Movement Skills And Students' Cognitive Function

Rola Angga Lardika[2], Beltasar Tarigan *[1], Hamidie Ronald Daniel Ray[1] , Yunyun Yudiana[1]

[1]Department of Sport Education Universitas Pendidikan Indonesia, Bandung, Indonesia. [2]Department Sport Education FKIP Universitas Riau, Pekanbaru, Indonesia.

*Corresponding Author: Beltasar Tarigan, beltasartarigan@upi.edu

Abstract

This research is a quantitative study with a correlational design that aims to determine the relationship between movement skills and cognitive function in students of public elementary schools in Kuantan Singingi Regency, Riau Province. The population of this study was students for the 2021/2022 school year, with a population of 37.085 children spread across 256 public elementary schools. The sampling technique used in this research is random sampling. With this technique, I obtained a sample of 4700 students. Methods of data collection using tests and measurements of cognitive function and movement skills Cognitive function uses the Concentration Grid Test (CGT) instrument and movement skills by observing movement learning. The results showed that students' cognitive function was in a good category, and their movement learning was also good. The results of the correlation analysis obtained a correlation coefficient of 0.471 > r_{table} = 0.160. This shows that there is a significant relationship between movement skills and cognitive function in public elementary school students in Kuantan Singingi District for the 2021/2022 academic year. The conclusion that can be drawn from the results of the research is that one student's movement skills is influenced by cognitive function. Students who have good cognitive function tend to have good movement skills.

Keywords: cognitive function, movement skills, physical education.

INTRODUCTION

A recent meta-analysis estimates that each additional year of education provides a cognitive benefit of about 1 to 5 IQ points(Keeley & Fox, 2009). Education has been linked to better cognitive function in people(Zhou et al., 2021). These effects then persist throughout the life course and are present in a wide range of cognitive abilities. A lifestyle that involves physical activity can protect against future brain damage(Bertuol et al., 2021). People who are more physically active are expected to perform well cognitively even when facing old age, which is thought to reduce their cognitive abilities(Liu et al., 2021). Thus, doing more physical activity should be linked to cognitive performance. Although proposed as a potential moderator of the relationship between physical activity and cognitive functioning, few studies have directly tested the moderating effect of education. Loprinzi et al., (2019) found that there was a relationship between physical activity and semantic knowledge in people with low education, while Irwin et al., (2018) found that moderate to vigorous walking had a stronger relationship. Research shows that the optimal effect of physical activity on neurocognitive preservation is obtained by maintaining a physically active lifestyle throughout life (Wang et al., 2020; Gasquoine, 2018).

On the other hand, research also shows that the cognitive benefits of physical activity are greater for those who are less active(Morais et al., 2018; Vestberg et al., 2017). This finding shows that education in physical education can affect the relationship between physical activity and cognition; however, it is difficult to determine a clear hypothesis about the direction of the educational moderation effect based on previous studies. Therefore, it is possible that there is a correlation between the average level of low physical activity and high physical activity and cognitive function. A number of studies have identified physical activity as a lifestyle factor that plays an important role in maintaining and even improving cognitive function throughout life (Hakked et al., 2017; Gomes da Silva & Arida, 2015). Meta-analyses and systematic reviews show a consistent pattern of prospective association between doing more physical activity and reduced risk of cognitive decline and neurodegenerative diseases (Aarsland et al., 2020; Alderman et al., 2019; Fiľo & Janoušek, 2021).

Intervention studies (MacDonald & Minahan, 2016; Pokorski, 2015) and meta-analyses of intervention studies show a positive effect on many cognitive domains(Loef & Walach, 2012; Milanović et al., 2019; Schneider et al., 2021; Meijer et al., 2020; Loprinzi et al., 2019). Despite the abundance of evidence supporting the cognitive benefits of physical activity, there is little research that describes the relationship between individuals(Cabirol et al., 2018). Influence between individuals is used to describe differences between individuals in one variable and other variables. Therefore, this article wants to explore information at a different level, namely at the elementary school level. This analysis will involve attributes that are considered stable and reflect the person as a whole, and this variable is independent of time. Expression in a person refers to the presence of intra-individual variations when assessed repeatedly(Mbhatsani et al., 2017). Effects on a person can only be observed directly when each person has been measured more than once(Veijalainen et al., 2021). Deciphering influence in a person is important because the results often differ between levels(Natalia, 2015; Matthews et al., 2017; Grebener et al., 2021).

In addition, little is known about the longitudinal association between physical activity and cognitive function (Coco et al., 2019; Charlett et al., 2021; Yongtawee et al., 2021; Irwin et al., 2018). Evidence of moderation exists if the relationship between two variables (e.g., physical activity and cognition) differs at different levels of the moderating variable (e.g., age). Greater understanding of the variables is essential because it allows the identification of subgroups that could specifically benefit from physical activity (Kilger & Blomberg, 2020; (Narkauskaitė-Nedzinskienė et al., 2020). This study therefore examined the relationship between motor learning and cognitive function to describe the relationship between one's self and examine whether the variables of cognitive function and movement learning have a strong relationship.

METHOD

The data collection method used in this study is a quantitative approach with a correlational design. This research was carried out in two places, namely in the school field and school room. For cognitive function tests, it was carried out in the classroom, while for motion literacy tests, it was carried out in the school yard. The time for the implementation of this research was carried out in January–May 2023 to take cognitive function and motion learning for the implementation of the test during class hours. In this study, the population taken was elementary school students in Kuantan Singingi Regency for the 2021–2022 academic year, with a population of 37,085 children spread over 256 elementary schools. The sample used was 4700 students with a random sampling technique. The IOWA TES movement learning test instrument is from Johnson Berry dan Jack K Nelson (1970:144-146) and for cognitive function tests, use the Concentration Grid Test (CGT) instrument. Data analysis uses product-moment correlation calculations.

RESULT

Based on data analysis, an overview of the movement learning of elementary school students in Kuantan Singingi Regency for the 2021–2022 academic year is obtained as follows:

Table 1. Description of the Data Categories of the Results of the Movement Learning Assessment for Elementary School Students in Kuantan Singingi Regency for the 2021/2022 Academic Year

Description	total	Percentage
Very well	1051	22.36%
Good	2849	60.63%
Currently	751	15.96%
Not enough	49	1.05%

Total	**4700**	**100%**

The table above shows that the majority of elementary school students in Kuantan Singingi Regency for the 2021–2022 academic year have good motor literacy (60.63%), the rest have very good motor literacy (22.36%), moderate (15.96%), and less (1.05%). For more details, it can be illustrated by the graph below:

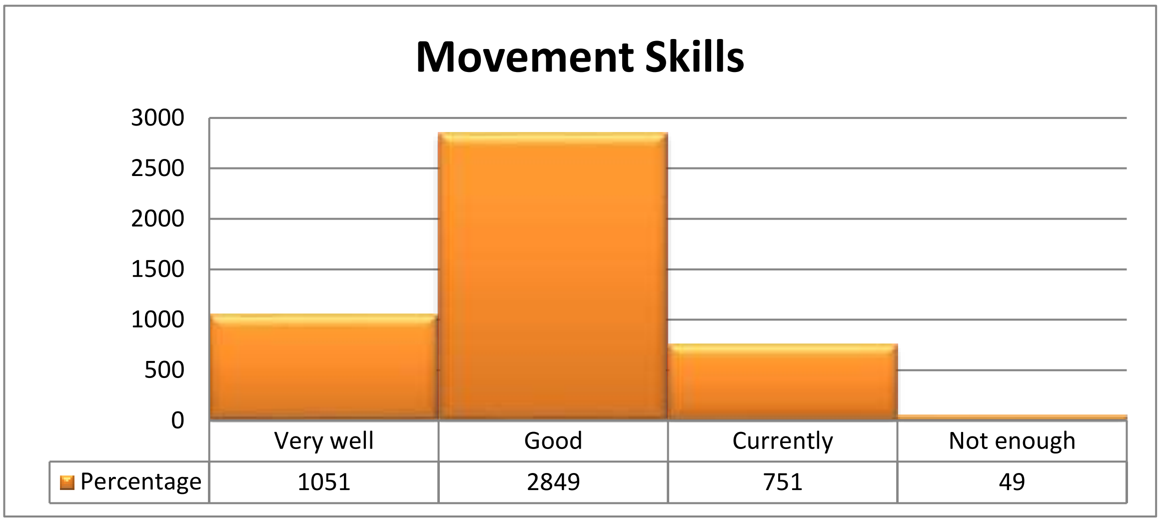

Figure 1. Percentage of Movement Learning Assessment for Elementary School Students in Kuantan Singingi Regency for the 2021/2022 Academic Year

Based on data analysis, an overview of the cognitive function of elementary school students in Kuantan Singingi Regency for the 2021–2022 academic year is obtained as follows:

Table 2. Description of Data Category Results of Cognitive Function of State Elementary Schools in Kuantan Singingi Regency

Description	**total**	**Percentage**
Very well	853	18.14%
Good	2698	57.40%
Currently	1002	21.32%
Not enough	147	3.14%
Total	**4700**	**100%**

The table above shows that the majority of elementary school students in Kuantan Singingi Regency for the 2021–2022 academic year have good cognitive function (57.40%), the rest have moderate movement learning (21.32%), very good (18.04%), and poor (3.14%). For more details, it can be illustrated by the graph below:

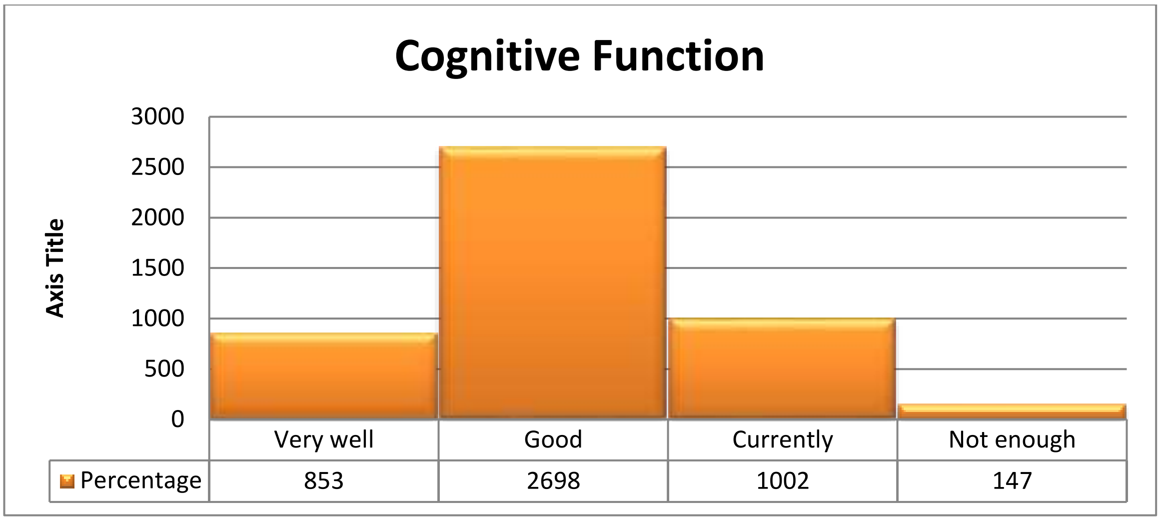

Figure 2. Percentage of Cognitive Function of Elementary School Students in Kuantan Singingi Regency for the 2021/2022 Academic Year

To test the hypothesis, this study uses correlation analysis. Based on the results of the correlation analysis, the results are obtained as in the following table:

Table 3. Analysis of Movement Learning with the Cognitive Function of Elementary School Students in Kuantan Singingi Regency for the 2021–2022 Academic Year

Variable	r	Sig	Error	Criteria
Movement Skills and Cognitive Function	0.471	0.00	5%	Significant

Based on the calculation results in Table 3 above, it shows that the correlation coefficient between movement learning and cognitive function is 0.471 with a significance of 0.00. Because the significance value obtained, which is 0.00, is smaller than the specified error limit, which is 0.05, it can be concluded that there is a significant relationship between movement learning and cognitive function in elementary school students in Kuantan Singingi Regency for the 2021–2022 academic year.

DISCUSSION

In this study, we examined the relationship between physical activity through movement learning and students' cognitive function. The results of the study show that physical activity through movement learning is related to cognitive function. The relationship between physical activity level, movement learning, and memory recall is stronger in active individuals. The relationship between physical activity and changes in cognitive function is much more informative. Related to this study, the initial level of physical activity is a reliable predictor of changes in cognitive outcomes(Lundgren et al., 2016). The relationship between people that links initial levels of physical activity and changes in cognitive function can be a strong indicator(Piepmeier et al., 2020; Loprinzi, 2019;Bianco et al., 2017). herefore, individuals who engage in more physical activity appear to have higher cognitive abilities, and these cognitive advantages are maintained over time. In line with several previous studies(BenOunis et al., 2013) and different from other studies (e.g., Holfelder et al., 2020; Hostinar et al., 2012; Lundgren et al., 2016; Wang et al., 2013). Regarding this study, it should be noted that Wallhead et al., (2021) found a stronger effect of executive function (i.e., an index based on verbal fluency) on physical activity than the effect of physical activity on subsequent executive function in a sample of older adults. Meijer et al., (2020) found only an association between early physical activity and reduced verbal fluency decline in older adults but found no association between early physical activity and changes in semantic memory, knowledge, or reasoning.

Finally, Broadbent et al., (2015) found that physical activity at a young age predicts less decline from old age in latent factors of general cognitive ability (i.e., based on four subtests: number symbol, block design, number range, and picture completion). Thus, there is some evidence that baseline or average levels of physical activity may have long-term effects on several cognitive domains. However, there is great heterogeneity between studies (e.g., regarding measures of cognitive and physical activity, measurement intervals, and age ranges), and most of the studies involved adults. This study covered a slightly wider age range (i.e., 40–85 years at study entry), and the results are in line with other studies that included samples across the adult age range(Fiľo & Janoušek, 2022). In addition to the more stationary, between-person-level relationships, it also examines the dynamic, between-person-level relationships between physical activity and cognitive function.

It represents the occasion-specific, person-to-person relationship between physical activity and cognitive functioning while controlling for the average rate of change over time. In line with previous research (e.g., Gomes da Silva & Arida, 2015; Irwin et al., 2018; Masel et al., 2010; Schnider et al., 2021), this study found a consistent relationship at the individual level between physical activity and cognitive outcomes. The magnitude of this person-to-person association was stronger for episodic memory recall (0.686) compared to verbal fluency (0.296) and visuospatial ability (0.255), and the pattern suggests that wave-to-wave fluctuations in physical activity around an individual's average trajectory are related to corresponding fluctuations in the cognitive domain. Other research has also found that age moderates the relationship between physical activity levels and all three cognitive outcomes at study entry, so the relationship is stronger among participants. More specifically, older participants who were more physically active at the start of the study performed better on cognitive tests at the start of the study compared to older participants who were less active. These findings may be related to changes in brain structure and function that occur with aging(Kilger & Blomberg, 2020). Physical activity has been found to predict total brain volume and gray matter volume(Clark et al., 2020), as well as regional brain volume in some areas (mie.g., the hippocampus;Loprinzi, 2019), which are prone to age-related decline(Antunes et al., 2020). Nerve activation, functional connectivity, and cerebral blood flow are also negatively affected by increasing age but have been shown to be positively affected by physical activity(Broadbent et al., 2015; Miyamoto et al., 2018).

Physical activity affects brain structure and function, which are known to decrease with age, indicating that the beneficial effects of physical activity may become more pronounced(Miyamoto et al., 2018; Soriano-Maldonado et al., 2016). However, given the mixed findings in the literature and the heterogeneity between studies on the moderating effect of age on the physical activity-cognition relationship(Broadbent et al., 2015; Gomes da Silva & Arida, 2015; Kraft, 2012; Viegas et al., 2021), research like this is urgently needed. At the individual level, the effect of physical activity on episodic memory is stronger in active people. This finding is in line with recent suggestions that the health benefits (including cognitive benefits) of physical activity may be most pronounced for individuals who are fit(Keeley & Fox, 2009; Liu et al., 2022). It is now known that the retrieval processes involved in episodic memory function are highly dependent on the formation of the hippocampus (Miyamoto et al., 2018; Ohko et al., 2021). It is also well documented that with increasing age, hippocampal volume decreases (e.g., Piepmeier et al., 2020) and that aerobic fitness and physical activity are related to hippocampal volume in individuals(Antunes et al., 2020, 2020). Thus, one possible explanation for this finding is that physical activity can positively influence the structure and function of the hippocampus and that increased activity levels can be highly beneficial for active individuals. We also found that years of education moderated the effect of a person's level of physical activity on verbal fluency. This may indicate that some of the cognitive benefits of physical activity are more pronounced in people who have been involved in intellectually stimulating activities (e.g., education) throughout their lives)(Ploughman, 2008).

The findings in the current study are in line with previous findings showing that the effect of physical activity on cognition is greater among those with education (e.g., Verswijveren et al., 2020). However, the interaction between physical activity and education is associated with different cognitive outcomes in this study (namely motor fluency) when compared to (Formenti et al., 2019) who found a relationship with semantic knowledge. Other previous studies have shown that the interaction between physical activity and education is positively related to working memory(Powell et al., 2016), ndicating an additive effect on cognition in the presence of several protective factors. Evidence from meta-analyses and systematic reviews indicates a greater effect of a combination of cognitive and physical interventions on cognitive function when compared to the control group or the physical intervention alone(Aarsland et al., 2020;

Coimbra et al., 2021; Kraft, 2012). This suggests that multiple factors (e.g., physical activity and cognitively stimulating activities) have an effect on cognitive function.

CONCLUSION

The results of this study support the effect of physical activity on cognitive function; conversely, the results of this study suggest that engaging in physical activity has cognitive benefits, which is more in line with the theory of use dependence(Masel et al., 2010; Wallhead et al., 2021). Overall, the effects of the relationship between physical and cognitive activity were consistent across levels of analysis. In line with previous findings, the findings of this study highlight the importance of deciphering the effect of age level on a person and separating level from change over time when examining predictors of cognitive function.

BIBLIOGRAPHY

Aarsland, V., Borda, M. G., Aarsland, D., Garcia-Cifuentes, E., Anderssen, S. A., Tovar-Rios, D. A., Gomez-Arteaga, C., & Perez-Zepeda, M. U. (2020). Association between physical activity and cognition in Mexican and Korean older adults. Archives of Gerontology and Geriatrics, 89(April), 104047. https://doi.org/10.1016/j.archger.2020.104047

Alderman, B. L., Olson, R. L., & Brush, C. J. (2019). Using event-related potentials to study the effects of chronic exercise on cognitive function. International Journal of Sport and Exercise Psychology, 17(2), 106–116. https://doi.org/10.1080/1612197X.2016.1223419

Antunes, B. M., Rossi, F. E., Teixeira, A. M., & Lira, F. S. (2020). Short-time high-intensity exercise increases peripheral BDNF in a physical fitness-dependent way in healthy men. European Journal of Sport Science, 20(1), 43–50. https://doi.org/10.1080/17461391.2019.1611929

BenOunis, O., BenAbderrahman, A., Chamari, K., Ajmol, A., BenBrahim, M., Hammouda, A., Hammami, M. A., & Zouhal, H. (2013). Association of short-passing ability with athletic performances in youth soccer players. Asian Journal of Sports Medicine, 4(1), 41–48. https://doi.org/10.5812/asjsm.34529

Bertuol, C., Tozetto, W. R., Streb, A. R., & Del Duca, G. F. (2021). Combined relationship of physical inactivity and sedentary behaviour with the prevalence of noncommunicable chronic diseases: data from 52,675 Brazilian adults and elderly. European Journal of Sport Science, 0(0), 1–10. https://doi.org/10.1080/17461391.2021.1880646

Bianco, V., Di Russo, F., Perri, R. L., & Berchicci, M. (2017). Different proactive and reactive action control in fencers' and boxers' brain. Neuroscience, 343(December), 260–268. https://doi.org/10.1016/j.neuroscience.2016.12.006

Broadbent, D. P., Causer, J., Williams, A. M., & Ford, P. R. (2015). Perceptual-cognitive skill training and its transfer to expert performance in the field: Future research directions. European Journal of Sport Science, 15(4), 322–331. https://doi.org/10.1080/17461391.2014.957727

Cabirol, A., Cope, A. J., Barron, A. B., & Devaud, J. M. (2018). Relationship between brain plasticity, learning and foraging performance in honey bees. PLoS ONE, 13(4), 1–18. https://doi.org/10.1371/journal.pone.0196749

Charlett, O. P., Morari, V., & Bailey, D. P. (2021). Impaired postprandial glucose and no improvement in other cardiometabolic responses or cognitive function by breaking up sitting with bodyweight resistance exercises: a randomised crossover trial. Journal of Sports Sciences, 39(7), 792–800. https://doi.org/10.1080/02640414.2020.1847478

Clark, J. M., Adanty, K., Post, A., Hoshizaki, T. B., Clissold, J., McGoldrick, A., Hill, J., Annaidh, A. N., & Gilchrist, M. D. (2020). Proposed injury thresholds for concussion in equestrian sports. Journal of Science and Medicine in Sport, 23(3), 222–236. https://doi.org/10.1016/j.jsams.2019.10.006

Coco, M., Di Corrado, D., Ramaci, T., Di Nuovo, S., Perciavalle, V., Puglisi, A., Cavallari, P., Bellomo, M., & Buscemi, A. (2019). Role of lactic acid on cognitive functions. Physician and Sportsmedicine, 47(3), 329–335. https://doi.org/10.1080/00913847.2018.1557025

Coimbra, M., Cody, R., Kreppke, J. N., & Gerber, M. (2021). Impact of a physical education-based behavioural skill training program on cognitive antecedents and exercise and sport behaviour among adolescents: a cluster-randomized controlled trial. Physical Education and Sport Pedagogy, 26(1), 16–35. https://doi.org/10.1080/17408989.2020.1799966

Fiľo, P., & Janoušek, O. (2021). The relation between physical and mental load, and the course of physiological functions and cognitive performance. Theoretical Issues in Ergonomics Science, 0(0), 1–22. https://doi.org/10.1080/1463922X.2021.1913535

Fiľo, P., & Janoušek, O. (2022). The relation between physical and mental load, and the course of physiological functions and cognitive performance. Theoretical Issues in Ergonomics Science, 23(1), 38–59. https://doi.org/10.1080/1463922X.2021.1913535

Formenti, D., Duca, M., Trecroci, A., Ansaldi, L., Bonfanti, L., Alberti, G., & Iodice, P. (2019). Perceptual vision training in non-sport-specific context: effect on performance skills and cognition in young females. Scientific Reports, 9(1), 1–13. https://doi.org/10.1038/s41598-019-55252-1

Gasquoine, P. G. (2018). Effects of physical activity on delayed memory measures in randomized controlled trials with nonclinical older, mild cognitive impairment, and dementia participants. Journal of Clinical and Experimental Neuropsychology, 40(9), 874–886. https://doi.org/10.1080/13803395.2018.1442815

Gomes da Silva, S., & Arida, R. M. (2015). Physical activity and brain development. Expert Review of Neurotherapeutics, 15(9), 1041–1051. https://doi.org/10.1586/14737175.2015.1077115

Grebener, B. L., Barth, J., Anders, S., Beißbarth, T., & Raupach, T. (2021). A prediction-based method to estimate student learning outcome: Impact of response rate and gender differences on evaluation results. Medical Teacher, 43(5), 524–530. https://doi.org/10.1080/0142159X.2020.1867714

Hakked, C. S., Balakrishnan, R., & Krishnamurthy, M. N. (2017). Yogic breathing practices improve lung functions of competitive young swimmers. Journal of Ayurveda and Integrative Medicine, 8(2). https://doi.org/10.1016/j.jaim.2016.12.005

Holfelder, B., Klotzbier, T. J., Eisele, M., & Schott, N. (2020). Hot and Cool Executive Function in Elite- and Amateur- Adolescent Athletes From Open and Closed Skills Sports. Frontiers in Psychology, 11(April), 1–16. https://doi.org/10.3389/fpsyg.2020.00694

Hostinar, C. E., Stellern, S. A., Schaefer, C., Carlson, S. M., & Gunnar, M. R. (2012). Associations between early life adversity and executive function in children adopted internationally from orphanages. Proceedings of the National Academy of Sciences of the United States of America, 109(SUPPL.2). https://doi.org/10.1073/pnas.1121246109

Irwin, C., Campagnolo, N., Iudakhina, E., Cox, G. R., & Desbrow, B. (2018). Effects of acute exercise, dehydration and rehydration on cognitive function in well-trained athletes. Journal of Sports Sciences, 36(3), 247–255. https://doi.org/10.1080/02640414.2017.1298828

Keeley, T. J. H., & Fox, K. R. (2009). The impact of physical activity and fitness on academic achievement and cognitive performance in children. International Review of Sport and Exercise Psychology, 2(2), 198–214. https://doi.org/10.1080/17509840903233822

Kilger, M., & Blomberg, H. (2020). Governing Talent Selection through the Brain: Constructing Cognitive Executive Function as a Way of Predicting Sporting Success. Sport, Ethics and Philosophy, 14(2), 206–225. https://doi.org/10.1080/17511321.2019.1631880

Kraft, E. (2012). Cognitive function, physical activity, and aging: Possible biological links and implications for multimodal interventions. Aging, Neuropsychology, and Cognition, 19(1–2), 248–263. https://doi.org/10.1080/13825585.2011.645010

Liu, M. L., Jiang, L. J., Wang, W. X., Zhang, X., Xing, X. H., Deng, W., & Li, T. (2021). The relationship between activity level and cognitive function in Chinese community-dwelling elderly. Research in Sports Medicine, 00(00), 1–9. https://doi.org/10.1080/15438627.2021.1888096

Liu, M. L., Jiang, L. J., Wang, W. X., Zhang, X., Xing, X. H., Deng, W., & Li, T. (2022). The relationship between activity level and cognitive function in Chinese community-dwelling elderly. Research in Sports Medicine, 30(1), 92–100. https://doi.org/10.1080/15438627.2021.1888096

Loef, M., & Walach, H. (2012). The combined effects of healthy lifestyle behaviors on all cause mortality: A systematic review and meta-analysis. Preventive Medicine, 55(3), 163–170. https://doi.org/10.1016/j.ypmed.2012.06.017

Loprinzi, P. D. (2019). Does brain-derived neurotrophic factor mediate the effects of exercise on memory? Physician and Sportsmedicine, 47(4), 395–405. https://doi.org/10.1080/00913847.2019.1610255

Loprinzi, P. D., Blough, J., Ryu, S., & Kang, M. (2019). Experimental effects of exercise on memory function among mild cognitive impairment: systematic review and meta-analysis. Physician and Sportsmedicine, 47(1), 21–26. https://doi.org/10.1080/00913847.2018.1527647

Lundgren, T., Näslund, M., Högman, L., & Parling, T. (2016). Preliminary investigation of executive functions in elite ice hockey players. Journal of Clinical Sport Psychology, 10(4), 324–335. https://doi.org/10.1123/jcsp.2015-0030

MacDonald, L. A., & Minahan, C. L. (2016). Indices of cognitive function measured in rugby union players using a computer-based test battery. Journal of Sports Sciences, 34(17), 1669–1674. https://doi.org/10.1080/02640414.2015.1132003

Masel, M. C., Raji, M., & Peek, M. K. (2010). Education and physical activity mediate the relationship between ethnicity and cognitive function in late middle-aged adults. Ethnicity and Health, 15(3), 283–302. https://doi.org/10.1080/13557851003681273

Matthews, K. E., Adams, P., & Goos, M. (2017). Quantitative skills as a graduate learning outcome: exploring students' evaluative expertise. Assessment and Evaluation in Higher Education, 42(4), 564–579. https://doi.org/10.1080/02602938.2016.1161725

Mbhatsani, V. H., Mbhenyane, X. G., & Mabapa, S. N. (2017). Development and Implementation of Nutrition Education on Dietary Diversification for Primary School Children. Ecology of Food and Nutrition, 56(6), 449–461. https://doi.org/10.1080/03670244.2017.1366319

Meijer, A., Königs, M., Vermeulen, G. T., Visscher, C., Bosker, R. J., Hartman, E., & Oosterlaan, J. (2020). The effects of physical activity on brain structure and neurophysiological functioning in children: A systematic review and meta-analysis. Developmental Cognitive Neuroscience, 45(July). https://doi.org/10.1016/j.dcn.2020.100828

Milanović, Z., Pantelić, S., Čović, N., Sporiš, G., Mohr, M., & Krustrup, P. (2019). Broad-spectrum physical fitness benefits of recreational football: a systematic review and meta-analysis. British Journal of Sports Medicine, 53(15). https://doi.org/10.1136/bjsports-2017-097885

Miyamoto, T., Hashimoto, S., Yanamoto, H., Ikawa, M., Nakano, Y., Sekiyama, T., Kou, K., Kashiwamura, S. I., Takeda, C., & Fujioka, H. (2018). Response of brain-derived neurotrophic factor to combining cognitive and physical exercise. European Journal of Sport Science, 18(8), 1119–1127. https://doi.org/10.1080/17461391.2018.1470676

Morais, V. A. C. de, Tourino, M. F. da S., Almeida, A. C. de S., Albuquerque, T. B. D., Linhares, R. C., Christo, P. P., Martinelli, P. M., & Scalzo, P. L. (2018). A single session of moderate intensity walking increases brain-derived neurotrophic factor (BDNF) in the chronic post-stroke patients*. Topics in Stroke Rehabilitation, 25(1), 1–5. https://doi.org/10.1080/10749357.2017.1373500

Narkauskaitė-Nedzinskienė, L., Samsonienė, L., Karanauskienė, D., & Stankutė, V. (2020). Psychomotor Abilities of Elderly People and Their Motivation to Participate in Organized Physical Activity. Experimental Aging Research, 46(3), 257–271. https://doi.org/10.1080/0361073X.2020.1743614

Natalia, K. (2015). Psycho-Pedagogical Support in the Preparation of Young Football Players. Procedia - Social and Behavioral Sciences, 185, 286–289. https://doi.org/10.1016/j.sbspro.2015.03.408

Ohko, H., Umemoto, Y., Sakurai, Y., Araki, S., Kojima, D., Kamijo, Y., Murai, K., Yasuoka, Y., & Tajima, F. (2021). The effects of endurance exercise combined with high-temperature head-out water immersion on serum concentration of brain-derived neurotrophic factor in healthy young men. International Journal of Hyperthermia, 38(1), 1077–1085. https://doi.org/10.1080/02656736.2021.1922761

Piepmeier, A. T., Etnier, J. L., Wideman, L., Berry, N. T., Kincaid, Z., & Weaver, M. A. (2020). A preliminary investigation of acute exercise intensity on memory and BDNF isoform concentrations. European Journal of Sport Science, 20(6), 819–830. https://doi.org/10.1080/17461391.2019.1660726

Ploughman, M. (2008). Exercise is brain food: The effects of physical activity on cognitive function. Developmental Neurorehabilitation, 11(3), 236–240. https://doi.org/10.1080/17518420801997007

Pokorski, M. (2015). Neurotransmitter interactions and cognitive function. In Advances in Experimental Medicine and Biology (Vol. 837). https://doi.org/10.1007/978-3-319-10006_7

Powell, E., Wood, L. A., & Nevill, A. M. (2016). Increasing physical activity levels in primary school physical education : The SHARP Principles Model. 3, 7–13. https://doi.org/10.1016/j.pmedr.2015.11.007

Schneider, V. M., Frank, P., Fuchs, S. C., & Ferrari, R. (2021). Effects of recreational sports and combined training on blood pressure and glycated hemoglobin in middle-aged and older adults: A systematic review with meta-analysis. Experimental Gerontology, 154(September), 111549. https://doi.org/10.1016/j.exger.2021.111549

Schnider, L., Schilling, R., Cody, R., Kreppke, J. N., & Gerber, M. (2021). Effects of behavioural skill training on cognitive antecedents and exercise and sport behaviour in high school students: a cluster-randomised controlled trial. International Journal of Sport and Exercise Psychology, 0(0), 1–23. https://doi.org/10.1080/1612197X.2021.1877329

Soriano-Maldonado, A., Artero, E. G., Segura-Jiménez, V., Aparicio, V. A., Estévez-López, F., Álvarez-Gallardo, I. C., Munguía-Izquierdo, D., Casimiro-Andújar, A. J., Delgado-Fernández, M., & Ortega, F. B. (2016). Association of physical fitness and fatness with cognitive function in women with fibromyalgia. Journal of Sports Sciences, 34(18), 1731–1739. https://doi.org/10.1080/02640414.2015.1136069

Veijalainen, J., Reunamo, J., & Heikkilä, M. (2021). Early gender differences in emotional expressions and self-regulation in settings of early childhood education and care. Early Child Development and Care, 191(2), 173–186. https://doi.org/10.1080/03004430.2019.1611045

Verswijveren, S. J. J. M., Wiebe, S. A., Rahman, A. A., Kuzik, N., & Carson, V. (2020). Longitudinal associations of sedentary time and physical activity duration and patterns with cognitive development in early childhood. Mental Health and Physical Activity, 19, 100340. https://doi.org/10.1016/j.mhpa.2020.100340

Vestberg, T., Reinebo, G., Maurex, L., Ingvar, M., & Petrovic, P. (2017). Core executive functions are associated with success in young elite soccer players. PLoS ONE, 12(2), 1–13. https://doi.org/10.1371/journal.pone.0170845

Viegas, Â. A., Mendonça, V. A., Pontes Nobre, J. N., Souza Morais, R. L. De, Fernandes, A. C., Oliveira Ferreira, F. De, Scheidt Figueiredo, P. H., Leite, H. R., Resende Camargos, A. C., & Rodrigues Lacerda, A. C. (2021). Associations of physical activity and cognitive function with gross motor skills in preschoolers: Cross-sectional study. Journal of Motor Behavior, 0(0), 1–16. https://doi.org/10.1080/00222895.2021.1897508

Wallhead, T. L., Hastie, P. A., Harvey, S., & Pill, S. (2021). Academics’ perspectives on the future of sport education. Physical Education and Sport Pedagogy, 26(5), 533–548. https://doi.org/10.1080/17408989.2020.1823960

Wang, C. H., Chang, C. C., Liang, Y. M., Shih, C. M., Chiu, W. S., Tseng, P., Hung, D. L., Tzeng, O. J. L., Muggleton, N. G., & Juan, C. H. (2013). Open vs. Closed Skill Sports and the Modulation of Inhibitory Control. PLoS ONE, 8(2), 4–13. https://doi.org/10.1371/journal.pone.0055773

Wang, C. H., Lin, C. C., Moreau, D., Yang, C. T., & Liang, W. K. (2020). Neural correlates of cognitive processing capacity in elite soccer players. In Biological Psychology (Vol. 157). Elsevier B.V. https://doi.org/10.1016/j.biopsycho.2020.107971

Yongtawee, A., Park, J. H., & Woo, M. J. (2021). Does sports intelligence, the ability to read the game, exist? A systematic review of the relationship between sports performance and cognitive functions. Journal of the Korea …, 12(3), 325–339. https://www.koreascience.or.kr/article/JAKO202111037333627.page%0Ahttps://www.koreascience.or.kr/article/JAKO202111037333627.pdf

Zhou, X., Liao, S., Qi, L., & Wang, R. (2021). Physical activity and its association with cognitive function in middle- and older-aged Chinese: Evidence from China Health and Retirement Longitudinal Study, 2015. European Journal of Sport Science, 0(0), 1–11. https://doi.org/10.1080/17461391.2021.1897164