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The effects of aerobic exercsie program on the bilateral coordination of preschool children

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Abstract

The aim of this study was to determine the effects of aerobic exercise program on the bilateral coordination of preschool children. The boys and girls (n = 60), aged five to six, were randomly assigned to the experimental group (n = 30) or the control group (n = 30). The children in the experimental group were involved in aerobic training program over a 12-week period. Three training sessions were performed per week, lasting 30 minutes each. For the evaluation of children's coordination, the Bilateral Coordination subtest from the BOT-2 (Bruininks-Oseretsky Test of Motor Proficiency) battery of tests was used. The children completed seven different tasks, both at the initial and the final measurement, which were further used to calculate the total score. To determine the changes in bilateral coordination, the two-factor (group × time) univariate analysis of variance (ANOVA) was used, while the effect size, presented by the partial Eta squared, was calculated for each task and the total score. A non-significant effect (p = .280) was observed for the task "Touching Nose with Index Fingers - Closed Eyes", whereas a significant improvements in all the other tasks and the total score were found in the intervention group (p < .05). The magnitude of effect size ranged from medium to large. The findings indicate that the aerobic exercise program contributes to the development of bilateral coordination in preschool children.

Keywords: *Aerobic training, Motor abilities, Bilateral movement, Preschoolers, BOT-2*

Introduction

The preschool age, which represents one of the most crucial stages in the development of personality, ranges from the ages of three to seven. During the preschool period it is immensely important for a child to encounter with innumerable motor tasks (Venetsanou & Kambas, 2004). Specifically, the basic exercises for developing fundamental motor abilities are preferable, including those with coordination and balance elements (Derri et al., 2001). Fine motor skills are often described as smaller muscle movements performed in order to manipulate objects (Bratovčić et al., 2016; Luo et al., 2007), while bilateral coordination refers to the ability to perform movements which involve simultaneous use of both sides of the body (Gazbare et al., 2020; Rutkowska, et al., 2016; Uzunovic, et al., 2018). An adequate level of bilateral coordination, which indicates that both sides of the brain have integrated function (Karambe et al., 2017), can be developed as early as preschool age (Katanić et al., 2020).

The commonly used protocol for evaluating the coordination of preschool children is the Bruininks-Oseretsky test of motor proficiency (BOTMP) (Jirovec, Musalek & Mess, 2019). The second edition (BOT-2) represents a standardized protocol, mostly used in the field of medicine for the assessment of those between the ages of four and 21 (Brown, 2019). That includes experts, such as pediatricians, physiotherapists and physical education teachers, in whose profession the application of the BOT-2 is observed. The BOT-2 uses a composite structure that encompasses four motor areas: fine motor manual control, manual coordination, body coordination and strength and agility, with which it covers a total of 53 tasks (Bruininks & Bruininks, 2005). The body coordination composite contains the bilateral coordination subtest, where the number of performance trials for each task is specified. A raw score, previously obtained for each task, is further used to calcu-

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late a numerical point score (Balakrishnan & Rao, 2007).

Various evidence can be found as well, supporting the effects of physical exercise on motor abilities in children. Despite the fact that numerous authors highlighted the positive effects that physical exercise has on the motor abilities of preschool children (Bellows et al., 2013; De Privitellio et al., 2007; Jaksic et al., 2020; Popovic et al., 2020; Roth et al., 2015), researches investigating the motor coordination of children are mainly conducted on primary school students, given that the relationship between coordination and academic achievement is among the primary interests (Axford, Joosten & Harris, 2018; Lopes et al., 2013; Piek et al., 2004; Rigoli et al., 2013; Rosa Guillamón, García Cantó & Martínez García, 2020). When it comes to the effects of aerobic exercise on the motor development of preschoolers, Puder (2011) reported better results in running tasks in children in the intervention group compared to the non-aerobic exercise group. Further, it was reported that children, involved in moderate to vigorous physical activity, had better gross motor coordination compared to sedentary children at the age of six (De Souza et al., 2014).

Contrary to the aforementioned, there is a lack of studies dealing with the aerobic exercise and the coordination of preschool children in the region of South East Europe. To our knowledge, the recent study of Katanić and associates (2022) was the first to investigate the effects of a specific aerobic training program on bilateral coordination of preschoolers. A significant effect was determined as the 12-week intervention program contributed to better results on the test of fine motor coordination ($p = .020$), bilateral coordination ($p = .000$) and body coordination ($p = .000$) (Katanić et al., 2022). Opposed to the expectations, authors have reported a non-significant effect of a training program on cognitive abilities. Consequently, understanding the impact of aerobic exercise on the specific cognitive abilities and the specific coordination skills requires further research. That includes the bilateral coordination, given that there is an insufficient data regarding aerobic exercise and bilateral movements in preschoolers. Moreover, investigating the impact of the specific training program on the bilateral coordination might be of great importance not only for coaches and teachers, but for medical staff as well, since bilateral movement has been brought into connection with synchronized brain function.

Therefore, the aim of this study was to determine the effects of 12-week aerobic exercise program on the bilateral coordination, estimated with BOT-2 battery of tests, in preschool children.

Methods

Participants

The longitudinal study design was adopted, which involved the participation of 60 preschool children, aged five to six. In randomized order, participants were assigned to two groups: 1) experimental group (n = 30, girls 18, and boys 12) from preschool institution "Pionir" Jagodina, which are performed aerobic training program (ATP); 2) control group (n = 30, girls 16, boys 14) from preschool institution "Pčelice" Jagodina.

The research, which was carried out in accordance with the Declaration of Helsinki, was approved by the Faculty of Sport and Physical Education in Niš. The benefits, risks and procedures involved with participation were explained to the parents/guardians. Further, their right to withdraw from the study, at any time, was emphasized to them prior to testing. A permission was obtained as all of the parents and guardians gave their written consent for the children's participation.

Procedures

The initial testing for the Experimental group was on December 14, 2021, and the final testing on December 22, 2021 in the gymnasium of the "Pionir" preschool institution in Jagodina. While the Control group conducted the initial testing on December 14, 2021, and the final testing on December 22, 2021 in the gymnasium of the preschool institution "Pčelice" in Jagodina. The testing was always carried out at the same time (10:30h), so as to preclude daily variations in the measurement. The air temperature in the room during testing ranged from 22°C to 24°C.

Instruments

Bilateral Coordination

For the evaluation of the bilateral coordination, the subtest from the BOT-2 (Bruininks-Oseretsky Test of Motor Proficiency) battery of tests was used. Subtest 4 "Bilateral Coordination", which has shown considerable validity (Deitz, Kartin, & Kopp, 2007), was administered to all participants. In addition, Bruininks and Bruininks (2005) presented evidence for the validity of subtest 4 in the Manual.

The tests, both initial and final, were conducted in accordance with the BOT-2 instructions (Bruininks & Bruininks, 2005). The "Bilateral Coordination" subtest consist of 7 different tasks, which each participant had to perform. The acquired raw scores were used to calculate the numerical score, based on the standardized BOT tables in relation to gender and age. The raw score for each task was converted into a score rated on a scale of 0 to 3, or 4 selection points, in accordance to the study protocol of the BOT-2 (Bruininks & Bruininks, 2005). The sum of raw scores from all the seven tasks ranged from 0 to 24 points. The obtained results were used for further analysis.

Participants performed seven tasks:

1. Touching Nose with Index Fingers—Eyes Closed (point score: 0–4 pt).
2. Jumping Jacks (point score: 0–3 pt).
3. Jumping in Place—Same Sides Synchronized (point score: 0–3 pt).
4. Jumping in Place—Opposite Sides Synchronized (point score: 0–3 pt).
5. Pivoting Thumbs and Index Fingers (point score: 0–3 pt).
6. Tapping Feet and Fingers—Same Sides Synchronized (point score: 0–4 pt).
7. Tapping Feet and Fingers—Opposite Sides Synchronized(point score: 0–4 pt).

The experimental program

The aerobic training program , which was used in previous research (Katanić et al., 2022), was created according to the guidelines of leading health institutions (US Department of Health and Human Services, 2008; World Health Organization, 2010). The intervention program was conducted over a period of 12 weeks. Each week of the intervention program included three training sessions, lasting 30 minutes. Training sessions consisted of three phases: the warm-up phase, main phase, and the cool-down phase (Table 1).

The purpose of the warm-up phase was to adequately and gradually prepare participants for the intensity in the main phase. Therefore, the warm-up phase was carried out at the beginning of every training session, lasting 5 minutes approximately, and including a low intensity dynamic exercise (marching or skipping) with simultaneous performance of shaping exercises. The main phase consisted of 8 to 10 cycles. According to the recommendations for aerobic interval training (Garzon, 2018), the each cycle included one high intensity exercise, followed by low intensity exercise, where the duration of each was 30 seconds. The cycle was performed twice. Subsequently, the following cycle was performed, which was repeated until all the cycles were completed. Completing 8 to 10 cycles lasted for approximately 20 minutes,

which was in accordance with the guidelines of Garzon (2018), who outlined that the duration of aerobic activities should be over 10 minutes. The primary goals of the cool-down phase were to reduce the heart rate and to gradually lower the body temperature. The cool-down phase represented the last part of each training session, lasting approximately 5 minutes, and including low intensity aerobic exercise with stretching and breathing exercises. The aerobic exercise of low intensity included light walking or marching in place, while stretching exercises involved maintaining a given position for 10 to 15 seconds.

Table 1. The structure of the aerobic training session (adapted from Katanić et al., 2022).

	Training session		
	Warm-up phase	**Main phase**	**Cool-down phase**
Activity	Low intensity aerobic exercise + dynamic stretching exercises	Cycle: 1 high intensity exercise - 30″ 1 low intensity exercise - 30″	Low intensity aerobic exercise + stretching and breathing exercises
Cycle	1	8-10	1
Duration	5min	20min	5min

Statistical analysis

All statistical analyses were performed in the IBM SPSS 25 software (Statistical Package for Social Sciences, v25.0, SPSS Inc., Chicago, IL, USA). The normality of the data was confirmed by the Kolmogorov-Smirnov test. The descriptive analysis of the data for general characteristics and measures of the BOT-2 battery tests was applied for each group. Changes in bilateral coordination parameters were compared for the experimental and the control group using two-factor (group × time) univariate analysis of variance (ANOVA). The effect size (ES), represented by the partial Eta squared (ηp^2), was calculated for each task and the total score. The magnitude of the ES values were interpreted as:small (< 0.010); medium (0.011 - 1.137); large (> 1.138)(Cohen, 1988). All p-values less than 0.05 were considered significant for 95% level of probability.

Results

The results of the bilateral coordination tests, obtained on the initial and the final measurement, as well as the effect of the aerobic exercise program, are presented in Table 2.

Table 2. The changes in bilateral coordination after the intervention period for the aerobic training group (n = 30) and the control group (n = 30).

Tasks	Aerobic training group		Control group		F	p	ηp^2	Magnitude
	Initial	Final	Initial	Final				
TNWIFCE	3.90 ± 0.55	4.00 ± 0.00	3.73 ± 0.83	3.87 ± 0.51	1.189	.280	.020	medium
JJ	1.90 ± 0.92	3.00 ± 0.00	1.97 ± 1.19	2.20 ± 1.13	29.662	.000	.342	large
JIPSSS	2.16 ± 1.21	3.00 ± 0.00	2.57 ± 0.86	2.77 ± 0.68	7.064	.010	.110	medium
JIPOSS	0.63 ± 1.07	2.57 ± 0.86	0.63 ± 1.13	0.87 ± 1.22	65.993	.000	.537	large
PTAIF	1.30 ± 1.15	2.60 ± 0.81	1.50 ± 1.31	2.20 ± 1.13	5.533	.022	.088	medium
TFAFSSS	3.53 ± 1.07	4.00 ± 0.00	3.40 ± 1.10	3.60 ± 0.81	9.735	.003	.146	large
TFAFOSS	1.36 ± 1.47	3.60 ± 0.56	1.03 ± 1.25	1.43 ± 1.50	82.124	.000	.590	large
Total score	14.80 ± 4.11	22.77 ± 1.59	14.83 ± 4.59	16.93 ± 4.30	128.339	.000	.692	large

TNWIFEC - Touching Nose with Index Fingers—Closed Eyes; JJ - Jumping Jacks; JIPSSS - Jumping in Place—Same Sides Synchronized; JIPOSS - Jumping in Place—Opposite Sides Synchronized; PTAIF - Pivoting Thumbs and Index Fingers; TFAFSSS - Tapping Feet and Fingers—Same Sides Synchronized; TFAFOSS - Tapping Feet and Fingers—Opposite Sides Synchronized; F - F statistic; p - significance; ηp2 - partial Eta squared.

The F value, statistical significance and the effect size were calculated for each task and the total score. A combined analysis of variance (ANOVA) showed that there was no significant effect of aerobic training on the first task in Bilateral Coordination subtest (p = .280), which refers to "Touching Nose with Index Fingers - Closed Eyes". However, a significant effect of the intervention protocol on the remaining tasks was established (p = .000 - .022), where the magnitude of the effect size ranged from medium to large. In addition, the effect of the aerobic training program on the total score was significant as well (p = .000). The effect size was rated as large, since the partial Eta squared reached the value of .692.

Discussion

This study investigated the effects of a 12-week aerobic exercise program on bilateral coordination in preschool children. A non-significant effect was observed for the task "Touching Nose with Index Fingers - Closed Eyes", whereas a significant improvements in all the other tasks and the total score were found in the aerobic training group. The magnitude of the ES ranged from medium to large, indicating that the aerobic training program contributed considerably to the development of bilateral coordination in preschool children.

The body coordination, as the basis of motor development, also represents one of the main elements of children's cognitive abilities (Goodway, et al., 2019). Within it, the starting point for any complex movement (e.g sports technique) is well developed bilateral coordination (Veljković, Katanić & Ilić, 2020). Hence, it is immensely important to correct any irregularities in motor coordination at preschool age (Katanić et al., 2020).

Based on the obtained results, it could be argued that aerobic exercise contributes to the development of bilateral movements, which is in accordance with previous research. Namely, in the aforementioned study of Katanić and associates (2022) the effect of aerobic training program on the cognitive and motor abilities was investigated. Authors reported a significant (p =

.000) positive effect of a program on the bilateral coordination in preschoolers (Katanić et al., 2022). Further, a positive effect on the bilateral coordination was reported, when the experimental program consisted of sports activities (De Privitellio et al., 2007; Uzunović et al., 2018). Additionally, an improvements were observed when preschoolers performed dance movements (Pantelić et al., 2018). The existing data indicate that aerobic training, regardless of the type of activity, contributes to the development of coordination. Indeed, a significant, positive effect of various aerobic activities on the coordination of preschoolers has been established (Bellows et al., 2017; Birnbaum et al., 2017; Krneta et al., 2015).

For this particular study, the exercises used in each training phase may represent the explanation for such a large effect of the training program. The bilateral movements observed in exercises such as marching or skipping, probably contributed to better limb synchronization. Moreover, performing a successive movements for 30 seconds require maintenance of the rhythm, which could further affect the development of bilateral coordination. When interpreting the results of this research should be borne in mind that the BOT-2 subtest for estimating the bilateral coordination may have been insufficiently demanding for older preschoolers. It was previously stated that the BOT-2 battery of tests is commonly used protocol for assessing the coordination in individuals with various types of limitations (Gupta, Rao & Kumaran, 2011; Hughes et al., 2018; Myrelid et al., 2010; Rutkowska et al., 2016; Yeh et al., 2021). Therefore, it should be considered that the test, although intended for the preschool age, may be insufficiently complex for children whose motor abilities are well developed. In support of this assumption are the similar results achieved by older preschoolers, which were, as reported, excellent in certain tasks of Bilateral Coordination subtest (Katanić et al., 2020; Veljković, Katanić & Ilić, 2020).

In addition to the aforementioned, several shortcomings need to be emphasized. Despite the fact that the identical number of respondents were in the intervention and the control group, both groups consisted of only 30 children. Further, the conducted aerobic training program was previously used (Katanić et al., 2022), hence it would be beneficial to investigate the effects of different aerobic exercises on bilateral movements at a young age. Should be taken into account that at preschool age many activities outside the training program, during the 12 weeks period, could affect the coordination, and thus the outcome. It is, therefore, necessary to limit activities outside of experimental treatment.

For further research, a larger sample should be provided with, preferably, a longer intervention period. Moreover, investigating the effect of aerobic training differently designed, is needed in order to comprehensively understand the impact on the bilateral coordination. Finally, authors should consider assessing the bilateral coordination with different protocol, more challenging and complex.

Conclusion

The findings in this study indicate that the application of aerobic training can be beneficial for the physical development of preschool children. It can be concluded that aerobic exercises also represent an adequate tool for improving the coordination of preschoolers, even though in practice they are rarely used for that purpose. Bearing in mind the positive effect of aerobic training on the bilateral coordination, physical education teachers and coaches should consider implementing this type of activities when working with children under seven years of age.

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Conflict of Interest
The authors declare that there is no conflicts of interest.

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