Research Journal of Management Reviews. Vol., 9 (1), 30-37, 2024
Available online at http://www.rjmrjournal.com
ISSN 2149-3316 ©2024
Doi: 10.61186/rjmr.9.1.30

The Relationships between Physical Activity with Working Memory and Fluid Intelligence in Children with ADHD

Abdulaziz Kulak *

Assistant Professor, Harran University, Physical Education And Sports School

*Corresponding Author Email: azizkulak@harran.edu.tr

Abstract: Background and aim: This study aims to examine the associations between physical activity intensities with working memory and fluid intelligence in children with ADHD.
Methods: The current research is conducted using a descriptive-correlation methodology, in alignment with its objectives. The statistical population for this study comprises 124 adults, who were chosen through convenience sampling. Standard tests were used for measuring research variables. Pearson's correlation test was applied for the inferential analysis of the relationships among the research variables.
Results: Children with ADHD showed a moderate level of physical activity (M = 2.59). Also, there was a direct and significant relationship between physical activity with working memory ($r=0.559$, $p<0.001$). Moreover, there was a direct relationship between physical activity and fluid intelligence ($r=0.337$, $p<0.001$).
Conclusion: Physical activity plays an important role in working memory and fluid intelligence of children with ADHD. Hence, it is strongly recommended that children with ADHD participate in enough level of physical activity.

Keywords: Physical Activity, Working Memory, Fluid Intelligence, Children, ADHD

Introduction

An active lifestyle in childhood appears to have a positive impact on the developing brain, particularly regarding its structure and function. Recent studies have emphasized the connection between physical activity in childhood and cognitive control. Cognitive control encompasses a higher-order cognitive process that integrates various mental functions, including inhibitory control, working memory, and cognitive flexibility, all of which are essential for goal-directed actions and self-regulation (Baniasadi et al., 2022; Gibson et al., 2011). Notably, working memory is a crucial element of cognitive control, functioning as a hierarchical system that allows for the temporary storage and manipulation of information to facilitate motivated behavior. Prior intervention studies have indicated a beneficial relationship between childhood physical activity and working memory. For instance, children participating in physical training programs lasting 8 weeks, 10 weeks, or 9 months exhibited enhancements in working memory performance, as assessed through tasks such as the delay-matching paradigm, the Sternberg paradigm, or the n-back task (Buehner et al., 2006; Gawrilow et al., 2016; Ilkım et al., 2021, Yurtseven et al., 2024; Karaaslan et al., 2021; Sekban et al., 2022).

Interventional research and cross-sectional studies employing objective measures of physical activity (PA) have been utilized to investigate the relationship between PA and working memory in children. In contrast to interventional studies that aimed to enhance children's PA levels beyond their usual patterns, cross-sectional studies have relied on objective assessments of daily, lifestyle-oriented PA, such as accelerometer data, to explore how children's typical activity patterns correlate with their working memory performance (Chaharbaghi et al., 2022; Kazemi, & Mohammadi, 2019; Omidvar et al., 2018). It is possible that the cross-sectional studies did not identify a significant relationship between physical activity and working memory due to insufficient control over potential confounding factors related to demographics or fitness, such as intelligence, aerobic fitness, or motor skills. Research indicates that intelligence may influence the responsiveness of working memory to external stimuli, such as working memory training, with individuals of higher intelligence exhibiting more substantial improvements from such training. Furthermore, there is a strong correlation between intelligence and working memory. According to Dang et al., fluid intelligence is linked to both the visuospatial and verbal-numerical components of working memory, although the association may be more pronounced with the visuospatial aspect. Additionally, it has been proposed that intelligence and working memory may originate from similar cognitive processes, albeit with varying degrees of dependence. These insights underscore the importance of considering individual differences in intelligence when examining working memory and its relationship with any specific exposure (Ghorbani et al., 2020; Najafzadeh et al., 2024).

Previous research has corroborated the beneficial impact of aerobic fitness on working memory performance, indicating that children with elevated levels of aerobic fitness tend to exhibit superior performance. It could be posited that aerobic fitness is a direct physiological outcome of engaging in physical activity; however, recent developmental studies challenge this notion. Unlike physical activity, which is a behavioral construct, aerobic fitness is characterized as a personal attribute that includes a genetic component (Hsieh et al., 2018; Mansur-Alves, & Saldanha-Silva, 2017). Additionally, interventional studies reveal that enhancements in aerobic fitness do not necessarily result from increased physical activity among children. Another dimension of fitness that may explain individual variations in working memory is motor fitness, were higher levels of motor fitness correlate with improved performance. It is clear that motor fitness influences cognitive function through different mechanisms compared to aerobic fitness. While aerobic fitness appears to enhance brain function primarily through biological and physiological pathways, motor fitness seems to operate through the mental processes it shares with higher-order cognitive functions. This is further supported by evidence that the execution of motor tasks—particularly those that are complex, unpredictable, time-sensitive, and demand rapid responses—engages brain regions linked to higher-order cognition. Therefore, motor fitness should be recognized as a distinct aspect of fitness, separate from aerobic fitness (Diamond & Ling, 2020; Khosravi et al., 2023).

Pre-adolescence is a period characterized by numerous transformations, during which cognitive development is particularly influential. Historically, the mental faculties associated with reasoning, planning, and problem-solving have been categorized under the concept of intelligence, which is further divided into two distinct types: crystallized and fluid intelligence (Bidzan-Bluma & Lipowska, 2018; Najafzadeh et al., 2024). Crystallized intelligence pertains to the accumulated knowledge gained over a lifetime, whereas fluid intelligence, often referred to as fluid reasoning, encompasses the capacity to think critically and resolve issues in new, unfamiliar situations. Fluid reasoning is especially crucial in educational settings during this developmental stage, as it correlates with working memory, inhibitory control, rapid knowledge acquisition, and the ability to navigate complex problem-solving scenarios, as well as psychosocial adjustment. Consequently, students exhibiting higher levels of fluid reasoning tend to achieve better academic outcomes, as they are more adept at learning and integrating new information (Dehn, 2017; Piepmeier et al., 2015).

Scientific investigations have examined the connection between fluid reasoning and physical fitness across various demographic groups. For example, Etnier and Berry performed a study assessing the impact of both a 3-month and an 18-month exercise regimen on cognitive performance among a cohort of 40 individuals aged between 55 and 80 years (Fernandes et al., 2016). The findings indicated that enhancements in physical fitness components, including cardiorespiratory fitness, strength, and speed, were linked to improvements in fluid intelligence in both exercise programs. In a separate study involving children and adolescents, Fochesatto et al. analyzed data from 317 schoolchildren aged 6 to 11, focusing on the interplay between physical fitness and fluid intelligence. Their results revealed a statistically significant correlation between agility and fluid intelligence. Nonetheless, there exists a scarcity of literature investigating these variables specifically in pre-adolescent populations (Abdoshahi & Ghorbani, 2022).

Although previous studies have examined the associations between physical activity and exercise with cognitive capability of children (such as working memory and fluid intelligence), however, its effects on memory function of children with ADHD has received less attention. Hence, this study was designed to explore the relationships between physical activity with working memory and fluid intelligence in children with ADHD.

Methods

The current research utilizes a descriptive-correlational approach that is consistent with its aims. The statistical sample comprises 125 children diagnosed with ADHD, ranging in age from 7 to 12 years, who were chosen using convenience sampling techniques.

Demographic factors were assessed, with participants providing information on their sex and age. The body mass index (BMI) was determined by dividing weight by height (kg/m²). Additionally, intelligence quotient (IQ) scores were derived from the Test of Nonverbal Intelligence–Second Edition.

Physical activity was assessed utilizing the short form of the International Physical Activity Questionnaire (IPAQ) (Baniasadi et al., 2022). This instrument comprises seven questions designed to collect data regarding individuals' physical activity levels over the preceding week. In accordance with the guidelines of the questionnaire, the overall intensity of physical activities is categorized into three distinct levels: light, moderate, and vigorous, determined by the energy expenditure recorded during the past seven days. Activities lasting less than 11 minutes are excluded from the calculations. In this assessment, walking is assigned a metabolic equivalent of task (MET) value of 3.3, moderate physical activity is valued at 4, and vigorous physical activity is rated at 8. A MET quantifies the energy expended per minute by an individual during physical activities. To compute the total weekly physical activity, one must aggregate the products of walking (MET × minutes × days), moderate physical activity (MET × minutes × days), and vigorous physical activity (MET × minutes × days) reported over the previous week. This questionnaire is specifically designed to evaluate the physical activity levels of adults aged 18 to 65 and has been widely employed in numerous studies, demonstrating robust validity and reliability.

The current investigation utilized a modified delayed-matching task, which serves as an assessment of perceptual working memory, akin to a methodology previously employed with children. The task was developed using STIM 2.0 software (Neuroscan Ltd, El Paso, TX). All visual stimuli were displayed on a 17-inch computer monitor positioned 60 cm from the participants. In alignment with the study conducted by Wang et al. (2017), the stimuli comprised a red dot (0.5° x 0.5°) that was randomly located within a gray rectangle measuring 3.8° x 7.4°. This rectangle was either centered on the screen or displaced 5.9° to the left or right of the central fixation point. The experiment included two conditions that varied in their cognitive load on working memory. In the non-delayed condition, two rectangles were shown simultaneously, with one rectangle situated at the center of the screen and the other either to the left or right. The red dot could occupy any of nine designated positions (i.e., center, center right, center left, upper center, upper right corner, upper left corner, lower center, lower right corner, and lower left corner) within its respective rectangle. The rectangles were displayed for 180 ms, a duration shorter than typical voluntary saccades, to reduce the likelihood of unintended saccadic movements influencing the outcomes. Participants were tasked with determining whether the red dots were located in the same position within their respective rectangles. Occasionally, the red dots exhibited slight variations, which might have led to confusion among the children and impacted their judgments; however, any such effects were expected to be consistent across the different groups.

The Matrices and Balances subtest of the Wechsler Intelligence Scale for Children (WISC-V) is specifically designed to assess fluid intelligence and problem-solving capabilities in children and adolescents aged 6 to 16 years. The matrices subtest comprises 32 matrices, where participants are required to identify the correct piece that completes each matrix from five provided options. These matrices are presented in color and vary in difficulty. The balance subtest includes 34 scenarios in which participants must select the option that maintains equilibrium among five alternatives, all within a specified time limit. To derive the results from each subtest, the number of correct responses (raw score) must be converted into a scaled score appropriate for each age group. Subsequently, the Fluid Reasoning Index (FRI) is calculated by summing the scaled scores from both subtests and referencing a conversion table to determine the FRI.

In this study, descriptive statistical methods, such as the mean and standard deviation, were employed to characterize the research variables. The Kolmogorov-Smirnov test was utilized to assess the normal distribution of the collected data. Furthermore, Pearson's correlation test was applied for the inferential analysis of the interrelationships among the research variables, with a significance level set at 0.05.

Results

Table 1 presents a comprehensive overview of the characteristics of the research participants, encompassing their age, height, weight, body mass index, and IQ. The mean age of the participants is noted to be 8.51 years. Furthermore, the participants exhibit a body mass index with an average of 17.22, indicating that they are classified within the normal range. Lastly, the average IQ scores of the children are reported to be 105.44, which also falls within the normal range.

Table 1. Demographic characteristics of the subjects

Variable	Age (year)	Height (cm)	Weight (kg)	BMI	IQ
Mean ± SD	8.51 ± 0.86	115.61 ± 3.27	45.11 ± 2.76	17.22 ± 1.77	105.44 ± 3.47

The average and standard deviation of the scores obtained by participants across all research variables are detailed in Table 2. Regarding the physical activity levels of children diagnosed with ADHD, it is apparent that the participants demonstrated a level of physical activity that is below the guidelines established by the World Health Organization. The analysis of physical activity patterns indicated that merely 32% of the participants engaged in moderate-to-vigorous physical activity, implying that around 68% of the participants fail to meet the essential physical activity standards necessary for optimal physical and mental health. Furthermore, the scores pertaining to working memory and fluid intelligence were observed to be within the average range.

Table 2. Description of research variables

Variable	physical activity (day of the week)	physical activity (minutes per week)	physical activity (intensity)			Working memory	Fluid intelligence
			light (percent)	moderate (percent)	vigorous (percent)		
Mean ± SD	2.11 ± 0.43	114.51 ± 10.23	68%	25%	7%	65.85±3.47	92.55 ± 6.25

Table 3 displays the results of the Kolmogorov-Smirnov test, which was performed to evaluate the normality of the data distribution. The results demonstrate that all research variables adhere to a normal distribution, as indicated by the significance level (P>0.05).

Table 3. The results of normal distribution

Variable	physical activity (day of the week)	physical activity (minutes per week)	physical activity (intensity)			Working memory	Fluid intelligence
			light (percent)	moderate (percent)	vigorous (percent)		
K-S	0.966	0.895	0.871	0.990	0.887	0.864	0.937
P	0.200	0.200	0.200	0.200	0.200	0.957	0.200

Table 4 presents the findings from the Pearson correlation analysis. The results indicate that 1) there exists a direct and statistically significant correlation between physical activity (measured in days per week) (r= 0.663, p<0.001), physical activity (measured in minutes per week) (r= 0.528, p<0.001), and the intensity of physical activity (r= 0.487, p<0.001) with working memory; 2) similarly, a direct and significant correlation was found between physical activity (days per week) (r=0.635, p<0.001), physical activity (minutes per week) (r=0.384, p<0.001), and intensity of physical activity (r=0.473, p<0.001) with fluid intelligence.

Table 4. The results of the relationship between physical activity with working memory and fluid intelligence

Variable	Working memory	Fluid intelligence
physical activity (day of the week	r= 0.663 p<0.001	r=0.635 p<0.001
physical activity (minutes per week)	r= 0.528 p<0.001	r=0.384 p<0.001
physical activity (intensity)	r= 0.487 p<0.001	r=0.473 p<0.001

Discussion

The objective of this research was to investigate the relationships between physical activity with working memory and fluid intelligence in children with ADHD. Table 4 presents the findings from the Pearson correlation analysis. The results indicate that there exists a direct and statistically significant correlation between physical activity (measured in days per week), physical activity (measured in minutes per week), and the intensity of physical activity with working memory. Similarly, a direct and significant correlation was found between physical activity (days per week), physical activity (minutes per week), and intensity of physical activity with fluid intelligence.

Previous research has indicated that engaging in physical activity or training can positively influence neurological and cognitive functions by enhancing neurogenesis, angiogenesis, and increasing cerebral blood flow (Barudin-Carreiro et al., 2022; Lahat et al., 2014; Potvin et al., 2015). Additionally, physical activity activates the motor regions of the brain, promotes the release of neurohormones, and accelerates the conduction velocity of nerve impulses (Al-Saad et al., 2021; Partanen et al., 2020). Various forms of physical exercise can exert distinct effects on the brain; however, some studies suggest that these differences may stem from variations in the secretion of specific biomarkers within the neurochemical system, as well as disparities in brain tissue volume and activation patterns associated with the type of exercise performed. While physical activity has particular impacts on neurocognitive performance, research indicates that all exercise modalities influence executive functions (Fry & Hale, 1996; Seyedi Asl et al., 2016, 2020; Shafaei et al., 2024 a,b). Findings from both human and animal studies reveal that different exercise interventions, such as open versus closed skill activities, can lead to unique effects on brain structures and neural activation. Furthermore, studies have demonstrated that attentional demands and information processing mechanisms differ between open and closed training environments (Ramos et al., 2020; Spanou et al., 2022; Swanson & McMurran, 2018; Wang et al., 2022). In closed settings, where changes among components are less perceptible, maintaining accuracy in timing tasks that rely on relatively stable environmental information is deemed a fundamental requirement for success. Conversely, in variable environmental conditions typical of open practice, the reliance on predictive mechanisms is diminished, necessitating real-time processing of working memory to adapt to fluctuating demands (Baniasadi et al., 2022; Perrig et al., 2009).

The environment plays a crucial role in the execution of skills. A sustained emphasis on environmental cues pertinent to a task enhances working memory performance when compared to training scenarios that are more closed in nature. In the context of open skills, the associated cognitive processes tend to occur rapidly and almost instantaneously, reflecting the inherent complexity of perception and decision-making, as each action must be adapted to the demands of the environment (Gaye et al., 2024). Conversely, in closed skills, the individual assesses the environmental and movement requirements in advance, free from time constraints, allowing for the organization and execution of responses without the need for adjustments (Christiansen et al., 2019). Research indicates that optimal performance in working memory is linked to the neural capacity to concentrate on task-relevant information while disregarding distractions. Furthermore, enhancements in working memory attributed to training are believed to stem from improvements in these cognitive abilities (Pindus et al., 2016). Studies have demonstrated a correlation between an individual's working memory capacity and their proficiency in directing attention toward relevant environmental stimuli. This ability to manage attention is essential for focusing on information that aligns with current objectives while filtering out distractions that may divert attention. The process of directing attention toward one's goals is influenced by "top-down" signals originating from the prefrontal cortex, which modulate processing in the dorsal cortical areas (Sofologi et al., 2022).

The rationale for these findings can be anchored in prior evidence indicating that consistent engagement in physical activity at specific intensities induces alterations in both the structure and functionality of the brain, thereby enhancing its development and fostering improved brain plasticity (Baniasadi et al., 2022; Taghva et al., 2020; Titz & Karbach, 2014). The research demonstrated that elevating the intensity of physical education sessions, particularly through interval aerobic running, positively affects numerical speed and the ability to solve simple mathematical problems. While two out of three cross-sectional studies indicated a favorable correlation between physical fitness and cognitive performance, a definitive consensus on this relationship remains elusive (Kofler et al., 2020; Suarez-Manzano et al., 2018). It is important to note that, given the cross-sectional nature of this research, causal inferences cannot be established. Nevertheless, it is reasonable to propose that individuals exhibiting higher levels of physical fitness may have previously engaged in greater amounts of physical activity to attain such fitness levels. Consequently, the cognitive enhancements documented in the literature may have developed progressively, leading to the outcomes observed in this study. Thus, superior physical fitness may serve as both an indicator and a consequence of an active lifestyle, resulting in neurophysiological changes that positively impact cognitive development among the participants examined (Yuan et al., 2006).

Conclusion

In conclusion, the principal findings of the present study indicate that children with ADHD exhibiting higher levels of physical activity (PA) showed enhanced performance on working memory tasks, both behaviorally and at the neuroelectric level, when compared to their fewer active peers. These results were achieved while accounting for potential confounding factors such as intelligence and fitness-related variables, including aerobic and motor fitness. The implications of this study are substantial, particularly given that (a) physical inactivity is increasingly common among children, (b) the childhood years (specifically ages 6 to 11) represent a crucial period for the development of working memory, and (c) working memory plays a vital role in moderating academic success among school-aged children. It is advisable for future research, especially randomized controlled trials (RCTs), to investigate the relationship between maturity and the extent of cognitive benefits derived from physical activity. Additionally, studies incorporating neurobiological measures, such as blood flow and biochemical variables, would be beneficial in elucidating the mechanisms that connect physical activity and working memory.

References

Abdoshahi, M., & Ghorbani, S. (2022). Effects of Playground Availability on Participation of Children in Physical Activity: The Role of Socioeconomic Status. *International Journal of School Health*, *9*(3), 186-191. [Google Scholar] [Publisher] https://doi.org/10.30476/intjsh.2022.96051.1245

Al-Saad, M. S. H., Al-Jabri, B., & Almarzouki, A. F. (2021). A review of working memory training in the management of attention deficit hyperactivity disorder. *Frontiers in behavioral neuroscience*, *15*, 686873. [Google Scholar] [Publisher] https://doi.org/10.3389/fnbeh.2021.686873

Asl, S. T. S., Sadeghi, K., Bakhtiari, M., Ahmadi, S. M., Anamagh, A. N., & Khayatan, T. (2016). Effect of group positive psychotherapy on improvement of life satisfaction and the quality of life in infertile woman. *International journal of fertility & sterility*, *10*(1), 105. [Google Scholar] [Publisher] https://doi.org/10.22074/ijfs.2016.4775

Baniasadi, T., Ranjbari, S., Abedini, A., Dana, A., & Ghorbani, S. (2022). Investigation the Association of Internet Addiction with Mental Health and Physical Activity in Teenage Girls: The Mediating Role of Parental Attitude. *Women's Health Bulletin*, *9*(4), 243-250. [Google Scholar] [Publisher] https://doi.org/10.30476/whb.2022.96915.1197

Baniasadi, T., Ranjbari, S., Khajehaflaton, S., Neshati, A., & Dana, A. (2022). Effects of physical activity on adiposity in children: mediating role of self-esteem and body-image. *International Journal of Pediatrics*, *10*(12), 17172-17181. [Google Scholar] [Publisher] https://doi.org/10.22038/ijp.2022.67562.5043

Baniasadi, T., Ranjbari, S., Mofrad, S. K., & Dana, A. (2022). Associations between device-measured physical activity and balance performance in children: Mediating role of motor self-efficacy. *Biomedical Human Kinetics*, *14*(1), 252-258. [Google Scholar] [Publisher] https://doi.org/10.2478/bhk-2022-0031

Barudin-Carreiro, A. M., Camhi, S. M., Lindsay, A. C., & Wright, J. A. (2022). Physical activity and executive function in children with ADHD: a systematic review. *Translational Journal of the American College of Sports Medicine*, *7*(1), e000183. [Google Scholar] [Publisher] http://dx.doi.org/10.1249/TJX.0000000000000183

Bidzan-Bluma, I., & Lipowska, M. (2018). Physical activity and cognitive functioning of children: a systematic review. *International journal of environmental research and public health*, *15*(4), 800. [Google Scholar] [Publisher] https://doi.org/10.3390/ijerph15040800

Buehner, M., Krumm, S., Ziegler, M., & Pluecken, T. (2006). Cognitive abilities and their interplay: Reasoning, crystallized intelligence, working memory components, and sustained attention. *Journal of individual differences*, *27*(2), 57-72. [Google Scholar] [Publisher] https://doi.org/10.1027/1614-0001.27.2.57

Chaharbaghi, Z., Baniasadi, T., & Ghorbani, S. (2022). Effects of Teacher's Teaching Style in Physical Education on Moderate-to-Vigorous Physical Activity of High-School Students: an Accelerometer-based Study. *International Journal of School Health*, *9*(3), 143-150. [Google Scholar] [Publisher] https://doi.org/10.30476/intjsh.2022.95204.1224

Christiansen, L., Beck, M. M., Bilenberg, N., Wienecke, J., Astrup, A., & Lundbye-Jensen, J. (2019). Effects of exercise on cognitive performance in children and adolescents with ADHD: potential mechanisms and evidence-based recommendations. *Journal of clinical medicine*, *8*(6), 841. [Google Scholar] [Publisher] https://doi.org/10.3390/jcm8060841

Dehn, M. J. (2017). How working memory enables fluid reasoning. *Applied Neuropsychology: Child*, *6*(3), 245-247. [Google Scholar] [Publisher] https://doi.org/10.1080/21622965.2017.1317490

Diamond, A., & Ling, D. S. (2020). Review of the evidence on, and fundamental questions about, efforts to improve executive functions, including working memory. *Cognitive and working memory training: Perspectives from psychology, neuroscience, and human development*, 143-431. [Google Scholar] [Publisher]

Fernandes, V. R., Ribeiro, M. L. S., Melo, T., de Tarso Maciel-Pinheiro, P., Guimarães, T. T., Araújo, N. B., ... & Deslandes, A. C. (2016). Motor coordination correlates with academic achievement and cognitive function in children. *Frontiers in psychology*, *7*, 318. [Google Scholar] [Publisher] https://doi.org/10.3389/fpsyg.2016.00318

Fry, A. F., & Hale, S. (1996). Processing speed, working memory, and fluid intelligence: Evidence for a developmental cascade. *Psychological science*, *7*(4), 237-241. [Google Scholar] [Publisher] https://doi.org/10.1111/j.1467-9280.1996.tb00366.x

Gawrilow, C., Stadler, G., Langguth, N., Naumann, A., & Boeck, A. (2016). Physical activity, affect, and cognition in children with symptoms of ADHD. *Journal of attention disorders*, *20*(2), 151-162. [Google Scholar] [Publisher] https://doi.org/10.1177/1087054713493318

Gaye, F., Groves, N. B., Chan, E. S., Cole, A. M., Jaisle, E. M., Soto, E. F., & Kofler, M. J. (2024). Working memory and math skills in children with and without ADHD. *Neuropsychology*, *38*(1), 1. [Google Scholar] [Publisher] https://psycnet.apa.org/doi/10.1037/neu0000920

Ghorbani, S., Rezaeeshirazi, R., Shakki, M., Noohpisheh, S., & Farzanegi, P. (2020). The role of BMI, physical activity and the use of electronic device in the status of trunk abnormalities in male adolescents. *Journal of Gorgan University of Medical Sciences*, *22*(3), 129-136. [Google Scholar] [Publisher]

Gibson, B. S., Gondoli, D. M., Johnson, A. C., Steeger, C. M., Dobrzenski, B. A., & Morrissey, R. A. (2011). Component analysis of verbal versus spatial working memory training in adolescents with ADHD: A randomized, controlled trial. *Child Neuropsychology*, *17*(6), 546-563. [Google Scholar] [Publisher] https://doi.org/10.1080/09297049.2010.551186

Hsieh, S. S., Fung, D., Tsai, H., Chang, Y. K., Huang, C. J., & Hung, T. M. (2018). Differences in working memory as a function of physical activity in children. *Neuropsychology*, *32*(7), 797. [Google Scholar] [Publisher] https://doi.org/10.1037/neu0000473

Ilkım, M., Çelik, T., & Mergan, B.. (2021). Investigation of Sports Management Students' Perceptions and Attitudes towards the COVID-19 Pandemic. Pakistan Journal Of Medical & Health Sciences, Volume15, 2. [Google Scholar] [Publisher]

Karaaslan, H., Ilkım, M., & Özdemir, Z. (2021). Turkey's Sports Success Assessment ın The World Para Taekwondo Championships. Pakıstan Journal Of Medıcal & Health Scıences, 15(11), 3185-3189. [Google Scholar] [Publisher] https://doi.org/10.53350/pjmhs2115113185

Kazemi, A. S., & Mohammadi, Z. (2019). The effect of working memory training on executive function of children with attention deficit/hyperactivity disorder. *BRAIN. Broad Research in Artificial Intelligence and Neuroscience*, *10*(3), 134-141. [Google Scholar] [Publisher]

Khosravi, M., Asl, S. T. S., Anamag, A. N., Langaroudi, M. S., Moharami, J., Ahmadi, S., ... & Kasaeiyan, R. (2023). Parenting styles, maladaptive coping styles, and disturbed eating attitudes and behaviors: a multiple mediation analysis in patients with feeding and eating disorders. *PeerJ*, *11*, e14880. [Google Scholar] [Publisher] https://doi.org/10.7717/peerj.14880

Kofler, M. J., Sarver, D. E., & Wells, E. L. (2020). Working memory and increased activity level (hyperactivity) in ADHD: Experimental evidence for a functional relation. *Journal of attention disorders*, *24*(9), 1330-1344. [Google Scholar] [Publisher] https://doi.org/10.1177/1087054715608439

Lahat, A., Van Lieshout, R. J., Saigal, S., Boyle, M. H., & Schmidt, L. A. (2014). ADHD among young adults born at extremely low birth weight: the role of fluid intelligence in childhood. *Frontiers in Psychology*, *5*, 446. [Google Scholar] [Publisher] https://doi.org/10.3389/fpsyg.2014.00446

Mansur-Alves, M., & Saldanha-Silva, R. (2017). Does working memory training promote changes in fluid intelligence?. *Temas em Psicologia*, *25*(2), 787-807. [Google Scholar] [Publisher] http://dx.doi.org/10.9788/TP2017.2-19Pt

Najafzadeh, F., Ranjbari, S., Shafaei, H., & Ghorbani, S. (2024). Correlation between Participation in Physical Activity and Psychological Well-being among Elderly Women: The Mediating Role of Resilience. *Women's Health Bulletin*, *11*(3), 188-194. [Google Scholar] [Publisher] https://doi.org/10.30476/whb.2024.102534.1291

Najafzadeh, F., Shafaei, H., Alizadeh, S., & Dana, A. (2024). Correlations between Physical Activity Participation and Anthropometric Features with Gross and Fine Motor Skills in School Children with Attention Deficit Hyperactivity Disorder. *International Journal of School Health*, *11*(3), 209-215. [Google Scholar] [Publisher] https://doi.org/10.30476/intjsh.2024.102533.1408

Omidvar, A., Dana, A., Hamzeh Sabzi, A., & Pourpanahi Koltapeh, M. (2018). The effect of education based on developmental physical education on working memory of elementary school students. *Journal of School Psychology*, *7*(1), 83-101. [Google Scholar] [Publisher] https://doi.org/10.22098/jsp.2018.658

Partanen, P., Jansson, B., & Sundin, Ö. (2020). Fluid reasoning, working memory and planning ability in assessment of risk for mathematical difficulties. *Educational Psychology in Practice*, *36*(3), 229-240. [Google Scholar] [Publisher] https://doi.org/10.1080/02667363.2020.1736518

Perrig, W. J., Hollenstein, M., & Oelhafen, S. (2009). Can we improve fluid intelligence with training on working memory in persons with intellectual disabilities. *Journal of Cognitive Education and Psychology*, *8*(2), 148-164. [Google Scholar] [Publisher] http://dx.doi.org/10.1891/1945-8959.8.2.148

Piepmeier, A. T., Shih, C. H., Whedon, M., Williams, L. M., Davis, M. E., Henning, D. A., ... & Etnier, J. L. (2015). The effect of acute exercise on cognitive performance in children with and without ADHD. *Journal of sport and Health science*, *4*(1), 97-104. [Google Scholar] [Publisher] https://doi.org/10.1016/j.jshs.2014.11.004

Pindus, D. M., Drollette, E. S., Scudder, M. R., Khan, N. A., Raine, L. B., Sherar, L. B., ... & Hillman, C. H. (2016). Moderate-to-vigorous physical activity, indices of cognitive control, and academic achievement in preadolescents. *The Journal of pediatrics*, *173*, 136-142. [Google Scholar] [Publisher] https://doi.org/10.1016/j.jpeds.2016.02.045

Potvin, D., Hardy, K. K., & Walsh, K. S. (2015). The relation between ADHD and cognitive profiles of children with NF1. *Journal of Pediatric Neuropsychology*, *1*, 42-49. [Google Scholar] [Publisher] http://dx.doi.org/10.1007/s40817-015-0007-3

Ramos, A. A., Hamdan, A. C., & Machado, L. (2020). A meta-analysis on verbal working memory in children and adolescents with ADHD. *The Clinical Neuropsychologist*, *34*(5), 873-898. [Google Scholar] [Publisher] https://doi.org/10.1080/13854046.2019.1604998

Sekban, G., Stojanovic, S., Ilkım, M., Ilbak, I., & Jorgic, B. (2022). Effects of Swimming on the Body Composition of Individuals with Down Syndrome: A Systematic Review. International Journal of Early Childhood Special Education, 14(5). [Google Scholar] [Publisher] https://doi.org/10.9756/INTJECSE/V14I5.467

Seyedi Asl, S. T., Rahnejat, A. M., Elikaee, M. M., Khademi, M., Shahed-HaghGhadam, H., & Taghva, A. (2020). The role of resilience, positive/negative emotions, and character strengths in predicting burnout of military personnel. *EBNESINA*, *22*(4), 4-13. [Google Scholar] [Publisher]

Shafaei, H., Najafzadeh, F., Shakki, M., & Ghorbani, S. (2024). Associations between Physical Activity and Quality of Life, Happiness, and Depression among Elderly Women. *Women's Health Bulletin*, *11*(2), 104-111. [Google Scholar] [Publisher] https://doi.org/10.30476/whb.2024.101984.1276

Shafaei, H., Rezaei, N., Mohammadi, S., & Ghorbani, S. (2024). Correlations between Physical Activity and Social Health, Moral Development and Physical Fitness among Middle School Students. *International Journal of School Health*, *11*(2), 97-104. [Google Scholar] [Publisher] https://doi.org/10.30476/intjsh.2024.101704.1388

Sofologi, M., Pliogou, V., Bonti, E., Efstratopoulou, M., Kougioumtzis, G. A., Papatzikis, E., ... & Papantoniou, G. (2022). An investigation of working memory profile and fluid intelligence in children with neurodevelopmental difficulties. *Frontiers in Psychology*, *12*, 773732. [Google Scholar] [Publisher] https://doi.org/10.3389/fpsyg.2021.773732

Spanou, M., Kaioglou, V., Pesce, C., Mavilidi, M. F., & Venetsanou, F. (2022). "Move" their brain: motor competence mediates the relationship of physical activity and executive functions in children. *Applied Sciences*, *12*(20), 10527. [Google Scholar] [Publisher] https://doi.org/10.3390/app122010527

Suarez-Manzano, S., Ruiz-Ariza, A., De La Torre-Cruz, M., & Martinez-Lopez, E. J. (2018). Acute and chronic effect of physical activity on cognition and behaviour in young people with ADHD: A systematic review of intervention studies. *Research in developmental disabilities*, *77*, 12-23. [Google Scholar] [Publisher] https://doi.org/10.1016/j.ridd.2018.03.015

Swanson, H. L., & McMurran, M. (2018). The impact of working memory training on near and far transfer measures: Is it all about fluid intelligence?. *Child Neuropsychology*, *24*(3), 370-395. [Google Scholar] [Publisher] https://doi.org/10.1080/09297049.2017.1280142

Taghva, A., Asl, S. T. S., Rahnejat, A. M., & Elikaee, M. M. (2020). Resilience, emotions, and character strengths as predictors of job stress in military personnel. *Iranian journal of psychiatry and behavioral sciences*, *14*(2). [Google Scholar] [Publisher] https://doi.org/10.5812/ijpbs.86477

Titz, C., & Karbach, J. (2014). Working memory and executive functions: effects of training on academic achievement. *Psychological research*, *78*, 852-868. [Google Scholar] [Publisher] https://doi.org/10.1007/s00426-013-0537-1

Wang, L., Sheng, A., Chang, L., & Zhou, R. (2022). Improving fluid intelligence of children through working memory training: The role of inhibition control. *Frontiers in Psychology*, *13*, 1025036. [Google Scholar] [Publisher] https://doi.org/10.3389/fpsyg.2022.1025036

Yuan, K., Steedle, J., Shavelson, R., Alonzo, A., & Oppezzo, M. (2006). Working memory, fluid intelligence, and science learning. *Educational Research Review*, *1*(2), 83-98. [Google Scholar] [Publisher] https://doi.org/10.1016/j.edurev.2006.08.005

Yurtseven, C. N., Ilkim, M., Toros, T., Aslan, T. V., Keskin, M. T., Efe, M., ... & Dişçeken, O. (2024). The Relationship Between Sports Addiction and Personality Dimensions Based on Cloninger's Theory in Bodybuilding and Fitness Trainers in Eastern Anatolia Region of Turkey. Revista de Psicología del Deporte (Journal of Sport Psychology), 33(3), 296-304. [Google Scholar] [Publisher]