EQOL Journal (2021) 13(1): 31-38

ORIGINAL ARTICLE

Relationship between cognitive abilities and manual coordination and balance in preschool children

Filip Sadri[1] • Ivo Sadri[2] • Željko Krneta[1] • Jovana Trbojević Jocić[3] • Maja Batez[1]

Received: 2nd March, 2021
Accepted: 25th May, 2021
DOI: 10.31382/eqol.210604

Abstract
Background: The purpose of this research was to investigate the relationship between cognitive abilities and manual coordination and balance in preschool children. Methods: The sample consisted of 41 preschool children aged 6.4±0.8 on average, of both sexes (30 boys and 11 girls). On top of their regular preschool activities, the children attended a school of sports for preschool children - multisport activities and exercises, twice a week. The sample of measuring instruments comprised 4 motor tests (One-leg stand test, Mann's test, Finger to nose, Front raises) and 2 cognitive tests (Raven's Colored Progressive Matrices, Cognitive Assessment System). Data was analyzed by applying Linear and Binary logistic regression analysis. Results: Based on the results of the research, one may conclude that there is a statistically significant relation between cognitive abilities and manual coordination in the tested sample of preschool children. The defined predictor system, which consisted of cognitive tests, showed a significant relationship with the hand coordination test, which was assessed by the Finger to Nose test with the eyes closed. A significant contribution to the established relation was given by the G factor estimated by Raven's colored progressive matrices. Conclusions: Physical activities contribute to the development of motor skills and thus to the development of some cognitive abilities in children, which is of great importance for their further development.

Keywords preschool children • cognitive function • motor skills • physical activity.

Introduction

During the first six years of their life, children explore the world around them through various movement patterns and thus they learn about their environment and their own body features and physical abilities (Rajović, 2017). A preschool child gratifies their natural need for movement through play, therefore this particular age is considered ideal for the development of the main motor skills (Goodway, Ozmun, & Gallahue, 2012). Recent studies show that physical activity contributes to the overall development of personality and improves fitness (Páez-Maldonado, 2020; Biddle, 2019; Maher, Toohey, & Ferguson, 2016; Smith, Eather, Morgan, Plotnikoff, Faigenbaum, & Lubans, 2014). However, positive impact of physical activity on the developments of cognitive abilities is also often mentioned (Biddle, 2019; Bidzan-Bluma, 2018; Gunnel, 2019; Abdelkarim et al., 2017; La Vinge, 2016). It has been proven that children produce better results on academic achievement assessment tests (reading, orthography, and ari-

filipsadri@uns.ac.rs

[1] University of Novi Sad, Faculty of Sport and Physical Education, Novi Sad, Serbia

[2] Primary school "Đura Daničić", Novi Sad, Serbia

[3] Matica Srpska, Novi Sad, Serbia

thmetic) after walking for 20 minutes immediately before the test. The regions in the brain responsible for cognitive control were much more active in the experimental group of children than in the control group of children that did not walk before the test (Hilman, 2009). An increased level of physical activity leads not only to the improvement in motor skills but also the improvement in the intellectual abilities of a child (Malina, Bouchard & Bar-Or, 2004; Clark, 2002) and prevention of cognitive decline (Sofi et al., 2011). Sedentary way of life, however, may be one of the factors contributing to the onset of cognitive decline in adults (Sofi et al., 2011). Preschool children regularly engaging in any physical activity experience long-term benefits in terms of both physical and psychological well-being (García-Hermoso et al., 2020).

In order for a child to master reading, writing, speech and gesticulation, or skills that appear to be exclusively academic, the child must be in good control over their motor abilities (2018), as these represent a basis for successfully mastering these skills (Rajović, 2017; Abdelkarim et al. 2017; Davis et al., 2016; Diamonf, 2010). On the other hand, both cognitive and motor abilities must function with a high level of coordination. Children with poor motor coordination show poorer academic skills and face significant difficulties when they start school (Michel et al., 2011). Vickerman (2008) indicates that the coordination involves a series of cerebral processes, such as sensory input, perceptive and cognitive processing. It is based on harmonization of the nervous system and the musculoskeletal system (Budde et al., 2008), resulting in quick, accurate, and balanced motor response (Corbin et al., 2000; Lopes et al., 2012). Budde et al., (2008) verified that 10 minutes of acute bilateral coordination exercises improve concentration and attention in school-aged children. Fernandes et al. 2016 indicate that the visual motor coordination and visual selective attention may affect cognitive functioning in children. According to the integrated development theory, the correlation between motor, cognitive, and emotional development of children declines with age (Stojanovic and Stojanovic 2006), so the most efficient approach is to focus on the mentioned aspects in the early period (Ismail and Gruber, 1971). The same authors state, in their other studies, that there is a high positive correlation between balance, coordination and general cognitive ability factor. As this refers to a partially symmetrical effect of cognitive abilities on motor abilities, it would be safe to presume that there is a positive effect of exercises for coordination and balance development on cognitive abilities (Pietch et al., 2017), especially in children younger than 6-7. Frick & Mohring (2016) emphasize that balance skills would help children investigate the world around them and build a firm comprehension of spatial relationships vital for higher academic achievement. Based on the presented facts, this research is focused on testing the relationship between cognitive abilities and manual coordination and balance in preschool children for the purpose of advancing their physical and mental development.

Method

The sample of respondents consisted of 41 children of preschool age who attend preschool institutions in preparatory groups. The mean age of children of both sexes was 6.4 ± 0.8 decimal years (30 boys and 11 girls). On top of their regular activities in preschool institutions, all the children frequented multisport activities and exercises twice a week at “Luka” school of sports from Novi Sad, Serbia. The children’s activities at the school of sports are of moderate to vigorous intensity and are focused on the development of basic motor skills and basic elements of both team sports and individual sports. The children’s parents furnished a written consent required for a child’s participation in the tests. Only physically and mentally healthy children, able to perform all the tests, were tested. Data for this study was taken from the scientific and research project “Possibilities of improving intellectual, motor, and cardiorespiratory abilities in children using kinesiological activities” (Ref. No. 179011), implemented at the Faculty of Sport and Physical Education in Novi Sad, Serbia in accordance with the Helsinki Declaration.

Instruments and measurements

The sample of measuring instruments included 4 motor tests generating the criterion variables: One-leg stand test, Mann’s test, Front raise and Finger-to-nose.

Two cognitive tests, Raven's colored progressive matrices (RCPM) and Cognitive assessment (CA), with a total of 5 scales for assessment of cognitive abilities in children, was comprised the system of predictor variables.

Description of Motor Skills Assessment

One-leg stand test

The respondent stands on the dominant leg, lifts the other leg off the ground, bending it at the knee in parallel to the ground. When the respondent finds balance, he/she closes his/her eyes and stands in that position until he/she loses balance. The result of the tests is the time from the moment the respondent closes his/her eyes in the initial position until he/she breaches any requirement of proper test performance.

Mann's test

The respondent stands on a line marked on the ground, maintaining balance, while his/her big toe of the rear foot touches the heel of the front foot, then he/she closes his/her eyes and remains in the same position until he/she loses balance. The result is the time measured from the moment the respondent closes his/her eyes in the initial position until he/she breached any requirement for the performance of the task.

Front raise

The respondent closes his/her eyes and raises the dominant arm straight out in front of him/her, stays in that position for a while so that the examiner may assess whether the arm is parallel to the ground, then he/she lowers the arm down to the hips and repeats the task for 3 more times (4 front raises in total). The task continues with the non-dominant arm for 4 times, and then with both arms for another 4 times. The task is finished only after 12 front raises have been performed (with both hands). Each front raise is assessed separately by a "yes" (+) if the front raise was in parallel with the ground and with a „no" if the front raise was above or below the parallel line marked on the board at the level of the respondent's shoulders. The result is the number of parallel front raises performed with eyes closed.

Finger-to-nose

The respondent stands firm on the ground with arms abducted. The respondent touches the nose with the index finger of the dominant hand and abducts the arm. The respondent performs the same task with the index finger of the non-dominant arm. The respondent continuously touches the nose, alternating the index fingers of both hands for 4 times continuously. The respondent's head must be upright (the arm towards the nose without leaning forward towards the finger). The task is completed after the 8th repetition (index finger of the non-dominant arm). The result is the number of proper index finger contacts with the tip of the nose, 4 attempts with the dominant and 4 attempts with the non-dominant hand (total of 8). Irregular attempts are marked with a minus (-).

Description of Cognitive assessment

Raven's colored progressive matrices (RCPM)

Raven's colored progressive matrices (Raven 1938, 2000) is one of the most commonly applied tests for assessing the intelligence of preschool children and early-elementary school-aged children in Serbia. RCPM tests are standard non-verbal tests of g-factor or fluid intelligence. RCPM comprises 3 series of 12 items: A, AB and B. The items of each series are listed in the order of difficulty as are the series themselves, with the series B being the hardest.

The tests were carried out in groups and the time for completion was unlimited in accordance with the recommendation of the Center for Applied Psychology (Serbia) which was in charge of the distribution of tests used in the research. The instructions for solving the test were identically presented to each group by the same examiners. The test was in the form of a booklet and the respondent's results-answers were recorded in answer sheets, in specially designed matrices. As for the respondents who couldn't write (children up to 7 years of age), the examiners recorded the answers in the answer sheets on their behalf.

Cognitive Assessment System (CAS)

Cognitive Assessment System battery of tests is intended to assess the abilities and the level of cognitive functioning in children with and without development defects and is designed based on PASS theory (Planning, Attention, Simultaneous, Successive) (Naglieri & Das, 1997). CAS provides data on the levels of cognitive efficiency in the processing of information and the accompanying test materials enable the establishing of the cognitive status of the respondents with respect to their age group. Results obtained from the CAS battery of tests may be used to predict achievement (Naglieri & Rojahn, 2004), assess the presence of attention deficit disorder or ADHD, learning problems (Naglieri, 2005), mental retardation, mechanical brain injuries (Das, Naglieri, & Kirby, 2003) or emotional issues. CAS may also be used within programs of identification and teaching of gifted children (Naglieri & Das, 1997). CAS battery comprises four scales: Planning, Attention, Simultaneous processes, and Successive processes. CAS battery is applied to each respondent separately. The time for solving the test and the number of correct answers were recorded in the results form, where the total test score was calculated later on.

Data analysis

The basics descriptive indicators were calculated for each test: arithmetic mean (M), standard deviation (S), minimum (MIN) and maximum (MAX) values, measure of asymmetric distribution (SKEW) and measure of homogenous distribution (KURT). The normality of data distribution was tested by applying the Shapiro-Wilk test (SW). The reliability of the Front raise and Finger-to-nose motor tests was checked by calculating the α-Cronbach reliability coefficient, as these tests had been modified and applied for the first time on the preschool children in Serbia.

Linear regression analysis was used for analyzing the relation between the system of cognitive predictors and the criteria variables One-leg stand test and Mann's test. For these variables, we applied a logarithmic transformation of the results with respect to the characteristics of their distribution. The effect size for the linear regression analysis was estimated based on the size of the adjusted R square ($adjR^2$). The assumption of the presence of heteroskedasticity was tested using the Breusch – Pagan test.

For criteria variables Front raise and Finger-to-nose results was transformed into a binary form based on the criteria of 60% of successful performances. Respondents who had less than 60% of successful attempts were coded with 0 and those who achieved that percentage of success with 1. Binary logistic regression was used for analyzing the relation between the system of cognitive predictors and these criteria variables. For binary regression analysis, two criteria were applied to determine the magnitude of the effect size, with the estimate of the possible effect expected between the Cox & Snell R Square and Nagelkerke R Square values.

The alpha level of statistical significance of $p=0.05$ was used for all analyses, where the values $p<0.05$ were considered statistically significant. The statistical data analysis was carried out using IBM SPSS Statistics 20.0 software (SPSS Inc., Armonik, NI, USA) and Jamovi (Jamovi project,ver 1.8).

Results

The analysis of the basics descriptive statistics (Table 1) indicates that the distribution of results in the applied variables does not significantly deviate from the normal distribution in terms of statistics. The obtained skewness values indicate that there is no substantial asymmetry of the results in the analyzed variables. The negative values of kurtosis for a significant number of variables indicate the presence of platykurtosis of distribution, meaning an increased result variability, especially referring to the variables for assessing manual coordination and balance.

Table 1. Basic descriptive statistics

Variable	Mean	SD	MIN	MAX	Skew	Kurt	SW
Raven's PMC	24.29	5.49	14	34	-0.09	-0.77	0.94
Planning	98.15	12.87	74	137	0.41	0.61	0.70
Simultaneous process	112.20	9.90	91	126	-0.46	-0.62	0.32
Attention	106.80	13.07	79	133	-0.21	-0.40	0.62
Successive process	108.32	14.39	75	140	0.06	0.15	0.69
One-leg stand test	3.96	0.83	2.30	5.48	0.09	-1.06	0.63
Mann's test	3.94	0.99	2.20	6.61	0.57	-0.04	0.61

SW – significance of Shapiro-Wilk normality test

The analysis of the relationship between the system of predictors and the criterion variable Mann's test (Table 2) indicated no statistically significant effect of the system of predictor variables on the criterion variable ($F = 1.129$; $P=0.363$; $adjR^2=0.139$). The presence of heteroskedasticity in the analyzed relationship was not determined. If each predictor variable is considered separately, one can also see that none of them has any statistically significant effect on the criterion variable.

Table 2. Results of Linear regression analysis for the Mann's test

Variables	β	t	p
Raven's PMC	0.240	1.317	0.196
Planning	-0.144	-0.748	0.459
Simultaneous	-0.298	-1.567	0.126
Attention	-0.108	-0.598	0.554
Successive process	0.021	0.125	0.901
BP = 4.82 P = 0.438			

β Beta - standardized regression coefficient; t – value of t-test; P – statistical significance of t test; BP - Breusch–Pagan test for heteroskedasticity; P- statistical significance of Breusch–Pagan test

The results of the regression analysis for the criterion variable One-leg stand test (Table 3) indicate that there is no statistically significant effect of the system of predictor variables on the criterion variable ($F = 0.794$; $P=0.561$; $adjR^2=0.102$). The presence of heteroskedasticity in the analyzed relationship was not determined. If each predictor variable is considered separately, one can also see that none of them has any statistically significant effect on the criterion variable.

Table 3. Results of Linear regression analysis for One-leg stand test variable

Variables	β	t	p
Raven's PMC	0.040	0.215	0.831
Planning	-0.246	-1.245	0.221
Simultaneous	-0.191	-0.984	0.332
Attention	0.057	0.309	0.759
Successive process	0.203	1.173	0.249
BP = 3.13 P = 0.681			

The results of the Binary logistic regression analysis of the relation between Finger-to-nose with eyes closed variable and cognitive variables (Table 4) indicate that there is a statistically significant effect (of all predictors) on the successful performance of the Finger-to-nose test with eyes closed. The model as a whole explains between 38.1% and 50.8% of Finger-to-nose test with eyes closed variability and accurately classifies 75% of cases of successful task performance. The table shows that only one predictor provided a uniquely statistically significant contribution to the model, namely the Raven's PMC variable. Responders with a higher score in Raven color matrices were 1.5 times more likely to successfully complete the task in this test.

Table 4. Results of Binary logistic regression of Finger-to-nose with eyes closed

Variable	Wald	p	OR	95% C.I	
Raven's PMC	8.970	0.003	1.461	1.140	1.872
Planning	1.414	0.234	0.950	0.873	1.034
Simultaneous process	0.239	0.625	0.971	0.862	1.093
Attention	0.341	0.559	1.023	0.949	1.102
Successive process	0.947	0.330	0.969	0.910	1.032
Chi-square/sig.	19.678	0.001			

Wald - value of Wald coefficient; p - significance of Wald coefficient; OR - odds ratio; 95% CI - 95% confidence interval for OR.

Based on the results of the logistic regression analysis of Front raise with both arms variable (Table 5), one may conclude that there is no statistically significant effect of the system of predictors on the successful performance of this test. None of the predictors showed statistically significant relation to this variable.

Table 5. Results of the Binary logistic regression of Front raise with both hands

Variable	Wald	p	OR	95% C.I	
Raven's PMC	1.450	0.229	1.097	0.943	1.276
Planning	2.528	0.112	0.944	0.879	1.013
Simultaneous process	0.003	0.955	1.003	0.918	1.094
Attention	2.233	0.135	1.050	0.985	1.119
Successive process	0.563	0.453	1.020	0.969	1.073
Chi-square/sig.	5.403	0.369			

Discussion

This research was aimed at exploring the relation between cognitive abilities and manual coordination and balance in preschool children. The results obtained indicate that the recent studies that explored the same or similar issues among different population confirm the results of the present research (Dunsky, 2019; Pietch el al., 2017; Hagovská & Olekszyová, 2016; Asonitou et al., 2012; Michel et al., 2011). Ismaila et al., (1917) pointed out that there is a high positive correlation between the balance and coordination factors and the general cognitive factor. Having in mind that this is a partially symmetric effect of cognitive abilities on motor skills, it is possible to assume that coordination and balance development exercises will have a positive effect on cognitive abilities, especially in children younger than 6-7. Phirom at al., (2020) also emphasize the effect of combined physical and cognitive exercises on the improvement of cognitive performance. Even the use of some video games such as Xbox Kinect, where physical activity is based on play, contributes significantly to the improvement of balance in older adults (Yang, 2020).

Cognitive abilities are responsible for the processes of anticipation, planning, decision-making, as well as comparison and processing of information in combination with long-term memory in situations requiring problem-solving. It may be said that complex motor tasks are more strongly correlated with cognitive abilities, as they include cognitive processes as well, whereas simple motor tasks, which are at a lower, elementary level, require minimum engagement of intellectual processes. Based on the above stated, motor tasks with atypical structure of movement, which, in addition to the accuracy of execution, require maximum speed, have a statistically significant positive relationship with intelligence. Motor skills related to the general cognitive factor are manifested in the performance of these movements, for which there are no predefined programs and where the speed of comprehension, learning and memorizing the manner and order of movements, as well as efficient use of feedback, may have an influence in that the respondents with a higher IQ achieve better results at motor skills tests, especially referring to coordination tests.

Motor coordination tests also comprise specific problem-solving tasks requiring efficiency in solving (Dolenc, Pistotnik, & Pinter, 2002). In addition, individuals who are physically more active are able to process more information in a quicker manner. Such data suggest that physical activity may contribute to the improvement in cognitive abilities and enable efficient response to the challenge at hand along with better performance.

The advantage of this study is reflected in its emphasis on the importance of motor skills development and early discovery of low cognitive functioning in children with the aim of timely intervention, which would prevent certain development defects in everyday life of children.

The present study also has its limitations. This research did not include a large sample of respondents, which may be deemed one of its disadvantages. The socioeconomic status of children and their parents should have been included in order to obtain a more comprehensive picture as to the relation between motor skills and cognitive functions. Secondly, it would be beneficial to include an experimental treatment and compare the results with the children who do not engage in additional physical activity, for the purpose of emphasizing the importance of the same.

Conclusion

Based on the results of the present research, a conclusion may be drawn that there is a statistically significant relation between cognitive abilities and manual coordination in the tested sample of preschool children. A better understanding of the significance and relation of motor skills and the psychosomatic status of children may contribute to designing new and more efficient programs of physical exercises, which would prove to be both socially and physically beneficial for the population.

Acknowledgments

The paper is a part scientific and research project “Possibilities of improving intellectual, motor, and cardiorespiratory abilities in children using kinesiological activities” (Ref. No. 179011), implemented at the Faculty of Sport and Physical Education in Novi Sad, Serbia in accordance with the Helsinki Declaration.

References

Abdelkarim, O., Ammar, A., Chtourou, H., Wagner, M., Knisel, E., Hökelmann, A., & Bös, K. (2017). Relationship between motor and cognitive learning abilities among primary school-aged children. *Alexandria Journal of Medicine*, *53*(4), 325-331.

Asonitou, K., Koutsouki, D., Kourtessis, T., & Charitou, S. (2012). Motor and cognitive performance differences between children with and without developmental coordination disorder (DCD). *Res Dev Disabil*. *33*(4), 996-1005. doi: 10.1016/j.ridd.2012.01.008.

Biddle, S. J., Ciaccioni, S., Thomas, G., & Vergeer, I. (2019). Physical activity and mental health in children and adolescents: An updated review of reviews and an analysis of causality. *Psychology of Sport and Exercise*, *42*, 146-155.

Bidzan-Bluma, I. & Lipowska, M. (2018). Physical activity and cognitive functioning of children: A systematic review. *Environ. Res. Public Health*, *15*, 800.

Budde, H., Voelcker-Rehage, C., Pietrabyk-Kendziorra, S., Ribeiro, P., Tidow, G., Pietraßyk-Kendziorra, S., et al. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neurosci. Lett.* 441, 219–223. doi: 10.1016/j.neulet.2008.06.024

Clark, J. E., & Metcalf, J. M. (2002). The mountain of motor development: A metaphor. In J.E. Clark & J. H. Humphrey (Eds.), *Motor development: Research and reviews* (vol. 2, pp. 163-190). Reston, VA: National Association for Sport and Physical Education.

Corbin, C. B., Pangrazi, R. P., and Franks, B. D. (2000). Definitions: health, fitness, and physical activity. *Pres. Counc. Phys. Fit. Sports Res. Dig. 3*, 1–11.

Das, J. P., Naglieri, J. A., & Kirby, J. R. (1994). *Assessment of cognitive processes*. Needham Heights, MA: Allyn & Bacon.

Davies, S., Janus, M., Duku, E., & Gaskin, A. (2016). Using the Early Development Instrument to examine cognitive and non-cognitive school readiness and elementary student achievement. *Early Childhood Research Quarterly*, *35*, 63–75. https://doi.org/10.1016/j.ecresq.2015.10.002

Diamond, A. (2010). The evidence base for improving school outcomes by addressing the whole child and by addressing skills and attitudes, not just content. *Early Education and Development*, *21*(5), 780-793.

Dolenc, M., Pistotnik, B., & Pinter, S. (2002). Correlation Between Coordination and Cognitive Abilities of Girls 7-11 Years. In D. Milanović, & F. Prot (Eds.) *Proceedings Book of 3rd International Scientific Conference "Kinesiology New Perspectives", Opatija, Croatia, september 25-29th, 2002*, 105-108. Zagreb: Faculty of Kinesiology.

Dunsky A. (2019). The Effect of Balance and Coordination Exercises on Quality of Life in Older Adults: A Mini-Review. *Frontiers in aging neuroscience*, *11*, 318. https://doi.org/10.3389/fnagi.2019.00318

Frick, A., & Möhring, W. (2016). A matter of balance: motor control is related to children's spatial and proportional reasoning skills. *Frontiers in Psychology*, *6*, 2049.

García-Hermoso, A., Alonso-Martinez, A. M., Ramírez-Vélez, R., & Izquierdo, M. (2020). Effects of Exercise Intervention on Health-Related Physical Fitness and Blood Pressure in Preschool Children: A Systematic Review and Meta-Analysis of Randomized Controlled Trials. *Sports medicine (Auckland, N.Z.)*, *50*(1), 187–203. https://doi.org/10.1007/s40279-019-01191-w

Goodway, J., Ozmun, J., & Gallahue, D. (2012). *Understanding motor development: Infants, children, adolescents, adults*; McGraw-Hill: New York.

Gunnel, K.E., Poitras, V.J., LeBlanc, A., Schibli, K., Barbeau, K., Hedayati, N., Pointfex, M.B., Goldfield, G.S., Dunlap, C., & Lehan, E. (2019). Physical activity and brain structure, brain function, and cognition in children and youth: A systematic review of randomized controlled trials. *Ment. Health Phys. Act. 16*, 105–127.

Hagovská, M., & Olekszyová, Z. (2016). Relationships between balance control and cognitive functions, gait speed, and activities of daily living. Beziehung zwischen der Kontrolle des Körpergleichgewichts und kognitiven Funktionen, Gehgeschwindigkeit sowie Aktivitäten des täglichen Lebens. *Zeitschrift fur Gerontologie und Geriatrie*, *49*(5), 379–385. https://doi.org/10.1007/s00391-015-0955-3

The jamovi project (2021). *jamovi*. (Version 1.8) [Computer Software]. Retrieved from https://www.jamovi.org.

Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., Hall, E. E., & Kramer, A. F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. Neuroscience, *159*(3):1044-54

Ismail, A. H., & Gruber, J. J. (1971). Integrated Development –Motor Aptitude and Intellectual Performance.Columbus: Charles E. Merrill Books.

LaVigne, T., Hoza, B., Smith, A. L., Shoulberg, E. K., & Bukowski, W. (2016). Associations between physical fitness and children's psychological well-being. *Journal of Clinical Sport Psychology*, *10*(1), 32–47. https://doi.org/10.1123/jcsp.2014-0053

Lopes, V. P., Stodden, D. F., Bianchi, M. M., Maia, J. A. R., & Rodrigues, L.P. (2012). Correlation between BMI and motor coordination in children. *J. Sci. Med. Sport. 15*, 38–43. doi: 10.1016/j.jsams.2011.07.005

Malina, R.M., Bouchard, C., & Bar-Or, O. (2004). *Growth, Maturation, and Physical Activity, 2nd edition*. Champaign, IL: Human Kinetics.

Michel, E., Roethlisberger, M., Neuenschwander, R., & Roebers, C. M. (2011). Development of cognitive skills in children with motor coordination impairments at 12-month follow-up. *Child Neuropsychology*, *17*(2), 151-172.

Naglieri, J. A. & Das, J. P. (2005*). Planning, Attention, Simultaneous, Successive (PASS) theory: A Revision of the Concept of Intelligence*. In D. P. Flanagan and P. L. Harrison (Eds.) Contemporary Intellectual Assessment (Second Edition) (pp. 136-182). New York: Guilford.

Naglieri, J. A., & Rojahn, J. R. (2004). Validity of the PASS Theory and CAS: Correlations with Achievement. *Journal of Educational Psychology*, *96*, 174–181

Naglieri, J. A., (2005). *The Cognitive Assessment System*. In D. P. Flanagan and P. L. Harrison (Eds.) Contemporary Intellectual Assessment (Second Edition), (pp. 441-460). New York: Guilford.

Páez-Maldonado, J. A., Reigal, R. E., Morillo-Baro, J. P., Carrasco-Beltrán, H., Hernández-Mendo, A., & Morales-Sánchez, V. (2020). Physical Fitness, Selective Attention and Academic Performance in a Pre-Adolescent Sample. *International Journal of Environmental Research and Public Health*, *17*(17), 6216.

Phirom, K., Kamnardsiri, T., & Sungkarat, S. (2020). Beneficial Effects of Interactive Physical-Cognitive Game-Based Training on Fall Risk and Cognitive Performance of Older Adults. *International Journal of Environmental Research and Public Health*, *17*(17), 6079.

Pietsch, S., Böttcher, C., & Jansen, P. (2017). Cognitive motor coordination training improves mental rotation performance in primary school-aged children. *Mind, Brain, and Education*, *11*(4), 176-180.

Rajović, R., Berić, D., Bratić, M., Živković, M., & Stojiljković, N. (2017). Effects of an "NTC" exercise program on the development of motor skills in preschool children. *Facta Universitatis, Series: Physical Education and Sport*, 315-329.

Raven, J. (2000). The Raven's progressive matrices: change and stability over culture and time. *Cognitive psychology, 41*(1), 1-48.

Raven, J. C., & JH Court. (1938). *Raven's progressive matrices*. Los Angeles, CA: Western Psychological Services.

Smith, J. J., Eather, N., Morgan, P. J., Plotnikoff, R. C., Faigenbaum, A. D., & Lubans, D. R. (2014). The health benefits of muscular fitness for children and adolescents: a systematic review and meta-analysis. *Sports medicine*, *44*(9), 1209-1223.

Sofi, F., Valecchi, D., Bacci, D., Abbate, R., Gensini, G.F., Casini, A., & Macchi, C. (2011). Physical activity and risk of cognitive decline: A meta-analysis of prospective studies. *J. Intern. Med, 269*, 107–117.

Stojanović, M. i Stojanović, M. (2006). Razvojne promene relacija motoričkog statusa i inteligencije dece uzrasta 5-7 godina sa teritorije Novog Sada. U G. Bala (ur.), Zbornik radova interdisciplinarne naučne konferencije sa međunarodnim učešćem *Antropološki status i fizička aktivnost dece i omladine* (str. 219-224). Novi Sad: Fakultet sporta i fizičkog vaspitanja.

Vickerman, P. (2008). Ecological intervention for children with movement difficulties (Manual) – By David Sugden and Sheila Henderson. *British Journal of Special Education, 35*(4), 252–253.

Yang, C.M., Hsieh, J.S.C., Chen, Y.C., Yang, S.Y., & Lin, H.C.K. (2020). Effects of Kinect exergames on balance training among community older adults. *Medicine, 99*.

How to cite this article:

APA: Sadri, F., Sadri, I., Krneta, Ž., Trbojević Jocić, J., & Batez, M. (2021). Relationship between cognitive abilities and manual coordination and balance in preschool children. *Exercise and Quality of Life, 13*(1), 31-38. doi:10.31382/eqol.210604

MLA: Sadri, Filip, et al. "Relationship between cognitive abilities and manual coordination and balance in preschool children." *Exercise and Quality of Life* 13.1 (2021): 31-38.

Chicago: Sadri, Filip, Ivo Sadri, Željko Krneta, Jovana Trbojević Jocić, and Maja Batez. "Relationship between cognitive abilities and manual coordination and balance in preschool children." *Exercise and Quality of Life* 13, no. 1 (2021): 31-38.