Spor Bilimleri Araştırmaları Dergisi
Journal of Sport Sciences Research
Vol: 9, Issue: 1, February 2024
E-ISSN: 2548-0723
URL: http://www.dergipark.org.tr/jssr

Effects of Tennis Training on Cognitive Control and Visuospatial Skills

Gökçe AKIN[1*], İlhan ODABAŞ[1], Billur YARSUVAT[1]
[1]Haliç University, Faculty of Sport Sciences, Istanbul.

Research Article **DOI: 10.25307/jssr.1417013**
Received: 10.01.2024 Accepted: 27.02.2024 Online Published: 29.02.2024

Abstract

The aim of this study was to examine the effect of accurate shot exercises in tennis on cognitive control and visuospatial skills. 15 sports science faculty student, 6 females and 9 males, aged between 18-22, with an average age of 18.53 were included in the research. Flanker Task and Spatial Visualization Test were applied to evaluate participants' cognitive control and visuospatial skills. Tennis training was performed once a week, for half an hour, with 500 hits (forehand and backhand) and an average of 2000 hits in four weeks. After performing the normality test and descriptive statistics, Wilcoxon Signed Rank Test was applied to compare the pre-test and post-test. The findings showed that there were significant differences between pre-test and post-test scores in the spatial visualization test (p = 0.019), correct response rate in the flanker task (p = 0.02=), and difference in reaction time between congruent and incongruent conditions in the flanker task (p = 0.02). Consequently, it can be concluded that tennis training significantly improved participants' cognitive control and visuospatial skills. The fact that tennis is a sport that requires the use of space and uses open skills may improve individuals' cognitive control and visuospatial skills.
Keywords: Tennis, Cognitive control, Visuospatial skills.

Tenis Antrenmanlarının Bilişsel Kontrol ve Görsel Uzamsal Beceriler Üzerindeki Etkisi

Öz

Bu çalışmanın amacı teniste isabetli vuruş çalışmalarının bilişsel kontrol ve görsel uzamsal beceriler üzerindeki etkisini incelemektir. Araştırmaya 18-22 yaşları arasında, yaş ortalaması 18.53 olan 6 kadın ve 9 erkek olmak üzere 15 spor bilimleri fakültesi öğrencisi dahil edilmiştir. Katılımcıların bilişsel kontrol ve görsel-uzamsal becerilerini değerlendirmek için Flanker Görevi ve Uzamsal Görselleştirme Testi uygulanmıştır. Tenis antrenmanı haftada bir gün, günde yarım saat, 500 vuruş (forehand ve backhand) ve dört haftada ortalama 2000 vuruş ile gerçekleştirilmiştir. Normallik testi ve tanımlayıcı istatistikler yapıldıktan sonra, öntest ve sontesti karşılaştırmak için Wilcoxon İşaretli Sıralar Testi uygulanmıştır. Bulgular, uzamsal görselleştirme testinde ön test ve son test puanları arasında (p= 0.019), flanker görevinde doğru tepki oranı (p=0.02), flanker görevinde uyumlu ve uyumsuz koşullar arasındaki tepki süresi farkı (p=0.02) açısından anlamlı farklılıklar olduğunu göstermiştir. Sonuç olarak, teniste isabetli vuruş çalışmalarının katılımcıların bilişsel kontrol ve görsel-uzamsal becerilerini önemli ölçüde geliştirdiği sonucuna varılabilir. Tenisin mekânın kullanımını gerektiren ve açık becerilerin kullanıldığı bir spor olması, bireylerin bilişsel kontrol ve görsel uzamsal becerilerini geliştiriyor olabilir.
Anahtar kelimeler: Tenis, Bilişsel kontrol, Görsel-uzamsal beceriler.

[*] **Corresponding Author:** Gökçe Akın, **E-mail:** gokceakin@halic.edu.tr

INTRODUCTION

Motor skills and cognitive functions continue to develop throughout early childhood (Cristofori et al., 2019; Van der Fels, 2015). Improvements in cognitive functions are observed in individuals who engage in sports and exercise, both in the short term and in the long term (Davranche et al., 2009; Peiffer et al., 2015). Athletes often show improvements in cognitive functions such as cognitive control, visuospatial skills, and perception based on the type of sport. It has been found that athletes generally exhibit superior cognitive functions compared to non-athletes, and expertise in sports is associated with development of cognitive functions (Yongtawee et al., 2022).

Cognitive functions are important for sports performance as the sports require cognitive tasks such as decision making, planning and perception. One of the cognitive functions required for sport is cognitive control and visuospatial skills (Muinos & Ballesteros, 2018; Peiffer et al., 2015). Studies show that cognitive functions play a role in open skill and closed skill sports (Yongtawee et al., 2022). A study of elite volleyball players found that reaction times in cognitive control and visuospatial skills were shorter, and overall cognitive skills were more developed than non-athletes (Alves et al., 2013). Chiu et al., (2017) compared volleyball with running and swimming and concluded that the type of sport influences cognitive performance. Since volleyball is an unpredictable sport, volleyball players' cognitive control skills are more developed.

Boxers, shooters, football players, and non-athletes were compared in terms of cognitive flexibility, visuospatial skills, and information processing speed. It was investigated that cognitive functions varies according to the type of sport. Participants engaged in blocking sports like boxing shows more developed visuospatial skills and processing speed. Strategic sports like football are associated with enhanced cognitive flexibility skills and working memory, while static sports like shooting exhibits the fastest visuospatial information processing time (Yongtawee et al. 2022).

Athletes develop cognitive functions based on the open and closed skill sports they engage in (Chiu et al., 2017). Tennis is an open skilled sport and requires planning, perception, visual skills, and cognitive control (Ishihara et al., 2017). Studies comparing tennis players and non-athletes have shown that tennis players have more developed cognitive control, concentration, and selective attention skills (Pacesova et al., 2018).

The literature involves studies investigating cognitive functions in both individual and team sports (Ishihara et al., 2017; Nuri et al., 2013). However, there is a lack of research on whether target training on the tennis wall over a specific period improve visuospatial skills and cognitive control. Tennis course among the elective courses in faculty of sports sciences, includes practical applications in a limited time and in crowded groups. Therefore, in this research, the effects of accurate tennis shot exercises practiced once a week by participants who had never taken tennis lessons before were evaluated on visuospatial skills and cognitive control.

In this context, the research problem was formulated as "Do accurate tennis shots impact cognitive skills?" The research hypothesis assumes that, following four weeks of tennis training, participants' levels of visuospatial skills and cognitive control will be higher compared to pre-test results. The aim of this research is to assess the changes in visuospatial skills and cognitive control resulting from four weeks of target training on the tennis wall in tennis.

METHOD

Research Model

This research is experimental research with a single group pre-test post-test model. Participants were evaluated at the beginning and end of the study to examine the effect of tennis training on visuospatial skills and cognitive control.

Study Group

After obtaining the necessary ethical permissions, participants were contacted and compliance with the Declaration of Helsinki was achieved. The sample of the research consists of 15 participants, six women and nine men, aged 18-22. The average age of the participants is 18.53±1.06.

The inclusion criteria for participants in this study are as follows:

- Participants must be between the ages of 18-22 as they are university students.
- Participants should be currently enrolled as students in the faculty of sports sciences.
- Participants should not hold ant licensing or national athlete status.
- Participants must be free from any physical injuries.
- Participants should not have prior experience or formal training in tennis.
- Participants should be willing to participate in the study voluntarily.

The exclusion criteria for participants in this study are as follows:

- Participants will be excluded from the study if they fail to complete the personal information form.
- Participants will be excluded if they choose not to participate voluntarily.

Ethical Approval

Prior to the study, ethics committee approval was obtained from Halic University Ethics Committee with the decision numbered 241 on 30/11/2022.

Data Collection Tools

In the study, a personal information form was used to obtain the demographic information of the participants such as age and gender. Cognitive control was assessed with Flanker Task, while spatial visualization was evaluated with Spatial Visualization Test. All assessments were performed twice (pre-test and post-test), both before and after 4-week tennis training program. The Flanker Task and Spatial Visualization Test were conducted at the Haliç University Sports and Exercise Psychology Laboratory.

Flanker Task

Flanker Task was designed by Eriksen and Eriksen (1974). The purpose of the task is for participants to react to one stimulus while ignoring the other. The Flanker Task has arrows arranged side by side. While responding to the target arrow in the center, the participant is asked to ignore the distracting arrow next to it. The reaction time between congruent and incongruent conditions is called the interference effect. In congruent conditions, all arrows are in the same direction as the direction of the central arrow. In incongruent conditions, the direction of the arrow in the center is different from the other arrows. The test was carried out in a digital environment. The participant's reaction time to the stimulus was recorded as a score. Flanker task sample is shown in Figure 1.

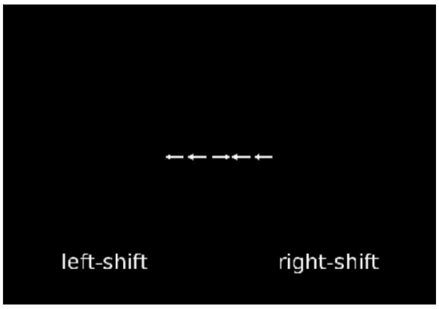

Figure 1. Flanker task incongruent condition

Spatial Visualization Test

Spatial Visualization Test is a 29-item scale developed by Sütçü and Oral (2019). The scale assesses two-dimensional and three-dimensional spatial visualization. The initial 14 items evaluate two-dimensional spatial visualization, while the remaining 15 items represent sub-dimensions assessing three-dimensional spatial visualization. The internal consistency coefficient was evaluated through KR-20. The KR-20 internal consistency coefficient for two-dimensional spatial visualization was .77, and the KR-20 internal consistency coefficient for three-dimensional spatial visualization was .78. It was found to be .78 for the overall test. Tests with a reliability coefficient of .70 and higher are considered reliable.

The test was carried out in a digital environment. Correct answers were counted as scores. One of the Spatial Visualization Test questions is in Figure 2.

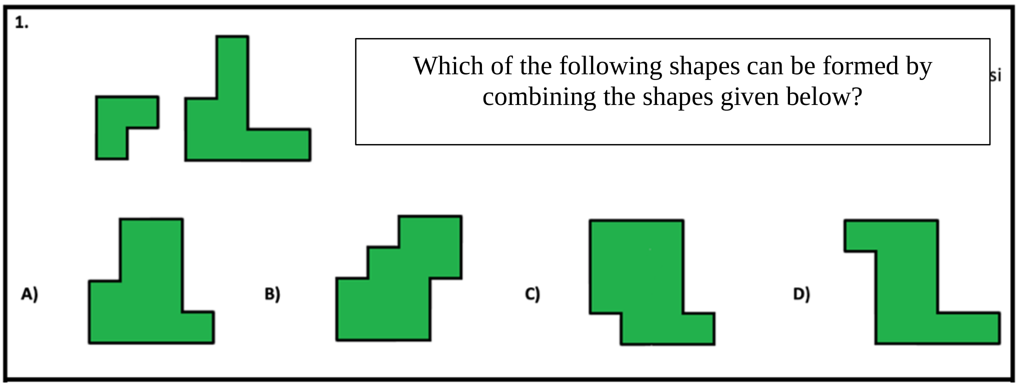

Figure 2. Spatial Visualization Test Question 1.

Procedure

The tests used in the study were performed at the beginning and end of the study. After confirming that participants voluntarily participated in the study, they participated in the Flanker Task and the Spatial Visualization Test.

In this study, Dyer Wall Test was used in the formulation of the training protocol implemented for 4 weeks. The purpose of Dyer Wall Test is measuring of tennis skills. Stopwatch, wall, tennis ball and rockets are used. A line is drawn on the wall (3 m high - 4.5 m wide). The line should be 91.7 cm above the floor. A boundary line is drawn 6 meters from the wall. The subject who starts the test is behind the boundary line and hits the wall for 30 seconds. After one attempt, 3 tests are performed. Each hit against the wall is one point and the total score of the 3 tests is evaluated (Dyer, 1935).

In our study, participants participated in wall training once a week for four weeks. Forehand and backhand strokes were performed by hitting on a line 6-9 meters away from the wall and 91 cm above the ground. Target training on tennis wall was performed once a week, for half an hour, with 500 hits (forehand and backhand) and an average of 2000 hits for four weeks. Program is prepared and given by the researcher who is an expert tennis coach and instructor for 20 years. At the end of four weeks, participants re-participated in the Flanker Task, Spatial Visualization Test. The study plan is given in Figure 3.

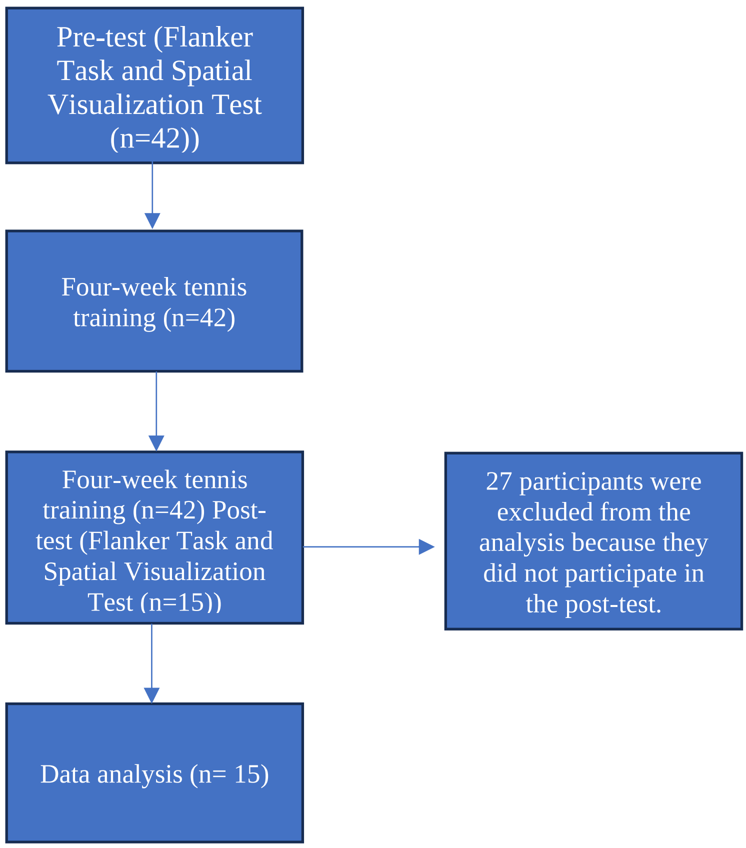

Figure 3. Study Plan

Data Analysis

IBM Statistical Package for the Social Sciences 28 (SPSS) was used to evaluate the data. Skewness and kurtosis values weren't between -2 and +2. Therefore, Wilcoxon Signed Rank Test, which is one of the nonparametric tests, was applied to compare the pre-test and post-test. Data were evaluated at $p < 0.05$ confidence interval. Alpha was set at .05, effect sizes are classified as small, moderate, and large effects, calculated in terms Cohen's d with values 0.20, 0.50 and 0.70.

FINDINGS

Table 1. Descriptive information about participants

N= 19		Min.	Max.	Mean	SD
Female (n=6)	**Weight (Kg)**	52	75	58.50	8.96
	Height (Cm)	160	174	168	4.84
	Body Mass Index (Kg/m^2)	17.18	26.57	20.64	3.64
Male (n=9)	**Weight (Kg)**	62	80	68.89	5.6
	Height (Cm)	170	185	177.67	5.63
	Body Mass Index (Kg/m^2)	20.31	25.61	21.83	1.71

There were six female (40%) and nine male (60%) participants in the study. Participants were 18 (n= 10), 19 (n= 4) and 22 (n=1) years old (M=18.53, SD =1.06). Descriptive information about participants is given above (Table 1).

Table 2. Differences in the correct response rate in flanker task

Pre-Test-Post-Test	n	Mean Rank	Sum of Ranks	Z	p
Negative Ranks	1	7	7	-2.319	**0.020***
Positive Ranks	10	5.90	59		
Ties	0				

***p<0.05**

In the study, the pre-test and post-test scores of the participants from the Flanker task and the Spatial Visualization test were compared. According to the findings, there were significant differences in the correct response rate for the flanker task (p=0.020) between the pre-test and the post-test (Table 2).

Table 3. Difference between the congruent and incongruent conditions in the flanker task

Pre-Test-Post-Test	n	Mean Rank	Sum of Ranks	Z	p
Negative Ranks	10	10	100	-2.272	**0.023***
Positive Ranks	5	4	20		
Ties	0				

***p<0.05**

It was observed that there were significant differences between the pre-test and post-test in the reaction time in difference between the congruent and incongruent conditions (p=0.023) in the Flanker task (Table 3). According to the findings, no significant difference was found between the Flanker task reaction time, congruent condition response time, and incongruent condition response time in pre-test and post-test measurements (p >0.05).

Table 4. Spatial visualization test

Pre-Test-Post-Test	n	Mean Rank	Sum of Ranks	Z	p
Negative Ranks	3	4	12	-2.351	**0.019***
Positive Ranks	10	7.90	79		
Ties	0				

***p<0.05**

There were significant differences between the pre-test and post-test in the Spatial Visualization test (p= 0.019) (Table 4). There were 10 participants whose spatial visualization score increased after four weeks of tennis training, 2 of the participants whose spatial visualization score did not change before and after training, and 3 participants whose spatial visualization score decreased after training compared to pre-test. A statistically significant difference was found between the mean rank scores of the participants in the research group before and after the training (p<0.01). It shows that the effect size of this detected difference is r= 0.15. The difference has a small effect, and this effect explains 24% of the total variance (R^2 = 0.15 = .024).

DISCUSSION

Cognitive Control

In this study, the effect of four-week target training on tennis wall on cognitive control and spatial visualization skills was evaluated in individuals who had never had tennis training before. According to the findings, there is a significant difference between the pre-test and post-test in the correct response rate for the Flanker task. After four weeks target training on tennis wall, the correct response rate on the Flanker task increased.

Pacesova et al., (2018) concluded that tennis players scored higher on the Stroop test, indicating that their cognitive control skills were more developed compared to the non-tennis-playing control group. Consequently, engaging in tennis was associated with enhanced cognitive control skills. Tennis, requiring both physical and cognitive efforts, affects cognitive functions such as decision-making, planning, and cognitive control during training. Tennis training is likely to contribute to the improvement of individuals' cognitive skills (Ishihara et al., 2017). The increasing number of correct responses in the Flanker task indicates enhanced cognitive control skills. Tennis training can be an effective method to improve cognitive control.

Another significant finding of the study is the decrease in the reaction time difference between congruent and incongruent conditions in the Flanker task during pre-test and post-test measurements. Decreasing reaction time indicates that individuals responded to both conditions in similar times, demonstrating improved reaction times in response to incongruent conditions. This improvement is indicative of the development of cognitive control skills in individuals (Eriksen & Eriksen, 1974). Engagement in physical activities demanding cognitive functions, such as tennis, reduced reaction times to incongruent conditions and leads to improved cognitive control skills.

Overall, the research suggests that targeted tennis wall training positively influences cognitive control and spatial visualization skills in individuals without previous tennis experience. This suggests that tennis training includes cognitive tasks such as cognitive control and it can be improved with practice. It can be said that the findings obtained in the study are in line with the studies in the literature (Drolette et al., 2012, Ishihara et al., 2017, Ishihara et al., 2018). In tennis, individuals need to pay attention to both the ball and the opponent. Therefore, they need to make quick decisions, ensure hand-eye coordination, and think strategically (García-González et al., 2014). It can be said that tennis training improves cognitive control skills. Sports-related characteristics provide the development of executive functions (Ishihara et al., 2018).

Visuospatial Skills

In some sports, athletes need to use the space around them effectively. In a study conducted by Glavas (2020), the relationship between visuospatial skills, technical-tactical skills and sports performance in football players was emphasized. Additionally, research on table tennis players conducted by Peng et al., (2022) concluded that long-term training improves the visuospatial processing ability of individuals, leading to neuroplasticity in the right hemisphere.

In this study, four-week target training on tennis wall improved spatial visualization skills of individuals. Participants were asked to complete tennis training using a specific space for four weeks. The participants performed the assigned task in this place. The fact that tennis is a sport that requires field use and open skills may improve the visual skills of individuals (Gökçe et al., 2021). According to the findings, making forehand and backhand shots in a certain space may require the individual to use the space. Visuospatial skills are the ability to understand and visualize the relationships and positions between objects (Sato et al., 2022). In tennis trainings, following the speed, direction, and spin of the ball, predicting the opponent's movements and shooting requires the use of visuospatial skills. During practice, players follow the movements of the ball. This skill supports individuals to make a shot by analyzing the position of the ball. Therefore, it is necessary to use visuospatial skills (Guo et al., 2016).

Recommendations

In this study, a four-week tennis training was conducted to evaluate the effect of tennis training on cognitive functions. According to the findings, tennis training improves cognitive control and spatial visualization. The research has strengths and limitations. One of the strengths of the study is that the participants had no tennis experience. This made it possible to investigate the effectiveness of tennis training on cognitive functions. Therefore, it can be said that the effect obtained is due to tennis training. Considering that being a national athlete may be a confounding variable that may affect the research findings, not being a national athlete was added as a criterion. The comparison of cognitive control and plasticity between novice and experienced athletes and the assessment of executive functions in experienced athletes is recommended. The fact that the study was an experimental study and the addition of a four-week training period to the participants supported the effect of tennis training on cognitive control and spatial visualization. However, the small sample size and the absence of a control group are limitations of the study. It may be recommended to repeat similar studies with a larger sample. One of the limitations is the study is that the study was designed as a single-blind study. Researcher knows that all participants have received tennis training.

Practical Implications

Previous studies have emphasized that there is a relationship between sport performance and cognitive functions (Kalén et al., 2020). This study provides evidence that four-week tennis training improves cognitive functions such as cognitive control and visuospatial skills. Four-week tennis training made differences in terms of response rate and reaction time between the congruent and incongruent conditions in Flanker Task and Spatial Visualization Test. It means target trainings on tennis wall improves cognitive control and visual skills. Based on this study, it can be said that the elective tennis course taken at university has a positive effect on cognitive skills. In this context, positive effect of long-term sports training on cognitive functions is also important for public health. If individuals start tennis in early stages of life, it can reveal positive results in terms of the development of cognitive skills in the long term. It is known that improved cognitive functioning is associated with improved sports performance in both open and closed skill sports. Therefore, it is important for athletes to include cognitive functions in the development of sports performance. Cognitive training can be added to athletes' programs.

Conflict of Interest: As the authors of the article, we declare that there is no personal or financial conflict of interest within the scope of the study.

Authors' Contribution: Study Design- GA, İO, BY; Data Collection- GA, İO, BY; Statistical Analysis- GA, İO; Manuscript Preparation- GA, İO. All authors read and approved the final manuscript.

Research Ethic Informations: Halic University Ethics Committee approved the study protocal.

Ethics Committee: Halic University Ethics Committee

Date/Protocol Number: 30th Nov 2022/241.

REFERENCES

Alves, H., Voss, M. W., Boot, W. R., Deslandes, A., Cossich, V., Salles, J. I., & Kramer, A. F. (2013). Perceptual-cognitive expertise in elite volleyball players. *Frontiers in Psychology*, *4*, Article 36. https://doi.org/10.3389/fpsyg.2013.00036

Chiu, C. N., Chen, C. Y., & Muggleton, N. G. (2017). Sport, time pressure, and cognitive performance. *Progress in Brain Research*, *234*, 85-99. https://doi.org/10.1016/bs.pbr.2017.06.007

Cristofori, I., Cohen-Zimerman, S., & Grafman, J. (2019). Executive functions. *Handbook of clinical neurology*, *163*, 197-219. https://doi.org/10.1016/B978-0-12-804281-6.00011-2

Davranche, K., Hall, B., & McMorris, T. (2009). Effect of acute exercise on cognitive control required during an Eriksen flanker task. *Journal of Sport and Exercise Psychology*, *31*(5), 628-639. https://doi.org/10.1123/jsep.31.5.628

Drollette, E. S., Shishido, T., Pontifex, M. B., & Hillman, C. H. (2012). Maintenance of cognitive control during and after walking in preadolescent children. *Med Sci Sports Exerc.*, *44*(10), 2017-24. https://doi.org/10.1249/MSS.0b013e318258bcd5

Dyer, J. T. (1935). The backboard test of tennis ability. Res. Quart. 6 (Suppl), 63-74. https://doi.org/10.1080/23267402.1935.10761690

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, *16*(1), 143-149. https://doi.org/10.3758/BF03203267

García-González, L., Moreno, A., Gil, A., Moreno, M. P., & Villar, F. D. (2014). Effects of decision training on decision making and performance in young tennis players: An applied research. *Journal of Applied Sport Psychology*, *26*(4), 426-440. https://doi.org/10.1080/10413200.2014.917441

Glavaš, D. (2020). Basic cognitive abilities relevant to male adolescents' soccer performance. *Perceptual and Motor skills*, *127*(6), 1079-1094. https://doi.org/10.1177/0031512520930158

Gokce, E., Gunes, E., Hayme, S., Aslan, E., Asutay, O., Asar, B., & Cevik, F. (2021). Effects of playing tennis on cognition: A pilot study to examine hand preference effect. *Journal of Ankara University Faculty of Medicine*, *74*(1), 27-33. https://doi.org/10.4274/atfm.galenos.2020.30301

Guo, W., Wang, B., Lu, Y., Zhu, Q., Shi, Z., & Ren, J. (2016). The relationship between different exercise modes and visuospatial working memory in older adults: A cross-sectional study. *PeerJ*, *4*, e2254. https://doi.org/10.7717/peerj.2254

Ishihara, T., Sugasawa, S., Matsuda, Y., & Mizuno, M. (2017). Relationship of tennis play to executive function in children and adolescents. *European Journal of Sport Science*, *17*(8), 1074-1083. https://doi.org/10.1080/17461391.2017.1334831

Ishihara, T., & Mizuno, M. (2018). Effects of tennis play on executive function in 6–11-year-old children: A 12-month longitudinal study. *European Journal of Sport Science*, *18*(5), 741-752. https://doi.org/10.1080/17461391.2018.1444792

Kalén, A., Bisagno, E., Musculus, L., Raab, M., Pérez-Ferreirós, A., Williams, A. M., & Ivarsson, A. (2021). The role of domain-specific and domain-general cognitive functions and skills in sports performance: A meta-analysis. *Psychological Bulletin*, *147*(12), 1290-1308. https://doi.org/10.1037/bul0000355

Muiños, M., & Ballesteros, S. (2018). Does physical exercise improve perceptual skills and visuospatial attention in older adults? A review. *European Review of Aging and Physical Activity*, *15*(1), 1-12. https://doi.org/10.1186/s11556-018-0191-0

Nuri, L., Shadmehr, A., Ghotbi, N., & Attarbashi Moghadam, B. (2013). Reaction time and anticipatory skill of athletes in open and closed skill-dominated sport. *European Journal of Sport Science*, *13*(5), 431-436. https://doi.org/10.1080/17461391.2012.738712

Pačesová, P., Šmela, P., Kraček, S., Kukurová, K., & Plevková, L. (2018). Cognitive function of young male tennis players and non-athletes. *Acta Gymnica*, *48*(2), 56-61. https://doi.org/10.5507/ag.2018.011

Peiffer, R., Darby, L. A., Fullenkamp, A., & Morgan, A. L. (2015). Effects of acute aerobic exercise on executive function in older women. *Journal of Sports Science & Medicine*, *14*(3), 574-583.

Peng, Z., Xu, L., Wang, H., Song, T., Shao, Y., Liu, Q., & Weng, X. (2022). The Lateralization of Spatial Cognition in Table Tennis Players: Neuroplasticity in the Dominant Hemisphere. *Brain Sciences*, *12*(12), Article 1607. https://doi.org/10.3390/brainsci12121607

Sato, T., Kosaki, K., Choi, Y., Tochigi, Y., Shindo-Hamasaki, A., Momma, R., & Maeda, S. (2022). Association between sport types and visuospatial working memory in athletes. *The Journal of Physical Fitness and Sports Medicine*, *11*(4), 247-253. https://doi.org/10.7600/jpfsm.11.247

Sütçü, N. D., & Oral, B. (2019). Uzamsal görselleştirme testinin geliştirilmesi: Geçerlik ve güvenirlik çalışmaları. *Kastamonu Eğitim Dergisi*, *27*(3), 1179-1195. https://doi.org/10.24106/kefdergi.2826

Van der Fels, I. M., Te Wierike, S. C., Hartman, E., Elferink-Gemser, M. T., Smith, J., & Visscher, C. (2015). The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. *Journal of Science and Medicine in Sport*, *18*(6), 697-703. https://doi.org/10.1016/j.jsams.2014.09.007

Yongtawee, A., Park, J., Kim, Y., & Woo, M. (2022). Athletes have different dominant cognitive functions depending on type of sport. *International Journal of Sport and Exercise Psychology*, *20*(1), 1-15. https://doi.org/10.1080/1612197X.2021.1956570