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BASIC SCIENCES / TEMEL TIP BİLİMLERİ

Effects of Playing Tennis on Cognition: A Pilot Study to Examine Hand Preference Effect

Tenis Oynamanın Bilişe Etkileri: El Tercihi Etkisini Anlamak İçin Bir Pilot Çalışma

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Abstract

Objectives: This pilot study aimed to explore the effects of playing tennis on cognitive functions and the effects of hand dominance on cognitive performance in tennis players.
Materials and Methods: Tennis players and sedentary controls participated in the study (n=24/24). Groups were divided into two based on their hand dominance, and right-handed and left-handed participants were equally distributed (for each group n=12/12). Hand preference test, exercise background and daily life questionnaires were used for matching handedness, age, education, and sporting levels. Cognitive performance was evaluated with the verbal fluency test, Corsi's block-tapping test (CBTT) and mental rotation test (MRT). MRT was performed bimanually, whereas CBTT was applied separately with right and left hands. Thus, we tried to determine the test that better reflected the hand effect.
Results: Left-hand scores of CBTT were significantly higher in tennis players than in the sedentary controls (p=0.02). For gender difference exhibited for CBTT left-hand scores, women were more responsive to exercise effect (p=0.029). No significant difference was found based on hand preference in both groups on the cognitive tests.
Conclusion: Tennis is an open skill sport that requires adaptation for continuously changing conditions and goal-directed behaviors. This can improve visuospatial skills and higher scores of tennis players in the left-handed visuospatial task may be associated with this. Besides, the widespread organization of the right hemisphere is an advantage for spatial abilities. Thus, it may create a technical advantage for left-handed tennis players. CBTT could be more indicative than the MRT for visuospatial functions.
Key Words: Tennis, Working Memory, Short-term Memory, Cognition, Exercise

Öz

Amaç: Bu pilot çalışma, tenis oynamanın ve tenisçilerde el tercihinin bilişsel işlevler üzerindeki etkilerini araştırmayı amaçlamıştır.
Gereç ve Yöntem: Çalışmaya tenisçiler ve sedanter kontroller katılmış (n=24/24), gruplar el tercihine göre sınıflandırılmış, sağ veya sol elini kullanan katılımcılar eşit dağıtılmıştır (her grup için n=12/12). El tercihi, egzersiz geçmişi ve günlük yaşam alışkanlıkları anketleri uygulanmış, katılımcıların yaş, eğitim ve spor düzeyleri eşleştirilmiştir. Sözel ve görsel uzaysal görevlere dayalı bilişsel testler uygulanmış, sözel akıcılık testi, Corsi'nin küp yerleştirme testi ve zihinsel döndürme testi (ZDT) yapılmıştır. ZDT iki el aynı anda kullanılarak yapılırken, küp yerleştirme testi sağ ve sol elle ayrı ayrı uygulanmıştır. Bu şekilde hangi testin el tercihi etkisini daha iyi yansıtacağını gözlemek amaçlanmıştır.
Bulgular: Küp yerleştirme testinde tenisçilerin sol el skorları, sedanter kontrol grubuna göre anlamlı olarak yüksektir (p=0,02). Bilişsel testlerde her iki grupta da el tercihine göre anlamlı bir fark bulunmamıştır.
Sonuç: Tenis, sürekli değişen koşullara ve hedefe yönelik davranışlara uyum gerektiren bir açık beceri sporudur. Bu, görsel-uzaysal becerileri geliştirebilir ve tenisçilerin daha yüksek sol el skorları bununla ilişkili olabilir. Sağ yarıkürenin yaygın organizasyonu uzaysal yetenekler için bir avantajdır ve solak tenisçiler için teknik bir avantaj yaratabilir. Küp yerleştirme testi, görsel-uzaysal işlevler için ZDT'den daha iyi bir belirteç olabilir.
Anahtar Kelimeler: Tenis, Çalışma Belleği, Kısa Süreli Bellek, Biliş, Egzersiz

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Introduction

It is widely accepted that exercise is a well-known non-pharmacological intervention to improve brain functions (1). Human and animal studies show that exercise protects brain functions including cognition, memory and motor performance, especially in the neurodegenerative process (2). Exercise enhances synaptic plasticity through neurogenesis, vascular functions, and metabolism, as well as its direct effect on synaptic structure (3). Type, duration, intensity, and frequency of exercise may affect the outcomes of physical training on brain functions (4).

Executive functions are a set of cognitive processes which refer to top-down mental process that are necessary for the cognitive control of behavior and they have been found to be more sensitive to exercise-induced cognitive benefits than other types of cognitive functions such as perception and processing speed (5). Executive function consists of three foundational components: inhibitory control, the ability to control one's attention, behavior, thoughts, and/or emotions to override a strong internal predisposition or external distraction, and focus on more adaptive and relevant stimuli instead; working memory, the ability to hold and process new and already stored information; and cognitive flexibility, the ability to switch perspectives or focus of attention (6).

The classification of open and closed skill exercises may offer a way to examine the effect of exercise on brain functions (7). Variability, predictability, and complexity of the environment in which the sport is performed are different between open and closed skill exercises.

Open skill exercise demands more cognitive and executive loadings. Various opponents and changing environment must be controlled by many sets of motor coordination skills for open skill exercises. It is important to define, judge and act quickly during problem-solving in our daily life. To judge and decide on the competitor's technique and tactic are important for athletes in sports, too. Senior athletes always predict well the next intention or action of their opponents, the stronger the athlete's professional skills, the faster and more accurate the predictive ability.

Tennis which is an open skill exercise requires intense metabolic and neuromuscular effort. Making a quick judgment about the competitor's technique and tactic is needed in tennis, and cognitive flexibility accompanies motor skills; these characteristics of tennis may contribute to the development of executive functions (8).

There is a strong relationship between executive functions and sports success and, it is shown that tennis enhances executive functions development independent of physical activity level in children (9,10). In an intervention study, 6 months of tennis training intervention improved the inhibitory control of children independent of physical fitness gain (11). Another study reported that tennis players exhibited greater inhibitory control than did swimmers and sedentary controls (12).

It is known that hand preference is a universal feature observed in primates as an indicator of cerebral asymmetry (13). Approximately 90% of people are right-handed, and archaeological evidence suggests that this is almost stable throughout history (14).

A study showed that left-handedness among athletes is more common than the sedentary population and it is also stated that left-handedness is more common in interactive sports especially for men (15). There is also some evidence pointing to a central advantage for left-handers in motor skills and it is explained by the settlement of spatial orientation and attention functions in the right hemisphere that controls the left hand (16). Left-handers show higher performance in motor skills due to bilateral representation of axial motor control and, it may enable them more successful in sports (17). Because of their relatively unfamiliar playing strategies and patterns, left-handed players might be thought to have a strategic advantage when facing a right-handed player. It is reported that the representation of left-handed players is two to five times more than right-handed players in international tennis competitions from 1968 through 1999 (18). However, a study showed that the positive impact of left-handed performance on high achievement in elite tennis was moderate and decreased in male professionals over time and was almost absent in female professionals (19). The effects of hand preference on cognition indicate different results. A research showed that hand preference had no significant effect on cognitive functions in upper middle-aged subjects for both genders (20). A research indicated that attention and memory scores were better in left-handed young adult women (21). Another study showed that left-handers had better visual skills as right-handers had shorter reaction times in children (22).

The effect of hand preference on cognitive functions in athletes has not been studied yet.

Thus, this study aims to investigate the effect of tennis on cognitive functions and the effect of hand preference on cognitive functions and sports performances of tennis players.

Materials and Methods

Forty eight adults (24 tennis players, 24 sedentary) aged 18-50 years (M=37.8±11.1) participated in the study (Table 1). Participants were divided equally for sub-groups including right-handed tennis players, left-handed tennis players, right-handed sedentary, left-handed sedentary. Athletes were playing tennis at least for 5 years and they were the members of tennis clubs in Ankara that are associated Turkish Tennis Federation.

The groups did not differ significantly for education years, they were all under-graduate or bachelor's degree. No participants had a history of neurological or psychiatric disorders and all had normal or corrected-to-normal vision. Participants were non-smokers and women were in pre-menopausal period. The study was approved by Ankara University Ethics Committee Undergraduate Student Research (No: 72189195-050.03.04-E.2704) and all participants provided written informed consent.

Tennis players were assessed with the type of exercise questionnaire. We evaluated the specific type of exercise and the frequency per week, the duration per time and the years of participating in tennis. Chapman and Chapman's Hand Preference Questionnaire was assessed for all participants (23). We used a modified version of Corsi's block-tapping test (CBTT) and mental rotation test (MRT) of free software PEBL 2 to assess selective attention and short term spatial memory (24).

Modified CBTT is based on CBTT developed in 1971 which is a serial recall task that involves the integration of temporal and spatial information (25). This test is designed to study cerebral lateralization of visuospatial functions in general and to investigate cognitive functions associated with the right temporal lobe in particularly. In this test, irregularly distributed blocks on the screen are lit up in the first screen for 4 seconds and the subject must tap their previous position on the second screen. CBTT task starts with sequences involving a small number of blocks and gradually increases in difficulty up to nine blocks.

It measures both the number of tapping blocks correctly recalled (total correct score) and the longest sequence recalled (span score). The test was performed with right and left hand in sequence. In this study, we applied CBTT with both hands to obtain more data and to compare the right and the left hand effect.

Mental rotation is imagining how a stimulus would look like if it would be rotated. In this task, the participant mentally rotates a visual grid without time pressure. The test is performed bimanually and there are 20 trials. Total correct score is recorded.

Verbal fluency test (VFT) is used as an efficient screening instrument of general verbal functioning. It consists of category fluency and letter fluency (26). Participants produce as many words as possible from a category and letter in a given time (60 seconds) and, the score in each task is the number of unique correct words.

All cognitive performance measurements were performed in an isolated environment and several pretest trials were given to all subjects to familiarize them with the tasks.

Statistical Analysis

Statistical analysis were performed using SPSS version. (SPSS Inc., Chicago, IL, USA). The normality of data distribution was tested with the Shapiro-Wilk test. The descriptive statistics of the data were given as median (minimum-maximum), mean ± standard deviation for continuous variables. The Mann-Whitney U test was used to compare differences between the groups, significance was set at p≤0.05.

Results

There was a significant difference between the groups for CBTT that is performed with the left hand but not with the right hand. Total right score and span score were higher in tennis players than sedentary control for CBTT which is performed with the left hand (p=0.013, p=0.02) (Table 2; Figure 1, 2).

Table 1: Baseline characteristics of groups (mean ± SD)

	RH tennis players	LF tennis players	RH control group	LH control group
Age (years)	37.09±12.03	38.9±10.8	39.4±11.3	34.8±11.2
Sports year (years)	6.7±2.8	7.6±2.3	-	-
Gender (man/woman)	8/4	6/6	5/7	6/6

SD: Standard deviation, RH: Right-handed; LH: Left-handed

Table 2: Cognitive task parameteres; median (min; max)

	Tennis players	Control group	p-value
Left hand CBT			
Total score	55.5 (16; 117)	40 (9; 162)	0.013*
Span score	6 (4; 9)	5 (3; 9)	0.02*
Right hand CBT			
Total score	60 (16; 144)	40 (20; 153)	0.099
Span score	6 (4; 9)	5 (4; 9)	0.097
Verbal fluency test	26 (8; 37)	28 (7; 43)	0.620
Matrix rotation test	15 (9; 18)	14 (5; 19)	0.534

CBT: cognitive behavioral therapy, min: Minimum, max: Maximum

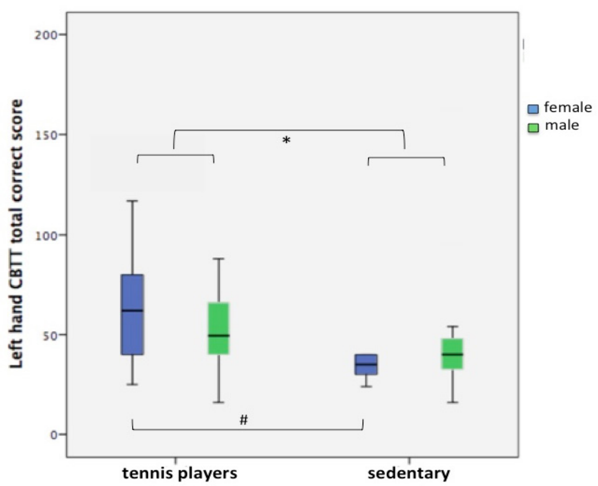

Figure 1: Left hand CBTT total score

CBTT: Corsi's block-tapping test; #indicates that tennis players' left hand CBTT score vs. sedentaries p<0.05;* indicates that female tennis players' left hand CBTT score vs. sedentary females p<0.05

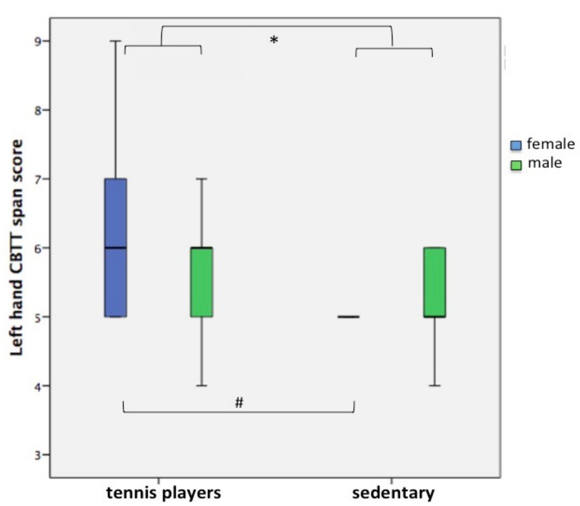

Figure 2: Left hand CBTT span score

CBTT: Corsi's block-tapping test *indicates that tennis players' left hand CBTT span score vs. sedentaries p<0.05; #indicates that female tennis players' left hand CBTT span score vs. sedentary females p<0.05

Gender difference exhibited for CBTT left-hand scores. There was a significant difference for CBTT left-hand total correct and span scores between tennis players and sedentary control in women but not much in men (p=0.029, p=0.048) (Figure 1, 2).

There was no significant difference for MRT and VFT between the groups (p=0.534; p=0.620) (Table 2).

Discussion

Working memory is the ability to protect and manipulate information and it is vulnerable to age. Working memory has been shown to be relevant to the progression of many developmental and neuropsychological disorders. It keeps and consolidates the complex information for long term storage and it is important for efficient cognitive functioning.

Prior studies suggested that there are two components for working memory which are referred as protection and manipulation. The "continuum" model proposes that visuospatial working memory is two part as passive storage and active manipulation. Passive storage means short-term processing of information and active manipulation means to integrate the stored information (27).

Many studies examined the relationship between exercise and working memory and demonstrated a positive effect of exercise on working memory performance (28).

It was demonstrated that physically active participants showed higher working memory capacity than sedentary in a reading span task (29). Researchers observed that fitter young adults showed better accuracy in a 2-back task and it was showed a greater working memory capacity in the physically active group compared to sedentary (30). In this study, it was observed that playing tennis regularly had a developing effect on visual-spatial memory performance. Significantly higher left-hand scores of CBTT in tennis players can be interpreted as a positive effect of exercise on working memory. Due to visuospatial skills are represented in the right hemisphere, higher left-hand scores of CBTT can be interpreted as a result of the right hemisphere is more sensitive to these task-related tests. The right hemisphere is actively involved during the left-hand CBTT and, tennis may have contributed to easier and faster activation of neural networks related to the left hand.

It is generally accepted that males show an advantage in spatial processing. Studies are reporting that males outperform females in CBTT (31). A study showed that significant differences pointing to a better performance of males on the spatial span score parameter of CBTT (32). Thus, the relationship between exercise and brain health might vary by gender. In our study, the basis of significant difference between tennis players and sedentary was women tennis players in left-hand CBTT scores. Improving the effect of playing tennis was more common in women. Women may be more responsive to the effects of exercise on visuospatial memory skills.

The visual processing capacity of the working memory can store information about shapes, distances, and colors, mentally rotate images, and reconstruct visual environments. The working memory tasks used in this study focus on different aspects of working memory. While CBTT focuses protection parameter of working memory, MRT focuses on active manipulation and transforming the stored visual information. Our results are in line with the finding that exercise improves the protection parameter of working memory (33).

A study showed that elite combat athletes demonstrated better mental rotation performance than elite runners (8). Another study indicates large differences in mental rotation performance that orienteers and gymnasts outperforming the non-athletes and endurance runners (34). In our study, the mental rotation performance of tennis players did not differ from that of sedentary contrary to expectations. The wide age range of our study may have had an impact on results given that working memory is age-related. So indeed, the findings of a systematic review suggested that the cognitive benefits of exercise may vary across the lifespan (35).

There are conflicting results on the effects of exercise on verbal memory and fluency. A study showed that twelve weeks of aerobic exercise over a 6-year period improved verbal fluency (36) and cardiorespiratory fitness are positively associated with verbal memory and fluency in healthy older adults (37). A study demonstrated that after 12 weeks of aerobic exercise, semantic verbal fluency output was better in the exercise group than sedentary (38).

On the contrary, a study demonstrated that elderly individuals who had been regularly playing tennis more than 10 years didn't show greater executive function and memory performance (39). It was showed that three times per week for 6 weeks aerobic exercise had the potential to improve visuospatial memory performance but no effect on verbal memory (40).

This study showed no significant association between playing tennis and verbal fluency. Literature that examines the relationship between exercise and verbal fluency predominantly involves older adults. The effect of exercise on verbal fluency may be a response to age-related cognitive loss. Our findings of the effects of exercise on verbal fluency may be related to that there is no participant over 65 years old in our study.

Furthermore, we only applied supermarket part in the category subsection of VBT. Lacking of letter subsection and other category tests may have had an impact on our results.

Conclusion

We found no significant hand preference effect on tennis players' cognition unlike a study which found a moderate effect of being left-handed for tennis ability. To further assess the relationship between hand preference effect on cognition in tennis players, broader experiment groups and narrow age range should be investigated. However, preferred cognitive tests should be reviewed again. In addition to VBT, verbal memory tests can be used; 3D visual images can be preferred for mental rotation test. Research that investigate the effects of regular sports on brain health will have noteworthy results to prevent and improve public health.

Ethics

Ethics Committee Approval: The study was approved by Ankara University Ethics Committee Undergraduate Student Research (No: 72189195-050.03.04-E.2704).

Informed Consent: All participants provided written informed consent.

Peer-reviewed: Externally peer-reviewed.

Authorship Contributions

Concept: E.Gü., E.G., E.A., O.A., B.A., M.N.Ç., F.Ç., Design: E.Gü., E.G., S.H., Data Collection or Processing: E.Gü., E.G., E.A., O.A., B.A., M.N.Ç., F.Ç., Analysis or Interpretation: E.G., E.Gü., S.H., Literature Search: E.Gü., E.G., E.A., O.A., B.A., M.N.Ç., F.Ç., Writing: E.G., E.Gü.

Conflict of Interest: No conflict of interest was declared by the authors.

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References

1. Erickson KI, Hillman C, Stillman CM, et al. Physical Activity, Cognition, and Brain Outcomes: A Review of the 2018 Physical Activity Guidelines. Med Sci Sports Exerc. 2019;51:1242-1251.
2. Ahlskog JE, Geda YE, Graff-Radford NR, et al. Physical exercise as a preventive or disease-modifying treatment of dementia and brain aging. Mayo Clin Proc. 2011;86:876-884.
3. Cotman CW, Berchtold NC, Christie LA. Exercise builds brain health: key roles of growth factor cascades and inflammation. Trends Neurosci. 2007;30:464-472.
4. Kramer AF, Colcombe S. Fitness Effects on the Cognitive Function of Older Adults: A Meta-Analytic Study-Revisited. Perspect Psychol Sci. 2018;13:213-217.
5. Chaddock L, Pontifex MB, Hillman CH, et al. A review of the relation of aerobic fitness and physical activity to brain structure and function in children. J Int Neuropsychol Soc. 2011;17:975-985.
6. Diamond A. Executive functions. Annu Rev Psychol. 2013;64:135-168.
7. Schmidt RA, Wrisberg CA. Motor learning and performance: A situation-based learning approach (4th ed.). Human kinetics; 2008.
8. Moreau D, Conway ARA. Cognitive enhancement: A comparative review of computerized and athletic training programs. International Review of Sport and Exercise Psychology. 2013;6:155-183.
9. Vestberg T, Reinebo G, Maurex L, et al. Core executive functions are associated with success in young elite soccer players. PLoS One. 2017;12:0170845.
10. Ishihara T, Sugasawa S, Matsuda Y, et al. Relationship between sports experience and executive function in 6-12-year-old children: independence from physical fitness and moderation by gender. Dev Sci. 2018;21:12555.
11. Crova C, Struzzolino I, Marchetti R, et al. Cognitively challenging physical activity benefits executive function in overweight children. J Sports Sci. 2014;32:201-211.
12. Wang CH, Chang CC, Liang YM, et al. Open vs. closed skill sports and the modulation of inhibitory control. PLoS One. 2013;8:55773.
13. Corballis MC, Badzakova-Trajkov G, Häberling IS. Right hand, left brain: genetic and evolutionary bases of cerebral asymmetries for language and manual action. Wiley Interdiscip Rev Cogn Sci. 2012;3:1-17.
14. Sherwood CC, Subiaul F, Zawidzki TW. A natural history of the human mind: tracing evolutionary changes in brain and cognition. J Anat. 2008;212:426-454.

15. Grouios G, Tsorbatzoudis H, Alexandris K, et al. Do left-handed competitors have an innate superiority in sports? Percept Mot Skills. 2000;90:1273-1282.
16. Toga AW, Thompson PM. Mapping brain asymmetry. Nat Rev Neurosci. 2003;4:37-48.
17. Judge J, Stirling J. Fine motor skill performance in left- and right-handers: Evidence of an advantage for left-handers. Laterality. 2003;8:297-306.
18. Holtzen DW. Handedness and professional tennis. Int J Neurosci. 2000;105:101-119.
19. Loffing F, Hagemann N, Strauss B. Left-handedness in professional and amateur tennis. PLoS One. 2012;7:49325.
20. Hatta T. Associations between handedness and executive function in upper-middle-aged people. Laterality. 2018;23:274-289.
21. Chaudhary S, Narkeesh A, Gupta N. A Study of Cognition in Relation with Hand Dominance. Journal of Exercise Science and Physiotherapy. 2009;5:20-23.
22. Al-Hashel JY, Ahmed SF, Al-Mutairi H, et al. Association of Cognitive Abilities and Brain Lateralization among Primary School Children in Kuwait. Neurosci J. 2016;2016:6740267.
23. Chapman LJ, Chapman JP. The measurement of handedness. Brain Cogn. 1987;6:175-183.
24. Mueller ST, Piper BJ. The Psychology Experiment Building Language (PEBL) and PEBL Test Battery. J Neurosci Methods. 2014;222:250-259.
25. Berch DB, Krikorian R, Huha EM. The Corsi block-tapping task: methodological and theoretical considerations. Brain Cogn. 1998;38:317-338.
26. Lezak MD, Howieson DB, Loring DW. Neuropsychological Assessment (5th ed.). New York, NY: Oxford University; 2012.
27. Cowan N. The many faces of working memory and short-term storage. Psychon Bull Rev. 2017;24:1158-1170.
28. Chang YK, Huang CJ, Chen KF, et al. Physical activity and working memory in healthy older adults: an ERP study. Psychophysiology. 2013;50:1174-1182.
29. Lambourne K. The relationship between working memory capacity and physical activity rates in young adults. J Sports Sci Med. 2006;5:149-153.
30. Padilla C, Pérez L, Andrés P. Chronic exercise keeps working memory and inhibitory capacities fit. Front Behav Neurosci. 2014;8:49.
31. Piccardi L, Iaria G, Ricci M, et al. Walking in the Corsi test: which type of memory do you need? Neurosci Lett. 2008;432:127-131.
32. Grossi D, Matarese V, Orsini A. Sex differences in adults' spatial and verbal memory span. Cortex. 1980;16:339-340.
33. Tsai CL, Chang YK, Chen FC, et al. Effects of cardiorespiratory fitness enhancement on deficits in visuospatial working memory in children with developmental coordination disorder: a cognitive electrophysiological study. Arch Clin Neuropsychol. 2014;29:173-185.
34. Schmidt M, Egger F, Kieliger M, et al. Gymnasts and orienteers display better mental rotation performance than nonathletes. J Individ Differ. 2016;37:1-7.
35. Gu Q, Zou L, Loprinzi PD, et al. Effects of Open Versus Closed Skill Exercise on Cognitive Function: A Systematic Review. Front Psychol. 2019;10:1707.
36. Alfini AJ, Weiss LR, Nielson KA, et al. Resting Cerebral Blood Flow After Exercise Training in Mild Cognitive Impairment. J Alzheimers Dis. 2019;67:671-684.
37. Barnes DE, Yaffe K, Satariano WA, et al. A longitudinal study of cardiorespiratory fitness and cognitive function in healthy older adults. J Am Geriatr Soc. 2003;51:459-465.
38. Nocera J, Crosson B, Mammino K, et al. Changes in Cortical Activation Patterns in Language Areas following an Aerobic Exercise Intervention in Older Adults. Neural Plast. 2017;2017:6340302.
39. Culpin S. Effects of long-term participation in tennis on cognitive function in elderly individuals. Doctoral dissertation Edith. Cowan University Joondalup, Australia: 2018.
40. Stroth S, Hille K, Spitzer M, et al. Aerobic endurance exercise benefits memory and affect in young adults. Neuropsychol Rehabil. 2009;19:223-243.