Journal of Exercise Science & Fitness 22 (2024) 456–462

Contents lists available at ScienceDirect

Journal of Exercise Science & Fitness

journal homepage: www.elsevier.com/locate/jesf

Effects of 8 weeks of rhythmic physical activity on gross motor movements in 4-5-year-olds: A randomized controlled trial

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ARTICLE INFO

Keywords:
Rhythmic physical activity
4-5-Year-olds
Children
Gross motor
Randomized controlled trial

ABSTRACT

Objective: Rhythmic physical activity holds promise for positively influencing the gross motor development of 4-5-year-old children, yet empirical research in this domain remains limited. This study aimed to investigate the effects of rhythmic physical activity on the gross motor development in children aged 4–5 years.

Methods: Fifty children aged 4–5 years were recruited and randomly assigned to either the intervention or control group. Both groups participated in a 10-week intervention program facilitated by a professional trainer, with support from numerous dedicated volunteers from reputable sports universities. This program comprised a one-week baseline assessment followed by 8 weeks of rhythmic physical activity training conducted three times per week. Gross motor performance was assessed using the PGMQ scale before and one week after the intervention.

Results: Following the 8-week intervention, the intervention group demonstrated significant enhancements in displacement ability, with notable improvements observed in. Specifically, the scores for running, sliding lateral transfer, leaping step, two-footed back-and-forth jump, and total displacement ability showed significant increases ($P < 0.05$). Moreover, the total scores for running, standing long jump, sliding lateral transfer, leaping step, two-footed back-and-forth jump, and displacement ability exhibited significant differences between the intervention and control groups ($P < 0.05$). Regarding manipulative ability, the intervention group showed significant increases in scores for over-the-shoulder throwing, two-handed catching, and kicking ($P < 0.05$). Moreover, there were significant differences between groups in the scores for two-handed catching and kicking ($P < 0.05$). Concerning balance ability, the intervention group exhibited significant improvements in scores for single-leg stand, double-leg stand, and total balance ability ($P < 0.05$). No significant differences were observed in any of the indices within the control group ($P > 0.05$). The two-way repeated measures ANOVA of intervention × time revealed significant differences in scores for running, sliding lateral movement, leaping step, jumping back and forth with both feet, leading ability, kicking, manipulation ability, single-leg stand, double-leg stand, balance ability, and gross motor scores ($P < 0.05$).

Conclusions: This study underscores the beneficial impact of engaging in eight weeks of rhythmic physical activity on the gross motor development of 4-5-year-olds. Furthermore, the improvements in gross motor development achieved through rhythmic physical activity may surpass those obtained through general physical activity.

1. Introduction

The World Health Organization (WHO) has issued guidelines on physical activity for young children,[1] aiming to foster the comprehensive development of fundamental motor skills. Motor development plays a pivotal role in early human growth and development, representing a

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https://doi.org/10.1016/j.jesf.2024.10.001
Received 15 July 2023; Received in revised form 28 September 2024; Accepted 6 October 2024
Available online 13 October 2024

fundamental aspect of an individual's future well-being and advancement.[2] Gross motor skill development during the physiological growth phase of early childhood ensures the successful engagement in daily physical activities, while also establishing a foundation for the subsequent refinement of fine and intricate motor skills.[3–6]

These skills form the foundational basis for the acquisition of specialized movement sequences essential for children, adolescents, and adults to actively engage in various organized and unstructured physical activities.[7] Recent years have witnessed an increasing research focus on gross motor skill development, owing to its association with children's physical well-being, cognitive and social development, and the establishment of a physically active lifestyle.[8–10] Additionally, the correlation between gross motor skill proficiency, motor development, and perceptions of health and fitness has been instrumental in predicting the likelihood of obesity from childhood through adulthood.[11] Hence, investigating effective strategies to promote gross motor development in young children is a pertinent issue warranting thorough examination and exploration.[12]

Rhythmic physical activity refers to a movement-based practice accompanied by music or song, incorporating various elements, including coordination exercises, rhythmic patterns, body movements synchronized with music or song, dance routines, and activities that promote balance, agility, and spatial awareness, that facilitate children's motor development.[13] Research has shown that infants are capable of responding to music and instinctively synchronizing their movements with its rhythm[14,15]. Building upon this innate response, Dalcroze eurythmics devised a somatic rhythm teaching method that enables children to explore the tempo and intensity of music and express their inner emotions through coordinated bodily movements.[16] By integrating the principles of learning transfer theory, the development of gross motor skills in young children is regarded as a malleable process that is influenced by both the individual and the environment. When certain factors in one learning task align with those in another task, they can positively affect the latter's acquisition.[17]

Acknowledging the multifaceted and rhythmic characteristics inherent in physical activities, we hypothesize their congruence with the gross motor development of preschool-aged children. Thus, we hypothesized that implementing a rhythmic physical activity intervention could augment the advancement of gross motor skills in 4-5-year-old children. To examine this hypothesis, we conducted an 8-week intervention employing rhythmic physical activities with children in the specified age range. The objective was to evaluate whether these interventions could enhance gross motor development and potentially lead to superior outcomes in gross motor skills compared to conventional approaches to physical activity. This study provides empirical groundwork for the utilization of movement interventions to enhance gross motor development in young children.

2. Methods

2.1. Participants

In May 2023, we enrolled 50 children aged 4–5 years from a kindergarten in Liaoning Province for this trial. Selection criteria ensured that participants, along with their guardians, possessed sufficient understanding of the intervention trial and voluntarily agreed to take part. Eligible participants had to meet specific requirements: they were aged 4–5 years, lacked regular physical activity habits such as children's swimming, fitness programs tailored for children, and running activities, had no physical impairments, did not have a pacemaker implant, were free from terminal illness, and demonstrated proficiency in typical physical activities such as running, jumping, throwing, kicking a ball, climbing, and swinging.

More specifically, participants were chosen based on their ability to stand on one foot for more than 9 s, perform somersaults and jumps, navigate stairs independently, walk forwards and backwards effortlessly, pedal a tricycle, replicate geometric shapes such as triangles, circles, squares, and other objects, stack 10 or more blocks, use utensils, dress and undress, brush teeth, and manage toileting with minimal assistance.

Furthermore, participants were required to abstain from participating in any other physical activity studies during the intervention period, except for the specified intervention activities. The designated kindergarten classrooms for the study were M1, M2, M3, M4, and M5. Children grasped the program relatively easily, as it involved playful experiments, whereas guardians had a deeper understanding of the intervention's objectives and were motivated to enhance their children's gross motor skills. They expressed eagerness to participate in the research aimed at identifying optimal strategies for improving their children's health through enhancing gross motor skills.

Participants were randomly assigned to either the intervention or control groups. Specifically, we conducted a randomized, double-blind, crossover clinical trial in accordance with existing literature.[7,18] This decision was based on the understanding that the onset of secondary sexual characteristics typically occurs around the age of 8 years, and due to the unique parental concerns regarding young children, it was challenging to recruit a sufficiently large sample with uniform indicators. Given the age range studied, we did not stratify participant s based on age or sex. Instead, we employed predetermined criteria to recruit participants. Each participant was assigned a unique identification number ranging from 1 to 50 in the order of enrollment. Subsequently, 25 numbers were randomly selected from this range using statistical software SPSS. Participants corresponding to these selected numbers were allocated to the intervention group, while the remaining participants were assigned to the control group. It is crucial to highlight that this study employed a double-blind design, ensuring that neither participants nor researchers were aware of group assignments during the intervention period. The allocation process was conducted by a specialized researcher and remained undisclosed until the conclusion of the study. Every participant successfully completed the intervention course or control course, engaged in regular extracurricular physical activity during the intervention period, and underwent a one-month follow-up after the intervention. No adverse effects were reported among the participants.

The study adhered to the principles outlined in the Declaration of Helsinki and received approval from the Experimental Ethics Committee for Sports Science of Beijing Sport University (2023131H). Participants and their guardians received comprehensive information regarding the study's objectives, procedures, and possible risks, and provided written informed consent. There were no participant withdrawals during the intervention period. To ensure the smooth execution of the entire experimental procedure, college student volunteers from Jiangnan University and Beijing Sport University provided individualized attention and closely monitored the entire process of children's physical exercise. Additionally, kindergarten teachers were actively involved in the process. These actions collectively contributed to ensuring participant engagement in the intervention. All participants successfully completed all training sessions, and they were followed up via text message one month after the intervention. No adverse effects were reported by the participants.

2.2. Experimental design

The study employed a randomized and controlled trial design, consisting of a baseline testing and intervention content adaptation period lasting 1 week, followed by an 8-week intervention phase, and concluding with a week of post-testing (refer to Fig. 1).

2.3. Gross motor evaluation

The gross motor skills of participants were evaluated using the Preschooler Gross Motor Quality (PGMQ) scale,[19,20] both before and after

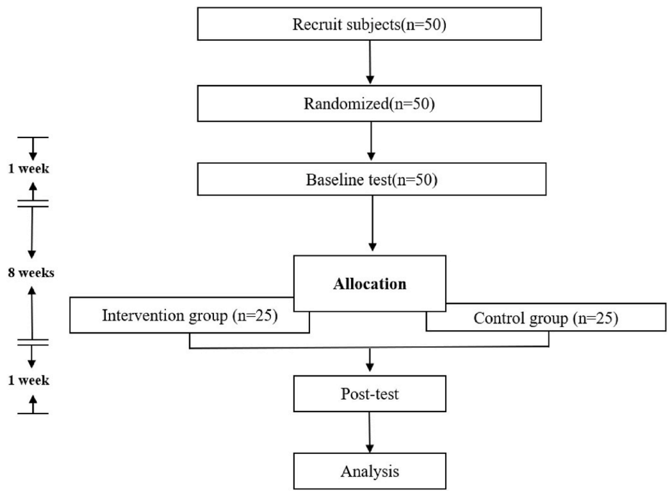

Fig. 1. Experimental design.

the intervention. This scale is designed to assess a wide range of gross motor abilities in preschool-aged children, spanning from 3 to 6 years old. It comprises three developmental functional categories: balance, movement, and object manipulation. Each category includes a variety of items, with 4 items in balance, 8 in movement, and 5 in object manipulation. Each item is evaluated based on 4 to 6 scoring criteria. The total score on the PGMQ scale is 84 points. To ensure consistency in scoring, a single rater, blinded to participant grouping, conducted the scoring for both intervention and control groups.

2.4. Intervention content

In this study, we initially identified music that aligns with the interests and age characteristics of young children. The chosen music is relaxing, pleasant, less stimulating, and characterized by repetition. According to the reference, we utilize the authoritative rhythmic physical activities endorsed by the Ministry of Education of the People's Republic of China, presented in the format of Chinese broadcast gymnastics.[7] This approach is grounded in the theory of children's dance creation and adheres to the developmental principles governing 3-5 year-olds' motor skills. In its design, particular attention is paid to the anatomical features of human joints, with a focus on articulating movements such as those involving the head and chest.

Subsequently, we selected various body movements based on the style and rhythm of each musical piece. These movements were tailored to match the rules and characteristics of the participants' movement development. During the selection process, we focused on rhythmic body movements that foster comprehensive gross motor development, such as imitating small animals, mimicking the movements of crabs and rabbits, and engaging in other motion patterns. These movements enable children to experience diverse body postures and variations in muscle force. We then collaborated with the participants' teachers and guardians to discuss the feasibility of incorporating similar movements and ultimately determined the movements' difficulty level and the number of required repetitions. For further details, please refer to the attachment.

2.5. Intervention programs

The interventions and tests were conducted at physical activity venues in kindergartens from August to December. We ensured comprehensive safety measures at the test site to mitigate potential risks for young children. The indoor temperature was maintained at 26 °C, while the humidity was regulated between 50 and 60 %.

The first session of the first week served as an orientation session for the intervention group participants. This session focused on providing instruction and conducting baseline tests. The first two sessions of the first week were dedicated to familiarizing the participants with the intervention content. A baseline test was conducted during the third session. The intervention group participants actively participated in rhythmic physical activity for 8 weeks, engaging three times a week for 50 min. The activities included a 10-min warm-up, a 30-min rhythmic physical activity intervention, and a 10-min relaxation exercise. The activities took place between 9 a.m. and 10 a.m., during which participants consumed breakfast under supervision. Meanwhile, the control group did not undergo any physical activity intervention and retained their existing lifestyle habits.

2.6. Dietary control during the intervention programs

Despite administering the same breakfast before each intervention, we acknowledged that our participants were undergoing a critical phase of physical development and exhibited individual differences. Consequently, we chose not to enforce strict control over their daily dietary intake. The rationale behind implementing dietary control in our study is rooted in its potential to elucidate the intricate relationship between diet and physical activity concerning health outcomes. It is widely recognized that nutrition significantly influences factors such as energy expenditure, muscle development, and overall physical fitness in children.

Through the implementation of dietary control, our aim is to mitigate confounding variables, thus facilitating a more precise interpretation of exercise-related outcomes. This comprehensive approach not only bolsters the scientific robustness of the study but also provides valuable insights for designing effective interventions aimed at promoting children's health and well-being. Instead, we provided verbal instructions to both guardians and participants, emphasizing the importance of maintaining a balanced diet and refraining from making significant alterations to their eating habits.

2.7. Blindness

Independent statisticians, unaffiliated with the experiment, oversaw the implementation of blinding procedures throughout the study. To ensure rigorous adherence to blinding protocols, distinct roles were assigned to the coach, assessor, and statistical analyst, each operating independently. Coaches delivered interventions to participants according to predetermined treatment protocols designated by specific numerical codes. Treatment consistency was maintained by assigning all interventions to a single proficient coach. The coach, while guiding participants through interventions, remained unaware of their group assignments, which were concealed within sealed envelopes. The assessor focused solely on evaluating outcome indicators, with no involvement in patient recruitment, grouping, or management. The statistician, responsible for dividing participants into groups, remained blind to specific group assignments throughout the study.

2.8. Statistical analysis

Data were analyzed using SPSS, version 25.0 (IBM Corp, Armonk, NY). For continuous variables, we calculated mean values and standard deviations. Independent samples t-tests and paired-sample t-tests were employed to compare the initial level differences and post-intervention group differences between the intervention and control groups. A two-way repeated measures ANOVA was employed to evaluate the interaction between time (pre- and post-intervention) and group (intervention and control groups). Post hoc Bonferroni tests were conducted when necessary.

The sample size was determined using GPower 3.1 software. Based on a *t*-test with an effect size of 0.5, an alpha error probability of 0.05, and a beta error probability of 0.05, a minimum of 42 participants was required to achieve an actual efficacy of 95.45 %. The trial was completed by a final cohort of 50 participants, and GPower software determined an effect size of 0.53.

3. Results

All participants successfully completed the 10-week intervention program. It's important to clarify that while our intervention spanned 8 weeks, an additional week was allocated both before and after the intervention for the collection of pre-test and post-test data, resulting in an overall experimental period of 10 weeks. Table 1 displays the demographic characteristics of the participants and compares the baseline differences between the intervention and control groups (including gender, age, and each indicator). No significant differences were found between the groups for any of the indicators ($p > 0.05$).

Throughout our experimental study, the results were consistently analyzed by comparing post-intervention outcomes with baseline measurements within each group. Following the 8-week intervention, the intervention group exhibited significant improvements in various aspects of displacement ability, including running, sliding lateral transfer, leaping step, double-legged back-and-forth jump, and total displacement ability ($p < 0.05$). Moreover, comparisons between groups revealed significant differences in the scores of running, standing long jump, sliding lateral transfer, leaping step, double-legged back-and-forth jump, and total displacement ability ($p < 0.05$).

Regarding manipulative ability, the intervention group demonstrated significant improvements in the scores of over-the-shoulder throwing, two-handed catching, and kicking ($p < 0.05$). Furthermore, there were significant differences between the groups in the scores of two-handed catching and kicking ($p < 0.05$).

The intervention group demonstrated significant improvements in balance ability, as evidenced by the significant increase in scores for single-leg stand, double-leg stand, and total balance ability ($p < 0.05$). Additionally, there were significant differences between the groups in the scores of single-leg stand, double-leg stand, and total balance ability ($p < 0.05$).

The control group did not show any significant differences in any of the indices ($p > 0.05$).A two-way repeated measures ANOVA, comprising intervention and time as factors, revealed significant differences ($p < 0.05$) in scores for running, sliding side-shift, leaping step,

Table 1
All participant indexes data in the pre- and post-intervention.

			Intervention group					Control group					
	Base line P	Post P	pre	post	Δ	es	p	pre	post	Δ	es	p	Interaction p
Gender	0.580												
Age	0.619												
Down stairs	0.866	0.304	2.64 ± 0.98	2.90 ± 0.68	0.26 ± 0.63	0.31	0.050	2.60 ± 0.65	2.72 ± 0.54	0.12 ± 0.60	0.2	0.327	0.448
Running	0.667	0.026[a]	2.22 ± 1.21	3.06 ± 0.92	0.84 ± 0.80	0.78	0.000[a]	2.36 ± 1.08	2.48 ± 0.88	0.12 ± 0.53	0.12	0.265	0.100[b]
Horizontal jumping	0.503	0.041[a]	2.40 ± 1.11	2.64 ± 0.82	0.24 ± 0.71	0.25	0.103	2.12 ± 0.88	2.20 ± 0.65	0.08 ± 0.64	0.1	0.538	0.406
Hopping	0.059	0.068	2.82 ± 1.07	2.88 ± 0.73	0.06 ± 0.46	0.07	0.524	2.24 ± 1.05	2.44 ± 0.92	0.20 ± 0.50	0.2	0.057	0.310
Sliding	0.735	0.030[a]	1.78 ± 1.14	2.48 ± 0.76	0.70 ± 0.76	0.72	0.000[a]	1.88 ± 0.93	2.00 ± 0.76	0.12 ± 0.60	0.14	0.327	0.005[b]
leaping step	0.672	0.001**	2.10 ± 0.84	2.58 ± 0.62	0.48 ± 0.64	0.65	0.001[a]	2.00 ± 0.82	1.92 ± 0.72	−0.08 ± 0.49	0.1	0.425	0.004[b]
Leaping	0.331	0.215	1.92 ± 0.64	2.04 ± 0.61	0.12 ± 0.44	0.19	0.185	1.72 ± 0.79	1.82 ± 0.62	0.10 ± 0.64	0.14	0.446	0.904
Jumping from side to side	0.391	0.008**	1.72 ± 0.84	2.64 ± 0.76	0.92 ± 0.67	1.15	0.000[a]	1.96 ± 1.10	2.06 ± 0.71	0.10 ± 0.84	0.11	0.558	0.000[b]
Total Mobility Score	0.589	0.000**	17.60 ± 5.29	21.22 ± 3.66	3.62 ± 2.47	0.8	0.000[a]	16.88 ± 3.98	17.64 ± 2.66	0.76 ± 2.31	0.22	0.114	0.000[b]
Overhand throwing	0.674	0.132	2.00 ± 1.03	2.30 ± 0.94	0.30 ± 0.58	0.3	0.016[a]	1.88 ± 0.97	1.92 ± 0.81	0.04 ± 0.84	0.04	0.814	0.261
Catching	0.214	0.039[a]	3.06 ± 1.94	3.36 ± 1.04	0.30 ± 0.54	0.27	0.010[a]	2.60 ± 1.38	2.72 ± 1.10	0.12 ± 0.52	0.1	0.265	0.241
Kicking	0.485	0.022[a]	1.68 ± 0.70	2.22 ± 0.50	0.54 ± 0.50	0.9	0.000[a]	1.80 ± 0.50	1.84 ± 0.62	0.04 ± 0.45	0.07	0.664	0.002[b]
Ball bouncing	0.887	0.693	1.36 ± 1.11	1.56 ± 0.71	0.20 ± 0.76	0.21	0.203	1.32 ± 0.85	1.48 ± 0.71	0.16 ± 0.55	0.18	0.161	0.832
Strike stationary ball	0.202	0.141	1.96 ± 0.98	2.00 ± 0.87	0.04 ± 0.45	0.04	0.664	1.64 ± 0.76	1.68 ± 0.63	0.04 ± 0.35	0.06	0.574	1.000
Total score for handling ability	0.336	0.008**	10.06 ± 3.49	11.44 ± 2.61	1.38 ± 1.45	0.45	0.000[a]	9.24 ± 2.37	9.64 ± 1.98	0.40 ± 1.41	0.18	0.170	0.031[b]
Single leg standing	0.328	0.015[a]	2.36 ± 1.32	2.74 ± 1.05	0.38 ± 0.63	0.32	0.006[a]	2.04 ± 0.93	2.08 ± 0.76	0.04 ± 0.54	0.05	0.714	0.046[b]
Tandem standing	0.617	0.040[a]	3.28 ± 1.40	3.86 ± 0.89	0.58 ± 0.81	0.5	0.002[a]	3.08 ± 1.41	3.20 ± 1.30	0.12 ± 0.44	0.09	0.185	0.016[b]
Walking line forward	0.875	0.360	2.12 ± 0.73	2.34 ± 0.47	0.22 ± 0.58	0.36	0.069	2.08 ± 1.03	2.16 ± 0.85	0.08 ± 0.64	0.08	0.538	0.421
Walking line backward	0.728	0.820	2.46 ± 0.89	2.66 ± 0.75	0.20 ± 0.66	0.24	0.144	2.56 ± 1.12	2.60 ± 1.08	0.04 ± 0.20	0.04	0.327	0.253
Total balanceability score	0.613	0.038[a]	10.22 ± 3.03	11.60 ± 2.15	1.38 ± 1.62	0.53	0.000[a]	9.76 ± 3.35	10.04 ± 2.95	0.28 ± 1.02	0.09	0.183	0.003[b]
Gross motor scores	0.428	0.000**	37.88 ± 9.86	44.26 ± 7.07	6.38 ± 3.95	0.74	0.000[a]	35.92 ± 7.26	37.32 ± 5.43	1.4 ± 3.51	0.22	0.058	0.000[b]

[a] Indicates a significant difference from pre-to post-intervention ($p < 0.05$).
[b] There is a significant difference in intervention × time.

jumping back and forth on both feet, elicitation ability, kicking, manipulation, single-leg stand, double-leg stand, balance, and gross motor scores.

4. Discussion

The findings of this study suggest that engaging in 8 weeks of rhythmic physical activity can enhance gross motor development in children aged 4–5 years. Gross motor skills were categorized into mobility skills, manipulative skills, and balance skills. The findings revealed that engaging in rhythmic physical activities positively impacted all three of these skills in young children.

Mobility refers to the examination of young children's physical dexterity and coordination as they transition from the starting point to the endpoint.[21] No significant differences were observed within the intervention group in terms of stair descent, standing long jump, single-leg continuous jump, and straddle jump measurements. These findings suggest that the outcomes may be influenced by the children's body proportions and leg strength. Our study revealed that children who had body proportions close to the golden mean exhibited greater rhythmic ability in descending stairs, a rhythmic physical activity. Additionally, certain children with body proportions near the golden mean experienced enhanced stability in their center of gravity, thereby compensating for certain rhythmic variations. These findings were observed despite no notable difference in height among the children. The performance of standing jumps and single-leg continuous jumps primarily depends on leg strength, while children's leg strength and body coordination impact their scores in the jumping category.[22,23] Despite the absence of significant differences in these three movements before and after the intervention, a noticeable trend toward improvement was detected. The potential impact of individual differences in physical development among children on motor skills improvement is a multifaceted and complex issue. Several factors may contribute to this phenomenon, including variations in body proportions, muscle strength, coordination, and motor learning abilities.

The overall mobility of both the intervention and control groups showed significant improvement compared to the control group following the intervention, indicating the positive impact of rhythmic physical activity on the mobility of 4- to 5-year-olds. This is consistent with the findings of LI et al.[24] Rhythmic physical activity involves repetitive movements that stimulate children's sensory perception and shares some similarities with gross motor development. Rhythmic physical activities play a crucial role in the holistic development of 4-5-year-olds, impacting various domains including physical, cognitive, social, and emotional development. Research within the field of early childhood development consistently highlights the significance of rhythmic activities in enhancing various developmental milestones during this critical stage. Simultaneously, early childhood represents a critical period for gross motor development, and engaging in rhythmic physical activities positively influences this developmental process.

Manipulation assesses a child's capacity to develop gross motor skills, including object-catching and object-hitting abilities.[21] The present study observed no statistically significant differences in tapping and ball-hitting performance between the intervention group before and after the intervention. This lack of specific ball movement instruction in the intervention may explain the need for a particular sequence of force while tapping and striking the ball.[25] Nevertheless, the final outcomes revealed a statistically significant enhancement in manipulative ability among children in the intervention group compared to the control group, aligning with the findings of Mattsson et al.[26] Mattsson et al. proposed that a structured physical activity intervention led to a notable improvement in overall manipulative abilities, whereas unstructured activities displayed greater enhancement in single-item abilities.

The intervention implemented in this study comprised a predefined curriculum aimed at enhancing toddlers' coordination, proprioceptive abilities, and body control during rapid movements. As a result, toddlers demonstrated heightened exploration of their surroundings, fostering the development of their physical capabilities beyond conventional patterns and trajectories. Consequently, their manipulative skills were inadvertently enhanced. Failure to strictly regulate physical activities in the control group may introduce confounding variables, jeopardizing the credibility of research outcomes. To mitigate this concern, future studies should adopt stringent control measures, including randomization, standardized protocols, activity monitoring, controlled environments, and blinding. These strategies bolster the internal validity of research designs and facilitate accurate interpretation of findings. In ensuring the scientific rigor of future research endeavors, it is imperative to effectively control various factors, including gender, sleep, and diet. In this particular study, the homogenous environment provided by kindergarten settings offers effective control over sleep and diet among children aged 4–5. The uniform management and lifestyle of kindergarten attendees facilitate consistent sleep patterns and dietary habits across participants. However, we opted not to differentiate by gender in our study. We reasoned that at such a young age, children have yet to develop noticeable secondary sexual characteristics, minimizing potential gender-related differences. Moreover, in striving for a robust and representative sample size to yield objective and reliable research outcomes, recruiting 50 boys and 50 girls proved challenging. The task of locating a sufficient number of eligible children, coupled with securing cooperation from their guardians, presented formidable obstacles. As a result, we refrained from stratifying by gender. Nevertheless, Despite the absence of gender-based analysis, we believe our research remains methodologically sound and offers valuable insights into the targeted phenomenon.

Balance serves as the foundation for the development of human movement and is a prerequisite for all other movements.[21] In this study, we observed no significant difference in forward and backward walking between the intervention group before and after the intervention. However, there was a noteworthy enhancement in two static movement skills, namely one-foot stand and two-foot stand. Our findings indicate that this result may be attributed to the relatively short duration of the 8-week intervention, which might not provide enough time for a substantial improvement in children's dynamic balance.[27] However, the intervention group demonstrated a greater increase in dynamic balance indicators compared to the control group. Therefore, it is possible that rhythmic physical activity has a facilitating effect on the dynamic balance of young children.

Overall, our study revealed notable disparities in leaping step, lateral jumping, total mobility score, total handling ability score, and gross motor scores among 4-5-year-old children after an 8-week regimen of rhythmic physical activities. While we currently lack an explanation for why these particular movements elicited more pronounced changes compared to others, we view these findings optimistically and prioritize their presentation. Moving forward, we aim to elucidate the physiological and molecular mechanisms underpinning these observed changes in subsequent research endeavors. These enhancements are pivotal in fostering the physical development of children aged 4–5, offering multifaceted benefits for their overall health and well-being. These include improved coordination, enhanced balance, strengthened muscles, cardiovascular fitness, total mobility score, total handling ability score, and promotion of an active lifestyle.

We conducted a two-way repeated measures ANOVA and observed an interaction between intervention and time for several indicators. Subsequent analysis revealed that, as the study was conducted during the summer holidays, the children in the control group did not engage in any other forms of physical activity. Nonetheless, the guardians of the participants enrolled them in various sports training programs, with some also attending early childhood fitness courses. This difference in participation might have been one of the factors influencing the observed interaction.[28] However, in terms of the results, rhythmic physical activity exhibited a more favorable impact on the gross motor development of young children, potentially surpassing general physical activity.

This study is subject to several limitations. Firstly, we did not impose strict restrictions on the physical activity of the control group, considering the critical ages of 4–5 for motor development in young children. This lack of control may have contributed to result heterogeneity, suggesting the need for future researchers to tightly regulate the physical activity of control groups. Secondly, although previous studies suggest minimal gender-based differences in physical characteristics and abilities, we did not discuss the potential impact of gender, sleep, and diet on intervention outcomes. However, gender-based differences in the acceptance of physical activity programs could still influence study results. Lastly, this study did not account for the specific physical and psychological developmental needs of young children or their individual circumstances. The comparison of various intervention times, frequencies, and periodicities lacked a foundation for determining optimal intervention measures.

Furthermore, our experimental application to real-life scenarios overlooked the psychological developmental needs of young children, potentially affecting the effectiveness of our intervention. Additionally, we did not thoroughly explore intervention timing, frequency, and periodicity to identify optimal strategies for our target age group. These shortcomings will be addressed in future research endeavors. Moving forward, we aim to conduct longitudinal studies to gain deeper insights into the enduring effects of these interventions on gross motor development and other developmental domains.5. Conclusion.

The findings of this study demonstrate that engaging in 8 weeks of rhythmic physical activity can effectively enhance gross motor development in children aged 4–5. Notably, the observed gains in gross motor development are likely to surpass those achieved through engaging in general physical activity.

Informed consent statement

Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the participants to publish this paper.

Author contributions

Conceptualization, H.T.Z., L.Y.S., G.S. and H.K.Z.; methodology, H.T. Z. and L.Y.S.; validation, H.T.Z. and G.S.; formal analysis, H.K.Z., Y.J.D. and C.L.; investigation, H.T.Z., H.X.L. and L.Y.S.; data curation, Y.Y. and Y.J.D.; writing—original draft preparation, H.T.Z. and G.S.; writing—review and editing, Y.Y.; visualization, Y.J.D.; supervision, C.L.; project administration, Y.J.D.; funding acquisition, H.T.Z., Y.Y. and C.L. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board statement

The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board of Beijing Sport University(2023131H).

Data availability statement

The original contributions presented in the study are included in the article; further inquiries can be directed to the corresponding author. The guardian of the participant does not want the author to disclose the height and weight of the participant. If necessary, contact the correspondent author (C.L. or Y.Y.). The specific content of the intervention can be obtained by contacting the corresponding author (C.L. or Y.Y.).

Funding

This work was supported by the 14th five-year Education Plan of Jiangsu Province (C/2022/01/78).

Declaration of competing interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Acknowledgments

H.T.Z. would like to thank Weiye Wang and Shichang Zheng, two teachers from the physical Education Department of Jiangnan University, for their help in data analysis, and for his parents' support and encouragement for his work all the time. H.T.Z. also thank his lover Ge Song for her spiritual companionship during his work.

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