The Cognitive Benefits of Playing Volleyball: A Systematic Review

Voleybol Oynamanın Bilişsel Yararları: Sistematik bir Derleme

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ABSTRACT

This systematic review examines the effects of playing volleyball, an open-skill sport, on cognition. Four hundred seventeen studies were accessed with specified search criteria, and 21 studies containing neurophysiological outcomes were found eligible for evaluation. Most studies reported cognitive improvement in volleyball players compared to control groups. Fewer studies demonstrated superior effects of playing volleyball over other sports types. Results indicate that playing volleyball has an improving effect on cognition, mainly executive functions.

Key words: *cognition; executive functions; open-skill exercise; volleyball*

ÖZET

Bu sistematik derleme, açık beceri sporu olan voleybolun biliş üzerindeki etkilerini incelemeyi hedeflemiştir. Belirlenen araştırma kriterleri ile 417 çalışmaya erişilmiş ve nörofizyolojik bulguları içeren 21 çalışma değerlendirmeye uygun bulunmuştur. Çalışmaların çoğunluğu, voleybolcularda kontrol gruplarına kıyasla bilişsel iyileşme bildirmiştir. Daha az sayıda çalışma, voleybol oynamanın diğer spor türlerine göre daha üstün etkileri olduğunu göstermiştir. Bulgular, voleybol oynamanın biliş üzerinde, özellikle yürütücü işlevlerde geliştirici bir etkiye sahip olduğunu göstermiştir.

Anahtar kelimeler: *açık beceri egzersizi; biliş; voleybol; yürütücü işlevler*

Introduction

A large number of studies demonstrated that physical activity creates structural and functional changes in the brain that promote cognitive functions[1,2]. Some studies suggest that different exercise types exert different effects on cognition[3]. A growing body of literature suggests that the effects of physical exercise on cognitive functions might be related to the exercise types[4,5].

Sport types are divided into two groups based on the predictability and consistency of the performing environment; open and closed skill sports[6]. Open-skill sports (e.g., volleyball, tennis, football, etc.) are externally paced activities performed in a dynamic, unpredictable environment, whereas closed-skill sports (e.g., running, swimming, archery, etc.) are internally paced and performed in a static and predictable environment. Within this scope, as an interactive and strategic sport, volleyball is an open-skill sport. The volleyball requires active decision-making and ongoing adaptability to randomly occurring external stimuli. The player's task involves the simultaneous processing of a significant amount of knowledge, such as teammates, opponents, field positions, and balls. The volleyball player must update the location of teammates/opponents, execute tactics, and follow the rules during the game[7]. Some studies demonstrate that open-skill athletes outperform the closed-skill athletes in visual attention, decision-making, action execution, and inhibitory control tasks[3,8,9]. For these reasons, volleyball players may be more cognitively flexible than closed-skill athletes in task-switching. A recent study showed that team sport athletes performed better in sustained attention and processing speed than recreational athletes[10]. As a team sport, volleyball might be more improving for some aspect of cognitive skills.

Additionally, volleyball is one of the sports with the lowest incidence of concussion[11]. Considering the cognitive functions such as attention, cognitive processing speed, and working memory are susceptible to the

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effects of sports-related concussion,[12] examining volleyball seems safer to understand the long-term effects of open-skill sports participation on cognition.

Therefore, based on the previous literature and focusing on neurophysiological outcomes, we did a systematic literature search to understand the effects of playing volleyball on cognition. We will present and discuss our findings to better understand how playing volleyball affects the brain and what the potential neurobiological mechanisms underlying are.

Materials and Methods

Search Strategy

PRISMA guideline[13] is used for the procedure of search. An electronic search was undertaken by two independent researchers between October 2020 and June 2021 in the Cochrane Library, PscyINFO and Pubmed databases. The last update for searching took place on June 24, 2021. We limited the search with papers published in English or Turkish. We used "AND" and "OR" operators to connect our search terms. The following search string has been used for each database: (volleyball) AND (cogniti* OR executive OR attention OR memory OR verbal OR working memory OR dual-task OR reaction time OR processing speed OR perceptual speed).

Selection Process and Data Extraction

We included studies published in peer-reviewed journals which recruited children and healthy adults investigating the effects of playing volleyball without any other intervention (e.g., further medicine and training prescription, or dietary). Multidomain interventions were excluded (e.g., volleyball plus lifestyle intervention). There was no restriction for participants' age range. Studies were eligible if at least there was a volleyball group that performed multiple weeks of training. Both intervention and cross-sectional studies were included. At least one of the following domains had to be represented in outcome measures: i) cognitive functions, ii) structural or functional brain data. Dissertations, conference papers, case studies, or studies that did not include any outcomes of interest were excluded.

Duplicates were eliminated and MESH terms, titles and abstracts were reviewed intensively. Two separate researchers evaluated the relevance of possible studies based on our inclusion and exclusion criteria. The remaining studies were read for the final selection in terms of their eligibility. In case of contradictory commentaries between two main reviewers, a third independent reviewer was consulted. Further studies found in the screened studies' reference lists were also evaluated for eligibility. All included studies were presented according to main study characteristics (First Author, Sample, Study Design, Procedure, Outcome Measures, Results, and Risk of Bias) (Table 1).

Methodological Quality of Included Studies

Methodological quality was assessed independently by two authors. Three different tools[14–16] were used to score the methodological quality of cross-sectional, intervention, and longitudinal studies (Supplementary Table I-II-III for details). The evaluation tool for cross-sectional studies consists of five components and 12 items in total. The maximum point can be obtained from was 12. The intervention study was assessed using the Physiotherapy Evidence Database (PEDro) scale, which consists of 11 items. The maximum point is obtained from was 11. The quality of studies are classified into three categories as follows; (<6 points = low, 6–9 points = moderate, ≥10 points = high). The quality of the longitudinal study was assessed by "The critical appraisal skill program" (CSAP) which consists of 12 item and three categories as follows; "low, moderate, high". The rating scores are presented in Table 2.

Results

Search Results

In the following section, we present the study characteristics details of the included studies.

Study Design and Participant Characteristics

Self-reports had reported participants' volleyball background in cross-sectional studies. All included 21 studies were published between 1998 and 2019 and conducted in 14 different countries (Italy=5, Brazil=2, Germany=2, Greece=2, Taiwan=2, Belgium=1, Canada=1, China=1, Iran=1, Israel=1, Japan=1, Poland=1, Spain=1, USA=1). Nineteen studies included control groups, seven of them had a passive control group that received no intervention (volleyball or any other sports activity). Six studies had only active control groups, and six studies administered active and passive control groups. Twenty of the studies were cross-sectional studies, and one was a randomized control study.

Participants were recruited from national sports teams, universities, volleyball courts. Participants' maximum mean age was 33.9, but the minimum mean age was not specified (in a study, there was a group under 14 years old.)

Among the 21 studies, 1438 participants were recruited, of which 967 were volleyball players and 471 were control groups. Group sizes ranged from 7 to 274 participants.

Methodological Quality of Included Studies

Based on this 12-item assessment tool, the average score of the methodological quality of the 19 studies was 7.9 with scores ranging from 5 to 10. Seventeen of the observational studies were found to be of "moderate quality", one study was found to be "low quality", and one study was found to be "high quality". According to the PEDro scale, the methodological quality score of one intervention study was 5 which means "low quality". Lastly, the methodological quality score of only one longitidunal study was "moderate". The rating scores are presented in Table 2.

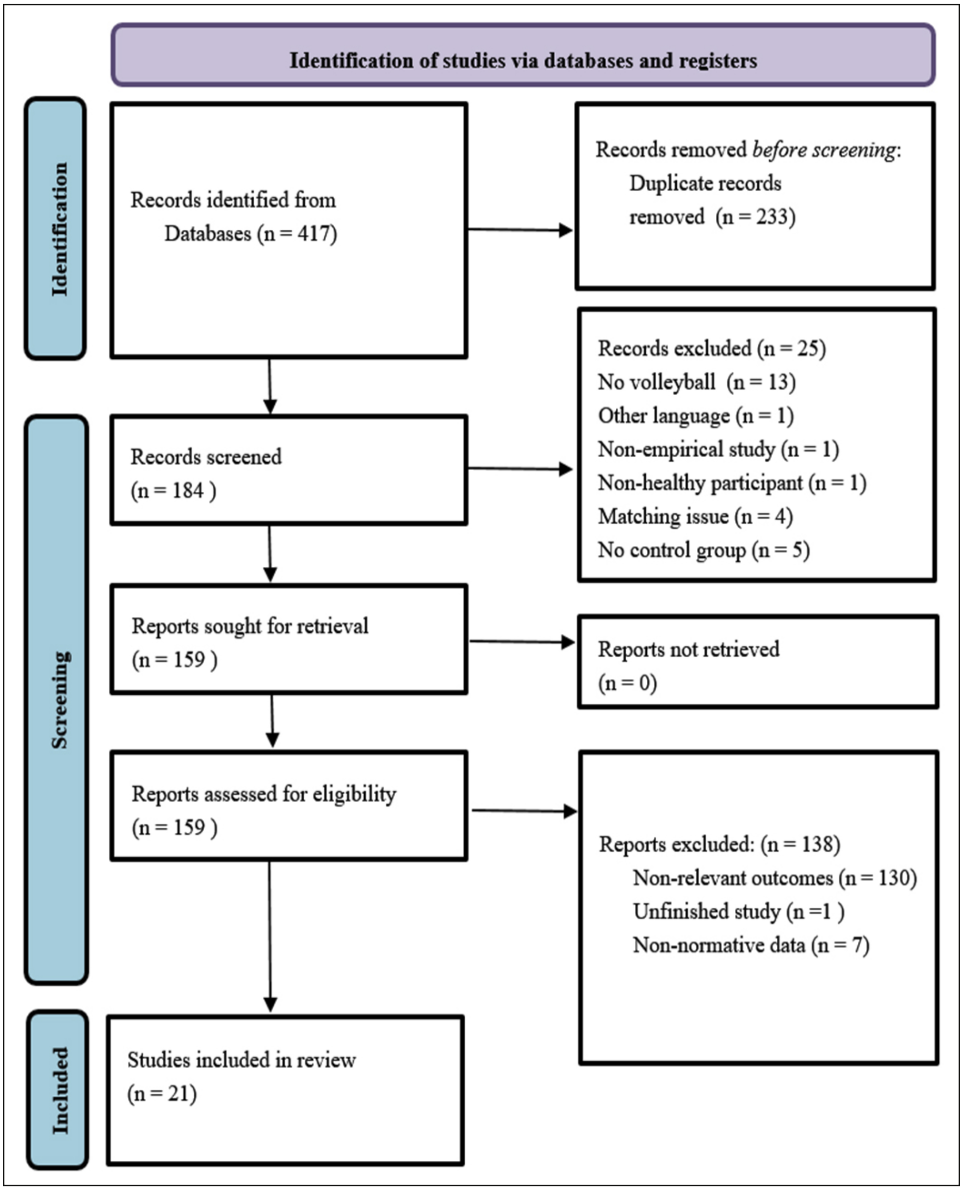

Table 1. *Prisma flow chart*

Table 2. Study characteristics

1st author; Quality score	Sample	Study design	Procedure	Outcome Measures	Results
Alves et al. (2013); (8)	Athlete group Va: n=30 Age=(F: 20.55±1.23, M: 24.85±4.40) Vj: n=57 Age=(F: 16.27±1.06, M: 17.58±0.92) Control group Ca: n=27 Age=(F: 21.55±1.50, M: 23.33±3.04) Cj: n=40 Age=(F: 16.45±1.5, M: 17.33±1.13)	USA, Brazil Two main groups and four subgroups (gender based)	Athlete group: A Control group: C Va: Adult volleybal player (F: 9.66±1.5, M: 11.61±4.75 training years) Vj: Junior volleyball player (F: 5.43±1.94 M: 5.25±2.43 training years) Ca: Adult control group (no training) Cj: Junior control group (no training)	Useful Field of View Visual Short-Term Memory (VSTM) Stopping (stop/go) Flanker Change Detection	Task switching RT: C >A Go RT: A >C Stop RT: C >A Stop probability: A >C Change detection RT: C >A
Chiu et al. (2017); (8)	V: n=11 Age=23.36±0.53 E: n=12 Age=21.50±0.58 C: n=8 Age=21.75±0.70	Taiwan, Three groups	V: volleyball group E: running and swimming group C: no exercise training years: n. a.	Flanker test	Accuracy: V >C V >E (approached significance, p: 0.053)
Costa et al. (2018); (7)	n=34 Nvc: n=n. a Evc: n=n. a Age=32.5±9.4	Brazil, Two groups	Nvc: Novice voleyball coach (<10 years) Evc: Experienced volleyball coach (>10 years)	Decision making task fNIRS: HbO_2 level during EF task	fNIRS: Nvc >Evc (PFC activity)
Fontani et al. (2006); (7)	Vh: n=12 Age=28±5 Vl: n=12 Age=19±2 Kh: n=9 Age=31±5 Kl: n=9 Age=32±5	Italy, Four groups	Vh: Volleyball group, (14±4 years training) Vl: Volleyball group (6±2 years training) Kh: Karate group (13±3 years training) Kl: Karate group (6±3 years training)	Alert Go/No-Go Divided Attention Working Memory reaction	RT Alert, Go/No-Go, Working Memory: Vh >Vl, Kl >Vh Divided Attention: Vh >Vl, Kh >Kl Variability Index Working Memory, Divided Attention: (Vh >Vl) Alert: Kl >Vh Errors Divided Attention: Vl >Vh, Kh >Kl
Giglia et al. (2011); (9)	Vn: n=12 Age=26±4.3 Vr: n=11 Age=25.6±3.4 R: n=10 Age=19.2±4.0 C: n=23 Age=24.8±2.5	Italy, Four groups	Vn: Volleyball group (national) Vr: Volleyball group (regional) R: Rower group C: Control group	Landmark task	RT Vn, Vr <R, C Errors Vn <Vr, R, C (total response) Vn < Vr, R, C (left response)
Gil et al. (2012); (7)	U14:n=261 U16:n=274	Spain, Two groups	U14:under 14 years old group (3.26±1.62 training years) U16:between 14–16 years old group (4.32±1.51 training years)	Declarative Knowledge (DK) Questionnaire Procedural Knowledge (PK) Questionnaire	DK, PK scores: U16>U14
Kioumourtzoglou et al. (1998); (7)	V: n=13 Age=18.5 B: n=12 Age=20.7 WP: n=19 Age=18.3 C1:n=18 Age=22.6 C2:n=21 Age=19.6	Greece, Five groups (only V and C2 are compared)	V: Volleyball group B: Basketball group WP: Water polo group C1:Control group of B C2:Control group of V and WP	Perceptual Speed Focus Attention Prediction Estimation of speed and direction of a moving object	RT Perceptual speed: V <C2 Accuracy Prediction: V >C2
Kioumourtzoglou et al. (2000); (7)	V: n=12 Age=18.5 C: n=18 Age=20.5	Greece, Two groups	V: Volleyball group (at least 10 years training) C: Control group (no volleyball or ball games training)	Perception speed (PS) Prediction Focused Attention Estimation of Speed and Direction of a Moving Object Analytic Ability Grouping of Information Retention of Information (RI)	PS (RT): V <C Prediction (correct response number): V >C Estimation (RT): V <C RI (Error, nonsport-specific task): V <C RI (missed response, nonsport-specific task): V <C RI (missed response, sport-specific task): V <C
Kokubu et al. (2006); (9)	V: n=10 Age=20.1±0.9 C: n=10 Age=22.3±1.3	Japan, Two groups	V: Volleyball group (6.6±2.5 years training) C: Control group (no training)	Saccadic-task Key-press task Dual-task	RT V <C (Key-press task)

Table 2. Study characteristics *(continues)*

1st author; Quality score	Sample	Study design	Procedure	Outcome Measures	Results
Loffing et al. (2015); (9)	V: n=20 Age=24.80±4.01 C: n=31 Age=25.10±3.94	Germany, Two groups,	V: volleyball group (12.40±5.05, training years) C: control group (no training)	Video-based perceptual-cognitive task	Prediction accuracy (target trials; non-target trials): V >C; V >C Response time (target trials; non-target trials): V <C; V <C
McAuliffe. (2004); (5)	V: n=11 Age: n. a. C: n=11 Age: n. a	Canada, Two groups	V: Volleyball group (college volleyball players) C: Control group (no training)	Spatial cueing task	<u>Cueing effect</u> V >C (onset cue–onset target, color cue–color target)
Meng et al. (2019); (10)	VG: n=25 Age=23.6±2.8 BG: n=35 Age=22.7±3.4 CG: n=27 Age=22.8±3.2	Taiwan, Three groups	VG: Volleyball group (11.57±3.1 training years) BG: Badminton group (11.31±3.1 training years) CG: control group (no training)	Inhibition control (Stop signal task) (SST) Attentional shifting (Task-Switching task) (TSWT). Visual sensory memory (Iconic memory task) (ICMT) Visual-spatial attention (Change detection task) (CDT). Attentional processing (Attention networks task) (ANT).	SST (SSR): VG >CG, BG TSWT (Global and Local Cost RT): CG >VG, BG Iconic memory (accuracy): VG, BG >CG ANT (alertness): VG >BG, CG
Nuri et al. (2012); (7)	V: n=11 Age=21.64±1.12 S: n=11 Age=22.91±2.16	Iran, Two groups	V: volleyball group (4.31±1.45, training years) S: sprinter group (4.27±1.47 training years)	Visual choice RT Visual complex choice RT Auditory choice RT Auditory complex choice RT Anticipatory skill (high/low speed)	Both auditory RT: S <V Both anticipatory skill: V >S
Schorer et al. (2013); (9)	Ve: n=11 Age=17.0±2.0 Va: n=13 Age=23.7±1.9 Vn: n=16 Age=23.5±2.3	Germany, Three groups	Ve: Expert volleyball (8.5±2.8 training years) Va: Advanced volleyball (11.9±2.8 training years) Vn: Novice volleyball (no regular training)	Perceptual-cognitive task	prediction accuracy (temporal occlusion): Ve >Va, Vn Va >Vn prediction accuracy (spatial occlusion): Ve >Va, Vn Va, Vn
Tomasino et al. (2012); (9)	V: n=21 Age=26.2±4.9 F: n=21 Age=33.9±8.4 C: n=21 Age=25.61±7.77	Italy, Three groups	V: volleyball group (10.7±3.2 training years) F: fans (7.1±2.6 volleyball watching experience years) C: control group (no training or watching)	Categorization task (CT) (RT, accuracy)	CT (accuracy): V >F, C; F >C CT (RT) V <F, C
Tomasino et al. (2013); (9)	VG: n=10 Age=27±7.35 CG: n=10 Age=25±4.07	Italy, Two groups	VG: Volleyball group (15±2.1 training years) CG: control group (no training)	Categorization task (CT) (RT, accuracy) fMRI	CT (accuracy): VG >CG fMRI: VG <CG (left M1 and left PMC activity for the impossible actions presented as positive commands)
Urgesi et al. (2012); (9)	V: n=12 Age=24.33±5.3 W: n=12 Age=27.5±8.97 C: n=12 Age=29.42±3.5	Italy, Three groups	V: Volleyball group (14.58±4.3 years training) W: Volleyball watchers (at least 10 years) C: Control group (no training or watching)	Prediction *viewing perspective (back, front) *cue (body, ball)	<u>RT</u> C >V, W (Back view (body/ball), front view (body/ball)) <u>Accuracy</u> V >W, C (Back view (body/ball), front view (ball)) W >C (Back view (ball))
Vansteenkiste et al. (2014); (9)	Ve: n=10 Age=20.0±1.2 Vi: n=10 Age=20.9±1.8 C: n=17 Age=20.1±1.6	Belgium, Three groups	Ve: Volleyball group (experienced) Vi: Volleyball group (intermediate) C: Control group (no training)	Visual search task	<u>Accuracy</u> Ve >Vi, Vc <u>RT</u> Ve, Vi <Vc approached significance, p: 0.053)
Zach and Shalom (2016); (5)	n=20 Age=27.3±3.2	Israel, one group, supervised	3 session acute exercise V: volleyball A: submaximal aerobic exercise AN: anearobic exercise	Visual memory span Digit span test (before and after the acute exercise)	V >A, AN (WM↑)
Zhang et al. (2009); (6)	V: n=17 Age:=20.2±1.9 C: n=20 Age=19.0±0.8	China, Two groups	V: Volleyball group (8–10 years training) C: Control group	Multiple object tracking task	<u>RT</u> V <C
Zwierko et al. (2014); (7)	V: n=11 Age=15.09±0.53 C: n=7 Age=14.85±0.38	Poland, Two groups	V: Volleyball group (3.37±0.44 years training) C: Control group (no training) Intervention: 2 years of systematic training for V (twice a day)	Visual evoked potentials	<u>P100 latency</u> V↓ <u>N75 latency</u> V↓

Note: ↑= within group improvements or ↓decrements; > or <= group by volleyball interaction effects; F= Female; fNIRS= functional Near-Infrared Spectroscopy; fMRI: Functional magnetic resonance imaging; HbO_2= Oxygenated Hemoglobin; M= Male, n.a= not available; PFC= Prefrontal Cortex; PMC= Premotor Cortex, RT= Reaction Time, WM= Working Memory.

Cognitive and Neurophysiological Outcome Measures

20 studies assessed at least one relevant cognitive function[7,17–35]. Two studies measured both cognitive skills and neurophysiological parameter[19,31]. There was only one study measured only neurophysiological parameter[36]. Executive functions (EFs) refer to a group of cognitive processes that allow humans to concentrate, plan, organize and make complex judgments[37]. We based on the general consensus that defines three core EFs which are inhibition, working memory and cognitive flexibility to assess the studies[38,39]. Given this model, there were fourteen studies that assessed core EFs[7,17,18,20,23–29,33–35].

As displayed in Table 1, eleven studies reported that playing volleyball decreases reaction times in cognitive tasks compared to untrained controls[7,17,21,23–26,30,32,33,35]. Two studies demonstrated that experience had an effect on reaction times;[20,21] experienced volleyball players were faster than novice ones in cognitive tasks. Additionally, two studies pointed out the effect of sport type on reaction times with contradictory findings[21,28].

Fourteen studies reported that playing volleyball increases the accuracy scores in visuopatial attention,[18,20,21,33] prediction,[23,24,26,28,29,32] categorization,[30,31] and working memory[7,34] tasks. See Table 1 for more comprehensive details of the outcome measures.

Discussion

In this review, we present an attentive overview of the effects of playing volleyball on healthy people's cognitive skills and brain functions. We found 21 studies that assessed the effects of playing volleyball on cognitive functions and neurophysiological parameters. Overall, playing volleyball has been shown to improve specific cognitive functions.

The first research that published the data about the association between cognitive functions and physical activity decades ago demonstrated that men regularly participating in sports outperform in reaction time tasks than their sedentary counterparts[40]. Since the first publication, an increasing body of evidence showed that exercise improves cognitive function, particularly EFs[1,41]. Consistent with the literature, most of the research reviewed within this study's scope suggested that volleyball players exhibited superior abilities in EFs as attention management, working memory, inhibition, and tasks of cognitive flexibility.

Effect of Training Characteristics of Volleyball

Motor and cognitive switching tasks are frequent while playing volleyball which is an open-skill exercise. Volleyball players must constantly adapt or switch to more proper actions to respond to the opponent's actions. They have to follow not only the rules of the game but also improve accurate strategies. An exercise that requires substantial cognitive demands such as volleyball may change neurocognitive functioning and affect the brain activation associated with EFs. Previous findings demonstrated that open-skill exercise improves cognitive flexibility at switching tasks[42,43] and led to greater improvement in inhibitory control[44,9], cognitive flexibility,[42,43,45,46] audio-visual perception,[47] problem solving,[48] visuospatial short-term memory[49] and visuospatial attention[50]. In line with the literature, four studies in this review supported that volleyball was more effective to improve cognitive skills than closed-skill sports. Volleyball effects were superior to closed-skill sports such as running, rowing, sprinting, aerobic/anaerobic activity in visuospatial attention processing, inhibition, anticipatory skill, working memory.

In this review, volleyball players were reported to have shown superior cognition scores than karate and badminton athletes[7,20]. Although karate and badminton are open-skill sports, the more significant effect of volleyball may be explained by its being a team sport. The social support that can arise from being a part of a team might positively affect cognitive skills[51].

Motor coordination involves a balanced, fast, and precise motor response that harmonizes the nervous and musculoskeletal systems. Sensory input, perceptual and cognitive processing, action production must occur in the proper sequence. Neuroimaging studies indicate that some brain regions such as the cerebellum and basal ganglia formerly thought to be only related to the motor activity are also activated during specific cognitive activities[52]. The prefrontal cortex, posterior parietal cortex, and cerebellum network are involved in cognitive functions such as working memory, attention, perception[53].

Chasing the ball and response selection in a volleyball match needs attentional control, visual processing (cerebellum, dorsolateral prefrontal cortex, posterior parietal cortex, middle occipital cortices), and planning (anterior cingulate cortex, supplementary motor areas)[53,54]. It was demonstrated that coordinative exercise interventions had shown more positive effects on cognition than standard sport lessons[55]. Studies showing the linear relationship between motor coordination and academic achievement are also evidence of how motor coordination improves cognition[56,57]. Due to volleyball being a sport involving complex motor tasks such as balance control, quick responses, and task-switches, the network mentioned above may be activated during the game.

A top-down control process is demanded to perform convenient judgment, accurate decision-making, and timely action in a coordinated and flexible way. Decision-making is a part of executive control, and the prefrontal cortex is the main area for this task. It is one of the most effective cognitive processes needed while playing volleyball. That executive function accomplishes identifying and choosing alternatives based on the advantages and preferences[58]. In order to maximize the performance, quick and accurate decision is essential in volleyball. This repetitive cognitive process may explain why the volleyball players are better at decision-making tasks[19,22]. Indeed, the fMRI study included in the review showed that volleyball players' activity in the left primary motor cortex hand area and the left premotor cortex was decreased in impossible actions whereby their accurate decision-making mechanism[31]. One possible explanation is that volleyball experts are able to discriminate possible vs. impossible actions, anticipate the context and use neural resources in this direction. Exposure to regular and repetitive commands and contexts in sport might improve the implicit motor simulation context in expert players so that expert players make more accurate decisions by recruiting fewer neural resources.

Neurobiological Considerations

Greater cardiorespiratory fitness is associated with better cognitive functioning[59]. Some researchers have suggested that exercise-induced increased levels of neurotrophins and increased cerebral blood flow explain the link between cardiorespiratory fitness and cognition. Training methods in volleyball create a higher metabolic profile and involve jumping and plyometric exercises designed to produce quick and explosive movements. Greater explosive strength had been associated with better cognitive function, information processing speed, and inhibitory control[60,61]. One possible explanation for the link between explosive strength and cognitive tasks is that they share similar physiological mechanisms. After the stimulus arrives at the sensory organ, a neural signal is created, and transmission, processing, and muscle activation occur[62]. From this point of view, athletes who can generate faster muscle activation may develop a faster reaction in cognitive tasks. This mechanism might explain the shorter reaction times in volleyball players. EEG study results supported that idea by showing that playing volleyball reduced signal conductivity time through the visual pathway and indicated that playing volleyball can affect very early sensory processing[36].

The location of the mirror neuron system (MNS) in the human and its function in understanding the movement and social cognition was demonstrated by previous work[63–66]. A recent study has shown the positive effect of exercise on the MNS[67]. Because volleyball is a team sport, both the opponent's and the teammates' actions and gestures must be followed during the game.

This recurrent experience may have an effect on the MNS of the volleyball player. It is possible to be activated the MNS to predict the opponent's movement and change or withdraw the planned action during the game so that enhanced MNS activation may contribute to the other cognitive tests that involve these tasks' anticipatory skills and inhibition.

One general hypothesis described as the broad transfer is that skill transfer will occur if the original and transfer tasks include overlapping processing elements and engage, at least in part, the same brain regions[68]. This idea may explain transfer from cognitive skills acquired during sports training and similar processes outside of the domain of sport[69]. Previous research findings into the broad transfer hypothesis have been inconsistent and contradictory. One study supports the broad transfer hypothesis by demonstrating that the expertise of athletes can be transferred to non-sports-specific contexts[70]. On the contrary, one study rejects the idea of the transfer hypothesis[71]. In the majority of research in this review the decrease of reaction times in favor of volleyball players may be the result of a skill acquired by athletes over years' practice and transferred to a non-sporting context[7,17,20,23–26,28,30,33,35]. In line with this opinion, a meta-analysis showed that athletes outperformed non-experts in cognitive skills like processing speed and visual attention[72].

Conclusion

Understanding how the brain differentiates following sports experience is essential to ensure that exercise is part of preventive and remedial interventions. The results presented here demonstrated playing volleyball is an improving way for cognition. Based on these outcomes, we concluded that the effects of volleyball experience on working memory, inhibition, visuospatial skills, attention shifting, perception, basic processing network are reflected essentially in measures of accuracy and reaction times.

Nevertheless, much remains to be learned about the relationship between sports experience and cognition, particularly influencing factors and underlying mechanisms. Further research on various sports disciplines and cognitive relationships should address different target groups and individual needs.

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Supplementary

Supplementary Table I. Quality assessment of observational studies

1st author, year	Quality scoring	Final score
Alves et al. (2013)	1-1-0-1-0-1-0-1-1-1-1-0	8
Chiu et al. (2017)	1-1-0-1-1-1-0-0-1-1-1-0	8
Costa et al. (2018)	1-1-0-0-1-0-0-0-1-1-1-1	7
Fontani et al. (2006)	1-1-0-1-1-0-0-0-1-1-1-0	7
Giglia et al. (2011)	1-1-0-0-1-1-0-1-1-1-1-1	9
Gil et al. (2012)	1-1-0-1-0-0-0-1-1-1-1-0	7
Kioumourtzoglou et al. (1998)	1-1-0-0-1-0-0-1-1-1-1-0	7
Kioumourtzoglou et al. (2000)	1-1-0-0-0-1-0-1-1-1-1-0	7
Kokubu et al. (2006)	1-1-0-1-1-1-0-1-1-1-1-0	9
Loffing et al. (2015)	1-1-0-1-1-0-0-1-1-1-1-1	9
McAuliffe. (2004)	1-1-0-0-0-0-0-1-1-0-1-0	5
Meng et al. (2019)	1-1-1-0-1-1-0-1-1-1-1-1	10
Nuri et al. (2012)	1-1-0-0-1-0-0-1-1-1-1-0	7
Schorer et al. (2013)	1-1-0-0-1-1-0-1-1-1-1-1	9
Tomasino et al. (2012)	1-1-0-1-1-1-0-1-1-1-1-0	9
Tomasino et al. (2013)	1-1-0-1-1-1-0-1-1-1-1-0	9
Urgesi et al. (2012)	1-1-0-1-1-1-0-1-1-1-1-0	9
Vansteenkiste et al. (2014)	1-1-0-1-1-1-0-1-1-1-1-0	9
Zhang et al. (2009)	1-1-0-1-0-0-0-1-1-0-1-0	6

Supplementary Table II. Quality assessment of intervention study

1st author, year	Quality scoring	Final score
Zach and Shalom (2016)	0-0-0-1-0-0-0-1-1-1-1	5

Supplementary Table III. Quality assessment of cohort study

1st author, year	Quality scoring	Final score
Zwierko et al. (2014)	+ + ? ? - + + + + - ? +	Moderate

A. Items of quality assessment tool for observational studies.

Study purpose

1. Was the study purpose clearly stated?

Study design and methods

2. Were eligibility criteria and the sources and methods of selection of participants clearly defined?
3. Were all outcomes, exposures, predictors, potential confounders, and effect modifiers clearly defined using standardized methods of acceptable quality?
4. Was exposure measurement carried out using standardized methods and measures and with acceptable quality?
5. Were the effects controlled for current (from physical activity assessment to cognitive function assessment) physical activity behavior?
6. Were the results adjusted for sedentary behavior?

Statistical methods

7. Was choice of confounders adjusted for, and in the case of subgroup analysis, was the definition of subgroups appropriate (sex, age, education or IQ, social surroundings, chronic diseases, alcohol, and smoking)?
8. Were all statistical methods, including those used to control for confounding and to examine subgroups and interactions, appropriate (i.e. sample size, statistical power)?
9. Were methods dealing with missing data appropriate?

Results

10. Were descriptive data and results of inductive analysis clearly stated?
11. Were unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (e.g., 95% confidence interval) given?

Discussion

12. Were study limitations clearly stated?

B. Items of quality assessment tool for intervention studies.

1. eligibility criteria
2. randomization
3. concealed allocation
4. similar baseline
5. blinding of all subjects
6. blinding of all therapists
7. blinding of all assessors
8. more than 85% retention
9. intention to treat analysis
10. between-group comparison
11. point measures and measures of variability

C. Critical appraisal skill program (CASP) score criteria of Oxford Center for Evidence-based Medicine

1. Whether the study address a clearly focused issue
2. Whether the cohort were chosen in an acceptable way
3. Whether the exposure precisely measured to reduce bias
4. Whether the outcome precisely measured to reduce bias
5. Whether the authors identified all significant confounding factors
   Whether they considered con-founding factors in the design or analysis
6. Whether the follow up of subjects was complete
   Whether the follow up of subjects was long enough
7. Whether the result of this study in complete
8. Whether the result was accurate
9. Whether the result of the study in believable
10. Whether the result could be applied to local population
11. Whether the result fit with other available evidence
12. Whether this study provided implication for practice