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Research article

EFFECTS OF A 12-WEEK AEROBIC TRAINING PROGRAM ON THE COGNITIVE AND MOTOR ABILITIES OF PRESCHOOL CHILDREN

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Abstract. *The aim of this longitudinal study was to determine the effects of aerobic training on the cognitive and motor abilities of preschool children. The sample of participants included 47 preschool children aged five to seven. The participants were randomly divided into two groups: the experimental (n=25, 6.35±0.32yrs) and the control group (n=22, 5.90±0.27yrs). The experimental group took part in aerobic training for children over a 12-week period at a rate of three training sessions per week, 30min each. To evaluate the children's cognitive abilities, the school maturity test was used, or more precisely, three of its subtests: visual memory, stacking cubes, and codes. To evaluate their motor abilities, the BOT-2 (Bruininks-Oseretsky Test of Motor Proficiency) battery of tests was used, that is, its subtests: fine motor integration, manual dexterity, bilateral coordination, and balance. The children completed a total of 77 tasks, of which 48 were cognitive and 29 motor, both at the initial and the final measurement. Finally, the paper analyzes a total of 10 variables, four cognitive and six motor, which represent the total standardized values based on gender and age for each of the abilities. No significant effect of the training was determined for any of the cognitive abilities variables. The results indicate that aerobic training had significant effects on the following motor variables: fine motor skills (p=.020), bilateral coordination (p=.000), motor balance (p=.001), and body coordination (p=.000). A significant effect was determined for all four variables. We can conclude that aerobic training can represent an excellent means for the psycho-physical development of preschool children.*

Key words: *aerobic exercise, motor abilities, cognition, preschoolers, BOT-2*

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INTRODUCTION

The preschool age ranges from the ages of three to seven, and in practice is divided into: the younger preschool age from the ages of three to four, the middle preschool age from the ages of four to five, and the older preschool age from the ages of five to six, that is, until the child begins school (Milanović & Stamatović, 2004). The preschool age is considered one of the most important phases in the entirety of personality formation (Bala, 2002). During this phase physical activity represents a key component of a child's life, since children learn precisely through movement and motion, and thus begin to understand themselves and the world around them (Zimmer, Christoforidis, Xanthi, Aggeloussis, & Kambas, 2008). It is known that physical activity represents the basis of early childhood development and also affects various aspects of health (King et al., 2003), so what should be singled out in particular is its positive effect on the motor, emotional, and cognitive domain (US Department of Health and Human Services, 2008). The greatest effect of physical exercise was noted in the domain of executive functions which are of considerable importance for everyday motor performance, for behavior adaptability among children, their intellectual functioning, and academic success (Tomporowski, McCullick, Pendleton, & Pesce, 2015).

Recently more and more studies indicate the effectiveness of aerobic activities which include physical exercise of low to high intensity, which in turn primarily depends on aerobic energy production (Plowman & Smith, 2013). The National Association for Sport and Physical Education (NASPE, USA) recommends that children aged five to 17 should have at least 60min of moderate to high intensity exercise daily, with the addition that an advantage should be given to aerobic activities (Guan et al., 2020). Research indicates that aerobic physical activity generates structural changes in the brain, such as neurogenesis, angiogenesis, and an increase in the volume of the hippocampus (Chaddock et al., 2010, Thomas, Dennis, Bandettini, & Johansen-Berg, 2012; Stojiljković, Mitić, & Sporiš, 2019). Among children, a positive association between aerobic conditioning and the volume of the hippocampus results in an increase in memory and retention, as well as in the regulation of stress (Chaddock et al., 2010, Thomas et al., 2012). Neurogenesis and increased connections in the white matter were also noted in certain studies as a response to this type of training (Thomas et al., 2012; Krafft et al., 2014). These changes in the structure and function of the brain are positively associated with an improvement in certain cognitive functions such as inhibition, working memory, and learning (Chaddock, Pontifex, Hillman, & Kramer, 2011), which are closely linked to success in school (Tomporowski, et al., 2015) and academic achievement (Lees & Hopkins, 2013).

The effect of exercise on the motor development of children is an increasingly more prevalent topic, and numerous studies have determined that physical exercise has a positive effect on the motor skills of preschool children (Dobrila, Sporiš, & Hraski, 2003; De Privitellio, Caput-Jogunica, Gulan, & Boschi, 2007; Alwasif, 2013; Krneta et al., 2015; Bellows et al., 2017; Birnbaum et al., 2017; Jaksic et al., 2020). The most frequently noted improvements are to: explosive strength, repetitive strength, coordination, speed, and flexibility. When it comes to the effects of specific aerobic training on the motor development of children, it was determined that the given activities have a positive effect on motor skills, and that particularly better results are achieved for obstacle course racing and reverse running, while the results for the balance test were the same as those for the standard program of physical exercise (Puder et al., 2011).

Based on the existing body of information which speaks to the positive impact of aerobic training on structural and functional changes in the brain of a child, the aim of this study was

to analyze the specific effect of aerobic training on certain cognitive functions. At the same time, when it comes to motor development, the aim was to study the impact of aerobic training on abilities which were not sufficiently studied or for which there were no clear findings, such as: fine motor skills, coordination, and balance. Bearing this in mind, the aim of this study was to determine the effects of a 12-week aerobic exercise program on the motor and cognitive abilities of preschool children.

METHODS

Participants

This longitudinal study included 47 participants, all preschool children. The participants were randomly divided into two groups: the experimental (n-25, 6.35±.32 yrs) and control group n-22, 5.90±.27yrs). The inclusion criteria and selection of participants were based on the following: healthy children of both genders, aged five to seven, who were not taking part in any organized form of physical exercise. This study was approved by the Faculty of Sport and Physical Education in Niš (Ref. No. 04-1186/2) and was conducted under the Declaration of Helsinki. All of the parents and guardians of the participants, prior to the study, voluntarily gave their written consent for the children to participate.

Procedures

Testing in this experimental study was carried out immediately prior to the (initial measurement) and after the implemented experimental exercise program (the final measurement) in the gymnasium of the "Ljubica Vrebalov" preschool in Požarevac. All of the testing, as well as the experimental program, took place in the gymnasium of the "Ljubica Vrebalov" preschool. The testing was always carried out at the same time (11h), so as to preclude daily variations in the measurement. The air temperature in the room during testing ranged from 22ºC to 26ºC.

Instruments

Cognitive skills

To identify certain cognitive functions that significantly contribute to cognitive development of preschool children, the school maturity test (in Serbian: *Test zrelosti za školu*, TZŠ+) was used, which consists of the following five subtests: a visual vocabulary, informedness levels, visual memory, stacking cubes, and codes (Novović, Biro, Baucal, & Tovilović, 2007). The TZŠ+ indicated a high reliability and validity on a sample of children aged five and a half to seven and a half, and it was suggested that there is a high correlation between TZŠ+ and the TIP-1 cognitive tests and the Raven's Coloured Progressive Matrices (Novović, Tovilović, Jovanović, & Biro, 2009).

This study included three subtests: visual memory, stacking cubes, and codes. The visual memory test is aimed at evaluating memory and attention, and consists of 15 tasks. The stacking cubes test is meant to evaluate visual-motor coordination, perceptive organization, and the ability to plan, and consists of eight tasks. The code is a test used to evaluate the ability to learn from experience, concentration, and visual-motor coordination, and it contains 25 tasks. The cognitive tests were carried out by a psychologist. The results

obtained for all three tests were converted using the standardized TZŠ+ table based on gender and age, and the obtained values were further analyzed.

Motor abilities

To evaluate the motor abilities, the subtests from the BOT-2 (Bruininks-Oseretsky Test of Motor Proficiency) battery of tests were used. BOT-2 is used as the standardized measure of the level of motor proficiency of children and adolescents from the ages of four to 21, and includes four areas: fine manual control, manual coordination, physical coordination, and strength and agility (Deitz, Kartin, & Kopp, 2007). Previous research in this field has shown that the BOT-2 test is quite valid (Abbas, Shanker, & Krishnan, 2011).

For the purpose of this study the following subtests were used: fine motor integration (eight tasks), manual dexterity (five), bilateral coordination (seven), and balance (nine). In addition, the overall values were converted based on the standardized BOT tables in relation to gender and age, and the results were further analyzed.

Variables

Every child took part in 77 cognitive and motor tasks, both at the initial and final measurement, of which 48 were cognitive and 29 were motor tasks. The aforementioned 48 cognitive tasks were divided into three subtests from which three variables were obtained and then converted based on gender and age, resulting in three standardized variables: Visual memory, Stacking cubes, and Code, while the fourth variable Cognitive abilities total represents the total mean value of the given variables.

Also, the children took part in 29 motor tasks, divided into four subtests. Once the data were converted based on standardized tables, four variables were obtained: Fine motor integration, Manual dexterity, Bilateral coordination, and Balance. The remaining two were defined by Fine motor skills which represents the sum of fine motor integration, and manual dexterity, while Body coordination represents the sum of bilateral coordination, and balance. For the purpose of further study, the paper analyzed the ten aforementioned variables.

The experimental program

The aerobic exercise program was carried out three times a week for a period of 30min, over 12 weeks. The program was designed based on the guidelines of leading health institutions and authors from the field (Baquet et al., 2003; Corbin et al., 2004; US Department of Health and Human Services, 2008; World Health Organization, 2010; Virgilio, 2011; Fahey, 2013; Garzon, 2018).

The aerobic training lasted for 30min and consisted of three parts: the warm-up, main activity, and the cool-down (Table 1). The warm-up takes place at the beginning of every aerobic training. This phase lasts approximately 5min and includes aerobic dynamic exercise which includes marching or light skipping with simultaneous shaping exercises.

The main part of the aerobic training lasts for approximately 20min, in accordance with recommendations that indicate that the duration of aerobic activities should be at least 10min (Garzon, 2018). During this phase, intervals of high intensity (30sec) alternate with periods of low intensity exercise (30sec), which is in accordance with the guidelines of aerobic interval training (Garzon, 2018). One complex, which includes one

exercise of higher and one of lower intensity, is repeated twice, and is then followed by the next complex. In total there are usually 8 to 10 complexes.

The cool-down concludes each aerobic training. This phase lasted approximately 5min. It includes aerobic activities of low intensity (slow marching in place and stretching with breathing exercises) for the heart rate to be reduced to the pre-exercise level. When it comes to stretching exercises, it is necessary to hold each position for 10-15sec.

Table 1 An overview of the aerobic training

Training session	Activity	Duration
Warm-up	Low intensity aerobic exercise and shaping exercises	5 min
Main activity	Complex: 1 exercise of high 30" - 1 exercise of low intensity 30" x2 (8-10 complexes)	20 min
Cool down	Low intensity aerobic exercise along with stretching and breathing exercises	5 min

Statistical analysis

For all of the data obtained during the testing, the descriptive statistics (basic central and distribution) parameters were calculated: the mean (Mean), and standard deviation (St. dev.). To determine the effects of the experimental program, the combined analysis of covariance was calculated ANOVA 2x2 (group x time). The level of statistical significance was set at $p<0.05$, while the effect size was represented by the partial Eta squared in the same table, whereby based on Cohen's recommendations values of up to 0.01 have a small effect size, up to 0.06 and above a medium, and over 0.138 have a large effect size (Cohen, 1988). The data were analyzed in the IBM SPSS Statistics 26 software (Statistical Package for Social Sciences, v26.0, SPSS Inc., Chicago, IL, USA).

RESULTS

Table 2 shows the general sample indicators. The aerobic group numbered 25 participants, unlike the control group which numbered 22. A difference was also noted in gender; namely, in the aerobic group there were more boys than girls, while in the control group the situation was reverse. The average age of the children in the aerobic group at the initial measurement was 6.35yrs, while in the control group it was 5.90yrs. This small mean difference which is in favor of the aerobic group is in alignment with the other parameters, and so the aerobic group has a somewhat greater body mass, body height, and BMI than the control group.

Table 3 shows the total standardized values of all the cognitive and motor subtests. Descriptive parameters were calculated for all the measured variables, that is, the mean and standard deviation, both at the initial and the final measurement. In addition, in the same table we also find the results of the combined analysis of variance - ANOVA (2x2), that is, the F value of the given test, the statistical significance, as well as the partial Eta squared which indicates the effect size.

A combined analysis of variance rated the effect of aerobic training on motor and cognitive abilities of the experimental group compared to the control group which carried out its usual activities.

No significant effect of aerobic training was achieved on any of the tests when compared to the results of the control group: Visual memory (p=.139), Stacking cubes (p=.351), Code (p=.480), and Cognitive abilities total (p=.751).

When it comes to the fine motor abilities tests, no significant effect of aerobic training was noted on the Fine motor integration test (p=.55), or on the Manual dexterity test (p=.313). But even with the given results, a significant effect was noted for the experimental program for the variable of Fine motor skills (p=.020).

A significant effect of the experimental program was noted on the tests of motor coordination for all the variables, including: Bilateral coordination (p=.000), Balance (p=.001), and Body coordination (p=.000). For all four variables in which a significant effect was noted, based on the partial Eta squared, a large effect size was noted.

Table 2 General indicator of the sample

	Aerobic group	Control group
Number	25	22
Sex	Boys: 14 Girls: 11	Boys: 9 Girls: 13
Age	Initial: 6.35±0.32 Final: 6.59±0.32	Initial: 5.90±0.27 Final: 6.14±0.27
Body weight (kg)	25.08±4.28	22.60±3.60
Body height (m)	1.22±0.05	1.17±0.05
BMI (kg/m2)	16.90±1.95	16.42±1.65

Table 3 ANOVA repeated mesures (2x2) aerobic and control group

Variables	Aerobic group		Control group		F	p	η_p^2
	Initial	Final	Initial	Final			
Visual memory	3.12 ± .60	3.00 ± .29	3.14 ± .35	3.27 ± .46	2.272	.139	.048
Stacking cubes	4.08 ± .91	4.04 ± .79	4.41 ± .67	4.18 ± .80	.887	.351	.019
Code	3.24 ± .78	3.60 ± .65	3.23 ± .61	3.41 ± .67	.506	.480	.011
Cognitive skills total	3.48 ± .57	3.55 ± .43	3.59 ± .40	3.62 ± .46	.102	.751	.002
Fine motor integration	13.36 ± 3.16	13.84 ±3.64	13.41 ± 3.83	11.82 ± 2.26	3.883	.055	.079
Manual dexterity	9.80 ± 3.64	12.52 ± 4.57	12.91 ± 4.26	14.00 ± 4.69	1.039	.313	.023
Fine motor total	23.16 ± 4.58	26.36 ± 6.83	26.32 ± 6.16	25.82 ± 5.48	5.797	**.020**	.114
Bilateral coordination	15.60 ± 3.24	18.96 ± 2.41	16.55 ± 1.99	16.68 ± 2.77	14.776	**.000**	.247
Balance	13.64 ± 4.22	15.80 ± 3.88	15.27 ± 3.01	13.27 ± 3.65	12.563	**.001**	.218
Coordination total	29.24 ± 6.40	34.76 ±5.64	31.82 ± 3.32	29.95 ± 5.43	21.035	**.000**	.319

Note: F- F statistic; p – significant; η_p^2-partial eta squared.

DISCUSSION

This study evaluated the effectiveness of a 12-weeks aerobic training on cognitive and motor abilities in preschool children. Effects on chosen cognitive functions remain inconclusive, because there was no significant improvement in the examined cognitive

functions during the 12 weeks of training. Significant improvements in fine motor skills, bilateral coordination, balance, and body coordination were observed in the intervention group when compared to the control group. Taken together, findings from this study suggest that aerobic training contributes to the development of motor abilities of preschoolers.

Even though numerous studies have confirmed that cognitive abilities increase during physical activity (Graham & Parker, 2003), the results of our study indicate the contrary, and point out that the aerobic program did not have a significant effect on the chosen cognitive functions of preschool children. Authors who studied the specific impact of aerobic training among children also noted positive effects on cognitive abilities (Reed et al., 2010; Fisher et al., 2011). In the aforementioned study, positive effects were achieved on the cognitive abilities evaluated by: Raven's Coloured Progressive Matrices, the CANTAB test of the visuospatial working memory capacity, and the ANT test used to assess efficiency.

Even though many studies suggest that exercise can increase the volume of a child's brain, have a positive effect on the structure and function of the brain, and improve a child's cognitive abilities and academic achievements (Hillman et al., 2009), not achieving these expected results in our study can be accounted for by the small sample, and/or the insufficient duration of the program itself. And certainly, we should bear in mind the analysis of Stojiljković et al. (2019) who determined that aerobic training, unlike other exercise programs, has the greatest significant effect on changes in the structure and function of the brain, especially if certain types of cognitive thinking and a higher level of attention are needed to perform certain tasks. This suggestion should be used a guideline for future studies in this field, that is, to design an aerobic exercise program which would also include the simultaneous solution of certain cognitive tasks.

It's well known that physical exercise at the preschool age results in positive effects on motor abilities, especially: explosive strength, repetitive strength, coordination, speed, and flexibility (Dobrila et al., 2003; De Privitellio et al., 2007; Alwasif, 2013; Krneta et al., 2015; Bellows et al., 2017; Birnbaum et al., 2017). In this paper we analyzed fine motor skills, motor coordination, balance and body coordinaton. When it comes to testing fine motor skills, a significant effect of the aerobic program was noted on the fine motor skills total, which is in accordance with the systematic review which shows positive effects of different physical exercise programs on fine motor skills in preschool children (Strooband, de Rosnay, Okely, & Veldman, 2020). Although it should be pointed out that no significant effect of aerobic training was noted on the variables of fine motor integration and manual dexterity. We should point out that the development of fine motor skills has a positive effect on the sensory-motor development of the nervous system (Ivković, Milanović, Velinov, & Nikolić, 2004), which is why attention should be paid to the development of the fine motor skills of children.

On the tests of motor coordination, a significant effect of the experimental program on all the variables was noted, including: bilateral coordination, balance, and motor coordination total, which is in accordance with the existing research (De Privitellio et al., 2007; Krneta et al., 2015; Bellows et al., 2017; Birnbaum et al., 2017). Motor coordination is one of the main elements of the motor skills of children, but also their cognitive abilities and psychological characteristics (da Silva Pacheco, Gabbard, Ries, & Bobbio, 2016). The proper development of body coordination is an exceptionally important factor since it can to a great extent affect the quality of life of the child, as well as various bio-psycho-social aspects. This is why it is very important to determine any irregularities in body coordination at an early age among children, and remove them in time (Veljković, Katanić, & Ilić, 2020).

In relation to the limitations of this study, recommendations for further research would be to: include a larger sample of respondents; conduct the intervention over a longer period; include cognitive tasks in aerobic exercises; use different cognitive tests, ie tests that will measure various cognitive abilities.

CONCLUSION

The preschool age is a time of life when motion plays an important role since children are eager to constantly run, jump, and play. Realizing physical education programs for preschool children can significantly affect the improvement of their overall psycho-physical development. Thus, it is possible to affect the improvement of motor and cognitive abilities, which will enable children to realize their potential more easily. This study did not determine a positive impact of aerobic training on the cognitive abilities of preschool children. However, a significant effect of aerobic training on motor skills such as: fine motor skills total, bilateral coordination, balance, and motor coordination was noted. It should be pointed out that the given abilities are exceptionally important since they represent one of the main elements of motor, but also cognitive and psychological skills. We can conclude that aerobic training can represent an excellent means for the psycho-physical development of preschool children.

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EFEKTI DVANAESTONEDELJNOG AEROBNOG TRENINGA NA KOGNITIVNE I MOTORIČKE SPOSOBNOSTI DECE PREDŠKOLSKOG UZRASTA

Cilj ovog longitudinalnog istraživanja bio je da se utvrde efekti aerobnog treninga na kognitivne i motoričke sposobnosti dece predškolskog uzrasta. Uzorak ispitanika obuhvatio je 47-oro dece predškolskog uzrasta od pet do sedam godina. Deca pohađaju predškolsku ustanovu „Ljubica Vrebalov" u Požarevcu. Učesnici su nasumično podeljeni u dve grupe: eksperimentalnu (n=25, 6.35±0.32 godina) i kontrolnu grupu (n=22, 5.90±0.27 godina). Eksperimentalna grupa je učestvovala u aerobnom treningu za decu u periodu od 12 nedelja u trajanju od tri treninga nedeljno po 30 minuta. Za procenu kognitivnih sposobnosti dece korišćen je Test Zrelosti za Školu, tačnije tri njegova podtesta: vizuelno pamćenje, kocke za slaganje i kodovi. Za procenu njihovih motoričkih sposobnosti korišćena je baterija testova BOT-2 (Bruininks-Oseretski Test of Motor Proficienci), odnosno njeni podtestovi: fina motorička integracija, manuelna spretnost, bilateralna koordinacija i ravnoteža. Ispitanici su uradili ukupno 77 zadataka, od čega 48 kognitivnih i 29 motoričkih, kako na inicijalnom tako i na finalnom merenju. U radu se analizira ukupno 10 varijabli, četiri kognitivne i šest motoričkih, koje predstavljaju ukupne standardizovane vrednosti na osnovu pola i uzrasta za svaku od sposobnosti. Ni za jednu od varijabli kognitivnih sposobnosti nije utvrđen značajan efekat primenjenog treninga. Rezultati pokazuju da je aerobni trening imao značajan uticaj na sledeće motoričke varijable: finu motoriku (p=.020), bilateralnu koordinaciju (p=.000), motoričku ravnotežu (p=.001) i koordinaciju tela (p=. 000). Utvrđen je značajan efekat za sve četiri varijable.

Ključne reči: *aerobne vežbe, motoričke sposobnosti, kognicija, predškolski uzrast, BOT-2*