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The Impact of Preschool Aerobics on the Physical Fitness and Executive Function of Young Children: An Experimental Study

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Abstract: *Background: Investigating the feasibility and optimal approach of an aerobics program to promote physical fitness and executive function development in young children.*

Methods: *We employ a comprehensive random sampling technique to execute a three-month aerobics experimental intervention on the children from the middle class of two premier kindergartens in Beijing. A third-party evaluation was conducted during the experiment's intermediate phase, and parent and teacher questionnaires regarding the child's behavior were disseminated among the experimental kindergarten's parents and educators.*

Results: *The Teachers Questionnaire for toddlers' behavior indicated significant improvements in sleep behavior, aggression, and dietary habits; likewise, the parent questionnaire revealed marked enhancements in cognitive response ability, parental listening, and physical resilience. 2. Intervention experiments demonstrated a significant reduction in toddlers' weight, BMI, and Kertole index ($P < 0.01$). However, scores for standing long jump, tennis throw distance, and sit-ups remained unchanged ($P > 0.05$). In contrast, double foot jumping, walking balance beam, and 10m turn-back running scores exhibited notable increases ($P < 0.01$). 3. A multivariate analysis of variance ($\triangle X$) comparing the executive function sub-functions of toddlers from experimental kindergarten and control kindergarten before and after the experiment revealed no statistically significant differences in scores between the two groups ($P > 0.05$).*

Conclusions: *The positive impact of the intervention, as evidenced by preschool teachers' and parents' evaluations, along with observed changes in children's physical fitness and executive function after three months of the program, demonstrates that preschool aerobic exercise can enhance children's physical fitness to a significant degree and elevate their overall health. 2.The implementation of a three-month aerobic exercise regimen enhances executive function in young children. 3.The application of preschool aerobics exercise serves as a viable movement pattern to enhance physical fitness and foster the development of executive function in preschool children.*

Keywords: *Young children; Aerobics; Physical fitness; Executive functions; Experimental study*

1. INTRODUCTION

In recent years, the exploration of physical and mental health in young children has emerged as a significant area of national research. The focus on their physical fitness and mental well-being has garnered considerable attention within society. The developmental stage of young children is crucial for fostering optimal physical fitness and cultivating executive function. Accordingly, this paper endeavors to provide empirical insights into enhancing the physical fitness and psychological executive function of young children through aerobic activities. This offers a practical framework for sports initiatives aimed at promoting the physical fitness and mental health of young children. Executive function pertains to the high-level cognitive process of controlling and regulating other cognitive processes during complex cognitive tasks. It encompasses three sub-functions: inhibition, refresh, and transformation.1The toddler stage, specifically between 3 and 6 years, is a crucial period for the development of executive functions. The early development of these functions is intricately

linked with cognitive, social abilities, physical and mental development, as well as behavioral capabilities such as academic achievement in adulthood. Consequently, it is imperative to focus on the early development of executive functions. Since Piaget's era, the interaction between movement and cognition has garnered significant attention and research. In recent years, the relationship between motor ability and executive functions has emerged as a focal point of research in the field of cognition. Domestic Research conducted both domestically and internationally has demonstrated foreign studies have shown that increasing the level of physical exercise levels and improving enhancing sports ability capabilities are beneficial conducive to the healthy development of an individuals' individual's executive functions. The research Studies focusing on short-term exercise intervention interventions for executive function offer valuable insights and provide a certain reference for designing the formulation of exercise intervention programs, such as determining the arrangement of appropriate intensity and duration of exercise. However, current research predominantly employs simplistic methods like treadmill running or pedal power cycling, which is less aligned with children's daily environments and lacks comprehensive exploration intensity and duration of exercise. However, current research predominantly employs simplistic methods like treadmill running or pedal power cycling, which are less aligned with children's daily environments and lack comprehensive exploration of exercise intensity and exercise time, but current research mostly adopts simple operation treadmill running, pedal power bicycle content, etc., which is more separated from children's living environment, lacking research on exercise content,2while long-term Longer-term (≥three months) aerobic exercise intervention interventions, particularly research on the those empirical empirically examining the study of the impact of on executive function and its three sub-functions, will help us comprehensively provide a more holistic understanding of the internal mechanism mechanisms of underlying the impact effects of exercise on executive function, function. This knowledge will further support and provide a theoretical basis for the view theory that aerobic exercise capacity ability has a positive influence on the executive function.

2. Subjects and Methods

This study employed cluster sampling methodology, selecting a level Aclass kindergarten in Beijing as the experimental site. An experimental intervention was conducted over a three months period from March to June 2023. A control kindergarten, located at a considerable distance from the experimental site and maintaining comparable conditions, was also selected. The middle class (comprising 34 individuals) within the experimental kindergarten underwent children's aerobics, while the control group (consisting of 27 individuals) remained unaltered without any intervention, serving as a blank control. The pre-experimental assessment involved 34 individuals in the experimental kindergarten, and the post-experimental evaluation included one individual who fell ill during the experiment, resulting in a total of 33 participants. In contrast, the control group remained static with all 27 individuals remaining unchanged. The intervention strategy consisted of children's aerobics for 50 minutes, thrice weekly.

2.1. Investigation Method

2.1.1. Questionnaire Method

During the experiment's midpoint, a modified version of the Infant Behavior Questionnaire [Teacher] and the Toddler Behavior Questionnaire [Parents] was developed using third-party evaluation techniques.3,4 These questionnaires were distributed to parents and kindergarten teachers (comprising one head teacher, one regular teacher, and one caregiver) of children enrolled in the experimental kindergarten at week 6. Three teachers conducted assessments on 34 children within the experimental kindergarten, while each parent of these children completed a separate questionnaire. Out of the total, 102 teacher questionnaires and 34 parent questionnaires were distributed; 99 and 30 questionnaires were respectively collected. The returned questionnaires underwent a thorough review process, excluding those that were either not completed or incompletely filled out. Ultimately, valid questionnaires were identified: 98 from teachers and 29 from parents.

2.1.2. Methodology for Expert Survey

In addressing the challenges associated with compiling questionnaires for toddler behavior surveys, designing paper-based experiments, devising toddler aerobics exercises, and executing classic tasks related to toddler executive function psychological experimentation, we sought expert consultation.

Experts have affirmed that both the structural and content validity of the questionnaire exceed 90 points. The experimental design employed in this study is both rigorous and logical. Taking into account the physical attributes and cognitive maturity of toddlers, the proposed scientific and practical toddler aerobics can be effectively implemented by children aged 3–5 years. This exercise encapsulates three classic tasks related to toddler executive function, offering a straightforward and functional approach to studying executive function. It serves as a canonical paradigm in this field. 5-7

2.2. Observation Method

A preliminary week-long experiment was undertaken in the experimental garden involving toddlers, aimed at assessing their acceptance of aerobic movements and rhythm, their understanding and ability to complete tasks related to executive function, and the appropriateness of the aerobics course arrangement. The validity of the experimental design was scrutinized, thereby providing a reference point for subsequent formal experiments.

2.3. Experimental Method

The anticipated outcomes of the experiment are to foster the enhancement of children's physical fitness and bolster their executive function through the implementation of a three-month preschool gymnastics program. Consequently, the efficacy of this intervention is assessed from two perspectives: the improvement in children's physical fitness and the augmentation of their executive function.

2.3.1. Assessment of the Impact of Physical Fitness Intervention on Toddlers

The early childhood phase is a pivotal juncture for the development of physical fitness, with young children's fitness predominantly manifested in attributes such as strength, flexibility, agility, speed, and endurance. Drawing upon the “National Physical Fitness Monitoring Early Childhood Test”index, this study primarily assessed six indicators of physical fitness in young children: balance beam walking, tennis throwing distance, double-footed continuous jumping, 10 m shuttle run, sit-and-reach, and standing long jump.8

2.3.2. Assessing the Impact of Executive Function Intervention in Toddlers

This section delves into a comprehensive evaluation of the effects exerted by executive function interventions on toddlers, aiming to elucidate the underlying mechanisms and potential implications for future research and practice. By the fundamental theory of executive functions and incorporating the three sub-function components, this study employed three classic experimental tasks to assess toddlers' executive function: card sorting, Stroop Day-Night, and gift-delayed satisfaction. The card sorting task involved 16 cards, eight each in blue and pink colors, and eight in round and square shapes. The Stroop Day-Night task featured two supplementary images of the sun and moon star, with all other factors such as image paper material and thickness being consistent. The gift delayed satisfaction task utilized an image analysis method to document the experimental process. Performance during the persistence process was recorded based on video judgments of toddlers' persistence time.9-11

2.4. Mathematical Statistics Method

Data from physical fitness tests were analyzed using SPSS26. Executive function experiment data was subjected to multivariate analysis of variance, comparing the post-test minus pretest differences $\triangle X1$ and $\triangle X2$ between experimental and control gardens. The adoption of a multivariate method is justified by two factors: firstly, due to the random grouping of children in both experimental and control gardens, it is impossible to ensure complete equality across groups; secondly, there exists a correlation among the three sub-functions of executive function, indicating interaction among these dimensions. Furthermore, the variance homogeneity test confirms that each group's variances are homogeneous, thereby meeting the prerequisites for multivariate analysis of variance.12

3. RESULTS

3.1. Results of the Questionnaire Survey on Toddler Behavior in the Mid-Term Experiment Garden of Intervention

Table1. *A Summary of the Teacher Questionnaire*

Indicator	Dimension	Corresponding to questionnaire	Number of valid questionnaires	Behavior Performance of Each Dimension					
				Never	%	Sometimes	%	Often	%
Physical fitness	Body resistance	3	98	85	86.7	10	10.2	3	3.1
	Diet	4		4	4.1	6	6.1	88	89.8
	Sleep	5		2	2.0	6	6.1	90	91.8
Executive Function	Communication	1、2		5	5.1	6	5.1	87	88.8
	Attention	6、8		6	6.1	8	8.2	84	85.7
	Observe discipline	7		3	3.1	10	10.2	85	86.7
	Aggressive behavior	9、10		89	90.8	4	4.1	5	5.1

Table2. *A Summary of the Parent Questionnaire*

Indicator	Dimension	Corresponding to questionnaire	Number of valid questionnaires	Behavior Performance of Each Dimension					
				Never	%	Sometimes	%	Often	%
Physical fitness	Body resistance	3	29	21	72.4	7	24.1	1	3.4
	Diet	4		7	24.1	16	55.2	6	6.1
	Sleep	5、6		2	6.9	8	27.6	19	19.4
Executive Function	Communication	1、2		5	17.2	10	34.5	14	48.3
	Listen to parents	8		0	0.0	8	27.6	21	72.4
	Attention	7		5	17.2	12	41.4	12	41.4
	Aggressive behavior	9		19	65.5	8	27.6	2	6.9
	Think and React	10		2	6.9	2	6.9	25	86.2
	Memory	11		18	62.1	10	34.5	1	3.4

The survey results indicate that 91.8% of children can fall asleep more quickly at noon and remain quiet in bed when they are unable to sleep. Additionally, a teacher questionnaire reveals that 90.8% of children who have taken aerobics classes no longer engage in conflicts over toys or other items with their peers. Furthermore, 89.8% of children can efficiently consume lunch and snacks during the lunch break. Concurrently, 86.2% of parents believe that their children's cognitive abilities and response times have improved significantly after taking aerobics classes, particularly during games such as chess or magic cube challenges. A majority of parents (72.4%) also report that their children have become more compliant since starting aerobics classes, following instructions without question. Notably, none of the surveyed parents reported any instances of disobedience from their children. Since March 2023, 72.4% of parents noted that their children have not fallen ill with colds or other epidemics.

3.2. Experimental Outcomes of the Intervention on Toddlers' Physical Morphology, Fitness, and Executive Function at the Program's Conclusion

3.2.1In the pre-experimental measurements, no significant differences were observed in four body morphology indicators (height, weight, BMI, Ketolaindex) and six physical fitness indicators (sit-and-reach, tennis serve, standing long jump, double hop, balance beam walk, 10m shuttle run). These results align with the anticipated outcomes of the experiment and demonstrate that the experimental conditions met the intervention requirements.

- In the post-experimental test, significant differences were observed between the two kindergartens for three morphological indexes (weight, BMI, Ketolaindex) and three physical fitness indexes (double-footed continuous jump, walking balance beam, 10m shuttle run). However, no statistical significance was identified in the height, sit-and-reach, tennis throw, and standing long jump of the four indexes between the two kindergartens.
- To ascertain that the observed variance in indicators was attributable to the experimental intervention, specifically aerobics for 3-month-old toddlers, and not due to inherent growth factors associated with toddler age, a comparative analysis was conducted between the pretest and post-test results of the experimental park difference index and those of the control park difference index. The findings revealed: (1) In the control park, there were no significant differences in the pretest vs post-test comparisons of the double-foot continuous jump, 10 m shuttle run, and walking balance beam indicators. However, in the experimental park, all three indicators exhibited marked differences, underscoring the efficacy of the experimental intervention. (2) Both the control and experimental park toddlers showed substantial differences in weight and BMI indicators at the pretest and post-test stages. Additionally, while the Ketola index displayed a significant difference in the control park toddlers, it also demonstrated substantial differences in the experimental park toddlers. This suggests that the experimental intervention had a discernible impact.
- The weight and BMI indicators, both in the control garden and experimental garden, exhibited significant differences before and after the experiment. A further comparison of the mean increase in these indicators between the two kindergartens revealed that children in the control garden experienced a greater increase in weight and BMI than those in the experimental garden.
- The three sub-functions of toddler executive function, namely card sorting, Stroop Day-Night, and delayed gratification in gift-giving, were evaluated for statistical significance through variance analysis of pre vs post experimental increases △X between toddlers from the experimental and control kindergartens. The findings indicated no statistically significant difference between the two groups of toddlers.

Table3. *Multivariate Analysis of Variance for Three Tasks of executive function*

Experimental Task	Indicators	Correlation	Homogeneity of variance	P value	Eta Squared
Card Sorting（Times）	Executive Function	.000	.371	.127*	.196
StroopDay-Night（Times）					
Delayed Gift-Giving（s）					

Notes: **P>0.05 difference is significant.*

4. DISCUSSION

4.1. Analysis of the Results of the Behavior Questionnaire in the Experimental Garden at Mid-intervention

The outcomes of the parent and teacher questionnaires conducted during the middle phase of the intervention demonstrated that aerobics-based interventions enhanced young children's physical resilience, dietary habits, sleep patterns, interpersonal communication, focus, self-discipline, aggressive tendencies, parental attentiveness, cognitive response capabilities, and memory. The rise in their physical resilience, coupled with improvements in diet and sleep quality, underscored an

enhancement in their overall physical health. This suggests that aerobics-based interventions bolstered young children's disease resistance, leading to a significant decrease in illness absence rates. Enhanced dietary habits and sleep patterns can be attributed to exercise's role in facilitating food digestion and absorption, while post-exercise fatigue aids in reducing the time required for sleep onset. Communication skills, aggressive behavior, parental responsiveness, and self-discipline are indicative of the inhibitory capabilities of young children's executive function sub-functions. Conversely, attention span, cognitive response abilities, and memory reflect the rejuvenating and switching capacities of these executive functions.13-15 Thus, aerobics-driven interventions fostered the development of three key sub-functions within the executive function spectrum, thereby enhancing inhibition, rejuvenation, and switching capacities.

4.2. Analysis of the End-of-Intervention Body Morphology Test

The experimental findings demonstrate that the disparity in height index between children in the experimental garden and those in the control garden is not statistically significant. This suggests that the three-month experimental intervention did not significantly enhance children's height growth. This outcome can primarily be attributed to the rapid physiological development of children aged 4–6 years, characterized by a swift increase in height and weight. The intervention's impact on this growth was minimal, indicating that it was more a reflection of natural physiological development at this age. Furthermore, the body mass index (BMI) of children in the experimental garden was significantly lower than that of their counterparts in the control garden. This difference was primarily because children in the experimental garden consumed more fat and calories during their 45-minute aerobics exercises three times a week. The experimental intervention took place from March to June, coinciding with the temperature rise. After each aerobics session, some children exhibited perspiration, which was more pronounced in overweight children. This observation suggests that the experimental intervention, specifically children's aerobics, effectively mitigated excessive weight gain in children and reduced the incidence of childhood obesity.

4.3. Analysis of the Physical Fitness Test Outcomes after the Intervention

The experimental results demonstrate that the disparity between the experimental kindergarten and the control kindergarten in terms of sit-ups, tennis throwing, and standing long jump after a 3-month children's aerobics intervention is not statistically significant. This suggests that the three-month experimental intervention did not significantly enhance the flexibility and strength qualities of the children. The reasons for this can be attributed to the project characteristics of children's aerobics and the laws governing the development of each physical quality at a child's stage.

Firstly, the nature of its target population differentiates children's aerobics significantly from adult aerobics. This differentiation is evident in aspects such as choreography, rhythm, music, and movement rate. The development of children's aerobics is grounded in the physiological laws governing young children's physical growth. It primarily targets the small strength of 4-6 year old children, emphasizing rhythmic movements and coordination of upper and lower limbs. Children are encouraged to move quickly, with an emphasis on arm extension and maintaining a steady pace while their feet follow the musical rhythm. There are no stringent requirements for controlling the force of upper and lower limb movements, hence the impact of children's aerobics on children's strength quality is not pronounced. Concurrently, the music used in children's aerobics is lively, rhythmic, and upbeat, keeping children engaged throughout practice. However, the training methods primarily focus on stretching muscles, ligaments, and tendons in a static state, which may not significantly enhance flexibility.16Experimental results indicate that children's aerobics significantly improves children's speed and sensitivity quality, as well as balance function. This improvement can be attributed to exercises such as standing still, running, jumping, rapid changes in posture, swift shifts of body center of gravity, and quick turns. These activities promote rapid improvements in children's flexibility, coordination, and balance abilities.

On the other hand, during the growth and development phase of young children, the evolution of various qualities exhibits characteristics of both phase and wave. The phase and wave shape traits of physical quality development primarily manifest as a sequence of initial development followed by rapid and gradual progression. The sensitive period for the enhancement of flexibility and coordination is typically observed in childhood, whereas the development of strength quality occurs

later. Furthermore, flexibility quality appears to be more influenced by innate genetic factors.17 Consequently, aerobic exercises for children predominantly foster the development of speed and sensitivity qualities, while there has been no significant improvement in strength or flexibility quality.

4.4. Analysis of Experimental Results on Executive Function in Preschool-aged Children's Intervention

Upon analyzing the results of the experiment conducted on the executive function of young children, it was observed that while there was no significant difference in the value-added between the experimental park and control park for three index tasks, the mean number of card task errors in the experimental park was 0.48 lower than that in the control park. Similarly, the Stroop task error mean number in the experimental park was 1.53 lower than that in the control park, indicating a relative maximum error reduction of 16 times, which still represents a certain degree of improvement. However, when considering the gift-delayed satisfaction task, the meantime taken in the experimental park was 4.19 seconds longer than that in the control park, with a relative best score of 60 seconds, suggesting that this effect was not statistically significant. The motivation for this analysis stems from the intervention method employed in children's aerobics, which involves three classes per week, each lasting approximately 45 minutes with a 10-minute intermission. The exercise intensity is not substantial, and children exhibit only minimal sweating, classifying it as short-term low-intensity aerobic exercise. This type of exercise significantly enhances refreshing and switching functions. In contrast, medium and high-intensity short-term aerobic exercises have been found to improve all three sub-functions of executive function. This observation aligns with the research findings of AiguoChen et al.18,19 offering an experimental foundation for studying the "Dose-Effect" of aerobic exercise on executive function. Furthermore, it provides a practical model for selecting appropriate exercise intervention strategies based on aerobic exercise intensity to enhance executive function in future studies.

5. Conclusions and Recommendations

5.1. Conclusions

- The positive impact of the intervention, as evidenced by preschool teachers' and parents' evaluations, along with observed changes in children's physical fitness and executive function after three months of the program, demonstrates that preschool aerobic exercise can enhance children's physical fitness to a significant degree and elevate their overall health.
- The implementation of a three-month aerobic exercise regimen enhances executive function in young children.
- The application of preschool aerobics exercise serves as a viable movement pattern to enhance physical fitness and foster the development of executive function in preschool children.

5.2. Recommendations

- Kindergarten implements systematic and scientific preschool aerobics classes to foster enhanced physical fitness and executive function development in children.
- The proficiency and expertise of kindergarten teachers are intrinsically linked to the optimal development of young children. Given the increasing prevalence of scientific aerobics courses, there is a pressing need for specialized aerobics instructors. Consequently, it is imperative for kindergarten teacher colleges and training institutions must bolster their curriculum in sports skills training specifically for kindergarten educators, thereby enhancing their overall teaching caliber.
- The nation should intensify its focus on the physical and mental well-being of young children, augment research investment in these areas, continually broaden the scope of studies concerning the physical and mental health of young children and provide more comprehensive support for their healthy development.

- The development of physical fitness and executive function in young children is influenced by numerous factors, with sports-focused interventions merely representing a minor facet. It is recommended that a more holistic approach be adopted, incorporating elements such as nutrition and family-rearing styles. This necessitates the establishment of a home-school co-construction model, wherein families and kindergartens collaborate to foster the comprehensive growth of physical fitness and executive function in young children.

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