensive exercise equipment can offer preschool children increased opportunities for motor skill practice, and that larger play areas allow for more extensive physical activity, both of which are strongly linked to the enhancement of children's physical fitness (Pawlowski et al., 2023).In our study, the physical training sessions were conducted mostly in an indoor space of about 130 m² with limited equipment and space, so the total amount of physical stimulus that children received in infrequent sessions was relatively small. Thus, under different venue and equipment conditions, the effectiveness of low-frequency intervention may vary. Future studies may consider comparing the effects of physical activity interventions across different environments—such as indoor versus outdoor settings, and large versus small spaces—to further elucidate the moderating role of environmental factors in the relationship between intervention frequency and physical fitness outcomes in preschool children.

This study also observed for the first time a phenomenon of diminishing returns at very high intervention frequencies. We found that while structured physical activity interventions at ≥2 times per week improved physical fitness more than <2 times, it does not imply that the higher the frequency, the greater the benefit without end. In prior research, Alves et al. noted that for obese youth aged 12-15, exercising 3 times per week yielded greater physical fitness improvements than 2 times per week(Alves et al., 2019). However, that study's participants were older obese adolescents, which is a very different context from our healthy preschool sample. In our study, while the group exercising ≥3 times weekly tended to show the highest improvements, their gains were not significantly different from those of the group exercising 2-3 times weekly. There are several possible reasons for this, closely related to preschool children's physiological and psychological characteristics. One factor is the balance between exercise load and recovery. Preschool children's bodies are still immature, and their physical endurance and recovery capacity are relatively limited. When physical training frequency exceeds three sessions per week, children may not have sufficient time for their bodies to recover between sessions. Rather than metabolic fatigue, a more likely explanation for preschoolers is insufficient neuromuscular recovery: movement quality, coordination, and attentional resources may decline when training occurs too frequently, reducing the effectiveness of subsequent sessions. Additionally, research indicates that excessive physical activity frequency can prolong the time it takes for preschool children to fall asleep (i.e., increase sleep latency)(Eythorsdottir et al., 2020), which could interfere with the recovery processes that occur during sleep. Another factor is psychological fatigue and loss of interest. Training too frequently can reduce novelty and lead to mental fatigue in preschool children. Preschoolers have short attention spans and prefer activities that are varied and novel (Ruff and Rothbart, 2001). If activities are too frequent and become repetitive, children may grow bored, resulting in lower enthusiasm and focus, which can diminish the effectiveness of each session. More frequent sessions could thus yield smaller incremental improvements if children are not fully engaged. These potential physiological and psychological mechanisms behind why very high frequencies show limited additional benefit warrant further quantitative research from both biological and behavioral perspectives.

There are two additional points to note in interpreting the effects of different intervention frequencies on preschool children's physical fitness. First, in the standing long jump test, even low-frequency training led to clear improvements. This may be because jumping exercises were embedded throughout each physical training session — including activities like vertical jumps, broad jumps, frog jumps, and bunny hops — so even at low frequency, children still received plenty of jumping practice. Furthermore, because jumping ability is easy for parents to observe and recognize, we noticed through post-class observations that parents often paid special attention to jumping and might have encouraged their children to practice jumping at home. With these factors, it is likely that regardless of class frequency, the children had many opportunities to practice jumping both during the sessions and in daily life, resulting in improved standing jump performance across all frequencies. Second, in the sit-and-reach flexibility test, performance did not improve notably in any group. The sit-and-reach primarily reflects flexibility, which typically requires a high volume of static stretching to improve — using one's own strength or external assistance to elongate muscles, tendons, and ligaments to increase joint range of motion. Since our physical training classes focused mainly on dynamic exercises to fully engage the children within the limited class time, very little time was devoted to static flexibility training (only a brief stretching during the closing segment of each class). Therefore, none of the frequency groups showed marked improvement in flexibility, a result that was expected. Improving flexibility likely requires more frequent and targeted static stretching training, which was beyond the scope of our intervention.

In summary, this study innovatively implemented four different intervention frequencies and systematically examined the dose-response relationship between structured physical activity frequency and physical fitness improvement in preschool children, filling a gap in the research. Our findings indicate that low-frequency physical activity (less than twice per week) did not significantly enhance preschoolers' physical fitness, especially in crucial physical fitness attributes such as speed, coordination, and strength. We also found, novelly, that very high frequency physical activity (three or more times per week) showed a trend of diminishing returns in physical fitness improvement compared to a moderate frequency (about two to three times per week). This finding challenges the common assumption that "more exercise is always better" for physical fitness development. Our results demonstrate that after a certain frequency threshold is reached, further increasing the frequency yields progressively smaller gains in physical fitness. This provides a new perspective for the field of physical education, reminding us that when planning physical fitness programs for preschoolers, more frequent activity is not always unequivocally better. This insight has important theoretical and practical value for optimizing pediatric physical fitness improvement programs, particularly in terms of frequency settings.

We suggest that preschools, children's sports training institutions, and activity clubs schedule at least two high-quality structured physical activity sessions per week (such as physical training classes) to ensure effective improvements in preschool children's physical fitness. If conditions allow, incorporating a fixed schedule of three sessions per week can further promote physical fitness development, although one should pay attention to the children's recovery status to avoid physiological fatigue or loss of interest from over-frequency. If even more frequent activity opportunities are desired, it would be advisable to increase the variety of activity types and content to maintain novelty, rather than simply adding more sessions of the same activity. Policy makers and educators should consider the frequency factor in early childhood physical fitness programs — ensuring a minimum effective frequency to obtain benefits, while also setting a reasonable upper limit to prevent counterproductive effects. This study provides initial evidence to inform guidelines for physical activity in preschoolers; however, further research with larger samples and in varied settings is needed to verify the long-term impacts of different exercise frequencies on preschool children's physical and mental development.

Of course, this study has certain limitations. First, the final sample size that met all criteria and was included in analysis was relatively small. The limited sample size may constrain the generalizability of the findings. Future studies should involve a larger and more diverse sample, covering different regions and children participating in various types of structured physical activities, to enhance the representativeness of the results. Second, this study used a non-randomized quasi-experimental design, which carries a risk of selection bias. Although we set strict inclusion criteria to ensure that participants had no extra sports training prior to the intervention and that their baseline physical fitness levels were comparable, we cannot completely rule out the influence of selection bias. Future research should employ randomized group assignment and include a control group to strengthen the internal validity of the causal inferences and improve the reliability of between-group comparisons. Third, although efforts were made to standardize class delivery and instructor supervision, we did not use quantitative methods (e.g., heart rate monitoring or accelerometers) to measure exercise intensity. This limits our ability to precisely evaluate training load or fully exclude the potential effect of intensity differences on the results. Fourth, this study did not include a direct assessment of motor competence. As motor competence is closely related to physical fitness and may influence children's ability to benefit from training, its omission limits our interpretation of the mechanisms underlying the observed improvements. Future studies should consider integrating validated motor competence measures to allow for a more comprehensive understanding of intervention effects.

Conclusion

Structured physical activity interventions delivered at a frequency of two or more times per week can significantly improve key components of physical fitness in preschool children, including speed, agility, strength, coordination, and balance. In contrast, interventions conducted less than twice weekly show relatively limited effects. Overall, the trend indicates that physical fitness improves progressively with increased intervention frequency; however, when the frequency exceeds three sessions per week, the rate of improvement tends to diminish, revealing a clear pattern of diminishing marginal returns.

Acknowledgements

The authors declare that financial support was received for the research. This study was funded by a grant from the National Social Science Foundation of China General Education Project: "Evaluation Methods of Physical Activity Intensity in Preschool Children and the Development and Application of AI-Based Assessment Systems" (Grant number BLA200222). The author reports no actual or potential conflicts of interest. While the datasets generated and analyzed in this study are not publicly available, they can be obtained from the corresponding author upon reasonable request. All experimental procedures were conducted in compliance with the relevant legal and ethical standards of the country where the study was carried out. The authors declare that no Generative AI or AI-assisted technologies were used in the writing of this manuscript.

References

Alves, A. S. R., Venancio, T. L., Honorio, S. A. A., and Martins, J. M. C. (2019) Multicomponent training with different frequencies on body composition and physical fitness in obese children. *Anais da Academia Brasileira de Ciências* **91(4)**, e20181264. https://doi.org/10.1590/0001-3765201920181264

Ara, I., Vicente-Rodríguez, G., Jimenez-Ramirez, J., Dorado, C., Serrano-Sanchez, J. A. and Calbet, J. A. L. (2004) Regular participation in sports is associated with enhanced physical fitness and lower fat mass in prepubertal boys. *International Journal of Obesity* **28(12)**, 1585-1593. https://doi.org/10.1038/sj.ijo.0802754

Bailey, D. A., McKay, H. A., Mirwald, R. L., Crocker, P. R. E. and Faulkner, R. A. (1999) A six-year longitudinal study of the relationship of physical activity to bone mineral accrual in growing children: The University of Saskatchewan Bone Mineral Accrual Study. *Journal of Bone and Mineral Research* **14(10)**, 1672-1679. https://doi.org/10.1359/jbmr.1999.14.10.1672

Bjelica, B., Milanović, L., Aksović, N., Zelenović, M. and Božić, D. (2020) Effects of physical activity to cardiorespiratory changes. *Turkish Journal of Kinesiology* **6(4)**, 164-174. https://doi.org/10.31459/turkjkin.832955

Buzescu, R., Nechita, F. and Cioroiu, S. G. (2021) The relationship between neuromuscular control and physical activity in the formation of the visual-psychomotor schemes in preschools. *Sensors* **21(1)**, 224. https://doi.org/10.3390/s21010224

Calzada-Rodríguez, J. I., Denche-Zamorano, Á. M., Pérez-Gómez, J., Mendoza-Muñoz, M., Carlos-Vivas, J., Barrios-Fernández, S. and Adsuar, J. C. (2021) Health-related quality of life and frequency of physical activity in Spanish students aged 8-14. *International Journal of Environmental Research and Public Health* **18(17)**, 9418. https://doi.org/10.3390/ijerph18179418

Carson, V., Lee, E.-Y., Hewitt, L., Jennings, C., Hunter, S., Kuzik, N., Stearns, J. A., Unrau, S. P., Poitras, V. J., Gray, C. E., Adamo, K. B., Janssen, I., Okely, A. D., Spence, J. C., Timmons, B. W., Sampson, M. and Tremblay, M. S. (2017) Systematic review of the relationships between physical activity and health indicators in the early years (0-4 years). *BMC Public Health* **17(5)**, 854. https://doi.org/10.1186/s12889-017-4860-0

Christian, H. E., Lester, L., Marzooqi, M. K. A., Trost, S. G. and Papageorgiou, A. (2021) The association between preschooler physical activity duration and intensity and social emotional development: Findings from the PLAYCE study. *Journal of Physical Activity and Health*. https://doi.org/10.1123/jpah.2020-0588

Cohen, J. (2013) *Statistical power analysis for the behavioral sciences* (2nd ed.). Routledge. https://doi.org/10.4324/9780203771587

Detter, F., Nilsson, J.-Å., Karlsson, C., Dencker, M., Rosengren, B. E. and Karlsson, M. K. (2014) A 3-year school-based exercise intervention improves muscle strength - A prospective controlled population-based study in 223 children. *BMC Musculoskeletal Disorders* **15(1)**, 353. https://doi.org/10.1186/1471-2474-15-353

Dobell, A. P., Faghy, M. A., Pringle, A. and Roscoe, C. M. P. (2023) Improving fundamental movement skills during early childhood: An intervention mapping approach. *Children* **10(6)**, 1004. https://doi.org/10.3390/children10061004

Eythorsdottir, D. Y., Frederiksen, P., Larsen, S. C., Olsen, N. J. and Heitmann, B. L. (2020) Associations between objective measures of physical activity, sleep and stress levels among preschool children. *BMC Pediatrics* **20(1)**, 258. https://doi.org/10.1186/s12887-020-02108-7

Fernandez, E. (2014) Early childhood: Dimensions and contexts of development and well-being. In *Handbook of child well-being* (pp. 1629-1647). Springer. https://doi.org/10.1007/978-90-481-9063-8_65

Finne, E., Bucksch, J., Lampert, T. and Kolip, P. (2013) Physical activity and screen-based media use: Cross-sectional associations with health-related quality of life and the role of body satisfaction in a representative sample of German adolescents. *Health Psychology and Behavioral Medicine*. https://doi.org/10.1080/21642850.2013.809313

García-Hermoso, A., Martinez-Gomez, D., del Rosario Fernández-Santos, J., Ortega, F. B., Castro-Piñero, J., Hillman, C. H., Izquierdo, M., and Smith, J. D. (2021) Longitudinal associations of physical fitness and body mass index with academic performance. *Scandinavian Journal of Medicine & Science in Sports* **31(1)**, 184-192. https://doi.org/10.1111/sms.13817

Gu, X., Chang, M. and Solmon, M. A. (2016) Physical activity, physical fitness, and health-related quality of life in school-aged children. *Journal of Teaching in Physical Education* **35(2)**, 117-126. https://doi.org/10.1123/jtpe.2015-0110

Hui, L., Wei, S., Luping, Q. and Nannan, G. (2024) Developing the optimal gross movement interventions to improve the physical fitness of 3-10 year-old children: A systematic review and meta-analysis. *Frontiers in Psychology* **15**, 1355821. https://doi.org/10.3389/fpsyg.2024.1355821

Kellis, E. and Hatzitaki, V. (2013) Development of neuromuscular coordination with implications in motor control. In *Paediatric biomechanics and motor control* (pp. 50-69). Routledge.

Kobel, S., Henle, L., Laemmle, C., Wartha, O., Szagun, B. and Steinacker, J. M. (2020) Intervention effects of a kindergarten-based health promotion programme on motor abilities in early childhood. *Frontiers in Public Health* **8**, 219. https://doi.org/10.3389/fpubh.2020.00219

Kojić, F., Arsenijević, R., Grujić, G., Toskić, L. and Šimenko, J. (2024) Effects of structured physical activity on motor fitness in preschool children. *Children* **11(4)**, 433. https://doi.org/10.3390/children11040433

Latorre Román, P. Á., Moreno Del Castillo, R., Lucena Zurita, M., Salas

Sánchez, J., García-Pinillos, F. and Mora López, D. (2017) Physical fitness in preschool children: Association with sex, age and weight status. *Child: Care, Health and Development* **43(2)**, 267-273. https://doi.org/10.1111/cch.12404

Latorre-Román, P. Á., Mora-López, D. and García-Pinillos, F. (2016) Intellectual maturity and physical fitness in preschool children. *Pediatrics International* **58(6)**, 450-455. https://doi.org/10.1111/ped.12898

Li, W., Gao, Y., Liu, G., Hao, R., Zhang, M. and Li, X. (2024) Shifting the paradigm: A fresh look at physical activity frequency and its impact on mental health, life satisfaction, and self-rated health in adolescents. *International Journal of Mental Health Promotion* **26(2)**. https://doi.org/10.32604/ijmhp.2023.042014

Ortega, F. B., Ruiz, J. R., Castillo, M. J. and Sjöström, M. (2008) Physical fitness in childhood and adolescence: A powerful marker of health. *International Journal of Obesity* **32(1)**, 1-11. https://doi.org/10.1038/sj.ijo.0803774

Pawlowski, C. S., Madsen, C. D., Toftager, M., Amholt, T. T. and Schipperijn, J. (2023) The role of playgrounds in the development of children's fundamental movement skills: A scoping review. *Plos One* **18(12)**, e0294296. https://doi.org/10.1371/journal.pone.0294296

Popović, B., Cvetković, M., Mačak, D., Šćepanović, T., Čokorilo, N., Belić, A., Filipović, B., Ilić, V. and Petrović, M. (2020) Nine months of a structured multisport program improve physical fitness in preschool children: A quasi-experimental study. *International Journal of Environmental Research and Public Health* **17(14)**, 4935. https://doi.org/10.3390/ijerph17144935

Quan, S., Liao, Y., Ji, Y. and Zheng, S. (2024) Structured training on gross motor skills and physical fitness in 4-5-year-old children. *Frontiers in Pediatrics* **12**, 1466911. https://doi.org/10.3389/fped.2024.1466911

Reigal, R. E., Barrero, S., Martín, I., Morales-Sánchez, V., Juárez-Ruiz de Mier, R. and Hernández-Mendo, A. (2019) Relationships between reaction time, selective attention, physical activity, and physical fitness in children. *Frontiers in Psychology* **10**, 2278. https://doi.org/10.3389/fpsyg.2019.02278

Ruff, H. A. and Rothbart, M. K. (2001) *Attention in early development: Themes and variations*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195136326.001.0001

Shi, C., Chen, S., Wang, L., Yan, J., Liang, K., Hong, J., Zhang, H., Liu, Y., and Zhao, X. (2022) Associations of sport participation, muscle-strengthening exercise and active commuting with self-reported physical fitness in school-aged children. *Frontiers in Public Health* **10**, 873141. https://doi.org/10.3389/fpubh.2022.873141

Tan, S., Chen, C., Sui, M., Xue, L. and Wang, J. (2017) Exercise training improved body composition, cardiovascular function, and physical fitness of 5-year-old children with obesity or normal body mass. *Pediatric Exercise Science*. https://doi.org/10.1123/pes.2016-0107

Tortella, P., Quinto, A., Fumagalli, G. F., Lipoma, M., Stodden, D. and Sgrò, F. (2023) Effects of different teaching approaches on proxy measures of physical fitness of Italian kindergarten children. *International Journal of Environmental Research and Public Health* **20(10)**, 5792. https://doi.org/10.3390/ijerph20105792

Tremblay, M. S., Chaput, J.-P., Adamo, K. B., Aubert, S., Barnes, J. D., Choquette, L., Duggan, M., Faulkner, G., Goldfield, G. S., Gray, C. E., Gruber, R., Janssen, I., Janssen, X., Jaramillo García, A., Kuzik, N., LeBlanc, C., MacLean, J., Okely, A. D., Roberts, K. C., Sampasa-Kanyinga, H., Sawyer, S. M., Shook, R. P., Tremblay, L., Tucker, P., Walsh, J. J., Warburton, D. E. R., and Carson, V. (2017) Canadian 24-hour movement guidelines for the early years (0-4 years): An integration of physical activity, sedentary behaviour, and sleep. *BMC Public Health* **17(S5)**, 874. https://doi.org/10.1186/s12889-017-4859-6

Vandorpe, B., Vandendriessche, J., Vaeyens, R., Pion, J., Matthys, S., Lefevre, J., Philippaerts, R. and Lenoir, M. (2012) Relationship between sports participation and the level of motor coordination in childhood: A longitudinal approach. *Journal of Science and Medicine in Sport* **15(3)**, 220-225. https://doi.org/10.1016/j.jsams.2011.09.006

Vlahov, E., Baghurst, T. M. and Mwavita, M. (2014) Preschool motor development predicting high school health-related physical fitness: A prospective study. *Perceptual and Motor Skills*. https://doi.org/10.2466/10.25.PMS.119c16z8

Wang, G., Zeng, D., Zhang, S., Hao, Y., Zhang, D. and Liu, Y. (2023) The effect of different physical exercise programs on physical fitness among preschool children: A cluster-randomized controlled trial. *International Journal of Environmental Research and Public Health* **20(5)**, 4254. https://doi.org/10.3390/ijerph20054254

Wang, X. and Zhou, B. (2024) Motor development-focused exercise training enhances gross motor skills more effectively than ordinary physical activity in healthy preschool children: An updated meta-analysis. *Frontiers in Public Health* **12**, 1414152. https://doi.org/10.3389/fpubh.2024.1414152

Wick, K., Kriemler, S. and Granacher, U. (2021) Effects of a strength-dominated exercise program on physical fitness and cognitive performance in preschool children. *The Journal of Strength & Conditioning Research* **35(4)**, 983-990. https://doi.org/10.1519/JSC.0000000000003942

Xia, R., Yang, L., Liang, C., Lyu, D., Zang, W., Sun, G. and Yan, J. (2024) Research on aerobic fitness in children and adolescents: A bibliometric analysis based on the 100 most-cited articles. *Frontiers in Medicine* **11**, 1409532. https://doi.org/10.3389/fmed.2024.1409532

Xu, Y., Zhang, W., Zhang, K., Feng, M., Duan, T., Chen, Y., Li, X., and Smith, J. (2022) Basketball training frequency is associated with executive functions in boys aged 6 to 8 years. *Frontiers in Human Neuroscience* **16**, 917385. https://doi.org/10.3389/fnhum.2022.917385

Zeng, N., Ayyub, M., Sun, H., Wen, X., Xiang, P. and Gao, Z. (2017) Effects of physical activity on motor skills and cognitive development in early childhood: A systematic review. *BioMed Research International* **2017(1)**, 2760716. https://doi.org/10.1155/2017/2760716

Zhang, Y., He, Z. and Xu, J. (2017) *National Physical Fitness Surveillance and Evaluation*. Beijing: Science Press.

Key points

- Structured physical activity less than twice per week was insufficient to improve preschool children's physical fitness.
- Engaging in structured physical activity at least twice weekly significantly enhanced key physical fitness indicators.
- The benefits plateaued when frequency exceeded three sessions per week, indicating diminishing marginal returns.

AUTHOR BIOGRAPHY

Fang REN
Employment
Beijing Sport University, Beijing, China
Degree
PhD candidate
Research interests
Promotion of Motor Development and Physical Fitness in Preschool Children
E-mail: 2019210151@bsu.edu.cn

Xing ZHAO
Employment
Beijing Sport University, Beijing, China
Degree
PhD
Research interests
Promotion of Motor Development and Physical Fitness in Preschool Children
E-mail: zhaoxing@bsu.edu.cn

Sha QU
Employment
Beijing Sport University, Beijing, China
Degree
PhD
Research interests
Promotion of Motor Development and Physical Fitness in Preschool Children
E-mail: qusha@bsu.edu.cn

✉ **Xing Zhao**
Beijing Sport University, School of Sport Science, Beijing 100000, China

Appendix A

Physical Fitness Testing Methods

The test consists of standing long jump, continuous jumping with both feet, tennis throwing, 10 m×2 shuttle run, sit-and-reach, walking the balance beam.

Standing long jump

A soft surface was used for the test. During the test, participants stood with their feet naturally apart behind the starting line, then swung their arms and jumped forward as far as possible by pushing off the ground with both feet. The measurement was taken as the straight-line distance from the starting line to the nearest heel of the feet.

Continuous jumping with both feet

The test was conducted using a tape measure and a stopwatch. On a flat surface, ten horizontal lines were drawn at 0.5-meter intervals, with a soft block (10 cm long, 5 cm wide, 5 cm high) placed across each line. A starting line was set 20 cm from the first soft block. During the test, participants stood with their feet together behind the starting line. Upon hearing the "start" command, they jumped forward with both feet simultaneously, hopping over one soft block at a time (either in one jump or two jumps), and continued jumping over all ten blocks. The tester started the stopwatch when the participant began, and stopped it when the participant's feet landed after jumping over the tenth soft block.

Tennis throwing

The test was conducted using a tennis ball and a tape measure. During the test, participants faced the throwing direction with their feet positioned one in front of the other, standing about one step behind the throwing line. They held the ball in one hand, raised it above their head, and threw it forward as far as possible. When releasing the ball, the back foot could step forward, but it could not touch or cross the throwing line. The effective result was the straight-line distance from the throwing line to the point where the ball landed.

10 m×2 shuttle run

The test was conducted using a stopwatch. Each lane had a turnaround line 10 meters from the starting line, marked by a cone. During the test, participants formed pairs and assumed a standing start position at the starting line. Upon hearing the command "go," they sprinted toward the turnaround line with maximum effort, and the tester started the stopwatch as the participants began. When participants reached the turnaround line, they touched the cone with their hand, then turned around and ran back to the starting line. The stopwatch was stopped when their chest crossed the vertical plane of the starting line.

Sit-and-reach

The sit-and-reach test was conducted using a sit-and-reach box. During the test, participants sat on a mat with their legs extended straight, heels together, and toes naturally apart, with the soles of their feet flat against the testing apparatus. Then, with palms facing downward and arms extended forward, they bent their upper body forward and used the fingertips of their middle fingers to push the slider smoothly forward until it could not be moved further.

Walking the balance beam

The test was conducted using a balance beam (3 meters long, 10 cm wide, and 30 cm high), with a starting line and an ending line at each end of the beam, and an additional platform (20 cm long, 20 cm wide, and 30 cm high) placed outside each end of the beam. During the test, participants stood on the platform facing the balance beam with their arms extended sideways. Upon hearing the "start" command, they moved forward across the beam. The tester started the stopwatch when the participant began and stopped it when any part of the participant's foot crossed the ending line.