Research Article

Association of cognition and its impact on physical performance in female football players with a history of concussion: a cross sectional study

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ABSTRACT

Background: Cognitive skills are important in athletics, especially in football, because quick thinking, teamwork and fast reaction times are key. Concussions have different results for female athletes than for males which can result in changes in both cognitive and physical performance. Yet, there is not much information available on cognition and performance link in female football players who have had concussions.

Objective: To determine the association between cognitive function and physical performance in female football players with a history of concussion.

Methodology: This cross-sectional study included n=84 female football players aged 14–25 years. Verbal Cognition Test (VCT) for executive function, Delayed Word Recall (DWR) for working memory, Digit Backward (DB) for memory and Attention and Month in Reverse Order (MRO) for executive function were used to test cognitive function. Physical performance assessments included the Vertical Jump, Run Three, 505 Agility and 3-HOP Tests (both right and left legs). The study used a multiple regression analysis while controlling for age, BMI, amount and timing of play, number of headings during games, collisions and temporary loss of consciousness.

Result: The results show that having lesser VCT and MRO leads to poorer results in the 3-HOP Right Leg test ($p<0.05$). Practicing high-heading skills allowed athletes to complete Run Three faster ($p=0.043$). Nearly significant findings indicated that concussion history did play a moderating role in the results ($p=0.079$). For Vertical Jump, 505 Agility and 3-HOP Left Leg tests, no significant relationships were discovered.

Conclusion: The performance of female football players in lower-body power and agility is affected by cognitive functions, especially by verbal skills and reaction time.

Keywords: concussion; cognition; female football players; physical performance

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INTRODUCTION

Concussion is a mild type of traumatic brain injury with sudden blow to head[1]. Sport-related concussion is the result of a collision that affects the brain, causing a brief loss of neurological function and usually no structural damage[2]. The most frequent symptoms of sports-related concussion are severe headaches and neck pain, problems with balance, cognitive problems, sleep problems, and mental disorders[3]. Repetitive incidence of heading has been linked with the neuro inflammatory changes and minor disturbances in neural functioning that may influence memory, attention, and how the brain processes information. (Cognition)[4].

Females exhibit higher concussion rates due to anatomical differences (e.g., neck strength) and hormonal influences[5]. Post-concussion, cognitive deficits may impair reaction time and coordination[6]. Football is a high contact sport that places a lot of physiological stress on the body and needs both aerobic endurance, anaerobic power and high bursts of energy. A typical match can see players cover up to 15 kilometres and the vast majority of this movement happens at close to 70% of their VO_2 max[7].

Cognition encompasses mental processes such as perception, memory, reasoning, and problem-solving, which are critical for athletic performance[8]. In football, cognitive abilities enable players to anticipate opponents' moves, execute strategies, and adapt to dynamic game situations[9]. Jean Piaget's theory highlights that cognitive maturation, particularly abstract reasoning, enhances decision-making in sports[10]. Female football players rely on executive functions (e.g., working memory, attention) for tactical execution[11]. Cognitive process like perception & Attention essential for tracking ball movement and teammate positioning[3]. Executive functions in cognition influence agility and response inhibition in football[12]. Social cognition facilitates teamwork and emotional regulation[13].

The available research showed that female athletes may experience concussions differently as compared to male, with higher susceptibility, more severe symptoms, and prolonged recovery. Gender based differences including neck muscle strength, hormonal changes, biomechanics, and symptom reporting, may further affect the relationship between cognition and physical performance. Despite increasing number of female footballers, gender specific research on concussion is limited. This study was aimed to investigate the impact of cognitive function on physical performance in female players with concussion history.

METHODOLOGY

Study design: Cross-sectional study conducted at Pakistan Sports Complex Islamabad, Pakistan Sports Complex Peshawar and football clubs (2024-2025). This study was approved by the Pakistan Sports Board(PSB-Pesh/July/30-1). It was carried out according to the principles stated in the Declaration of Helsinki with informed consent was obtained from participants.

Participants: Participants included were active female footballers, aged 14–25 and either have no history of concussion or have experienced one in the past 1 month, participating in practices or games that involve frequent heading. The criteria for exclusion were recent Musculo-skeletal injuries, concussion not linked to sports, diagnosed neurological/psychiatric disorders, malignancies and substance abuse. A non-probability convenience sampling technique was used for sample collection.

Outcome measures: To predict the association between cognitive function and physical performance in female football players with a history of concussion by using a structured questionnaire having demographics, Cantu grading system for concussion[14], and SCOAT-6[15]. Physical performance was evaluated through the Vertical Jump (explosive power), Run Three (acceleration and speed), 505 Agility (change-of-direction ability), and 3-HOP Test (unilateral leg power). Cognitive function was assessed using four standardized tests: the Verbal Cognition Test (VCT) for language processing, Delayed Word Recall (DWR) for memory, Digit Backward (DB) for working memory, and Month in Reverse Order (MRO) for reaction time and executive function by SCOAT-6. Covariates included age, body mass index (BMI), daily playtime (hours), and heading frequency (ball impacts per session) to control for confounding factors.

Sample size: A total of n=99 participants were required as calculated through G*Power version 3.1.9.7, keeping effect size medium (f^2=0.15), α error probability at 0.05, and power (1-β) at 0.90 with 3 predictors. A total of N=99 female football players were screened for eligibility, with n=84 meeting inclusion criteria and completing the study protocol. The final sample had a mean age of 18.4±2.1 years, with 11 participants (13.1%) reporting a history of concussion.

Statistical methods: The data was presented using tables and graphs, where continuous variables showed mean±SD and categorical variables showed numbers and percentages. Multiple linear regression was carried out to explore the relationship between mental and physical tests (VCT, DWR, DB, MRO; Vertical Jump, Run Three, 505

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Agility and 3-HOP). Concussion history (Yes/No) was considered as a moderator variable to investigate for interactions. The variables age (years), BMI (kg/m²) and playtime in hours per week were treated as continuous, while heading frequency, history of head collisions and episodes of losing consciousness were treated as categorical. All analyses were done using SPSS version 26 and results were considered statistically significant if p<0.05.

RESULTS

In this study, the performance of cognitive and performance was examined in 84 female football players (mean age 18.4 ± 2.1). The important outcomes are being discussed. A multiple linear regression analysis used to find the association of cognition and physical performance with history of concussion as moderator. The concussion history did not significantly moderate cognition-physical performance relationships (p > 0.05), a trend-level interaction was noted for the 3-HOP Right Leg (Concu_VCT: β=0.126, p=0.079)

The explained variance was low across tests, with R^2 ranging from 0.036 for Vertical Jump to 0.189 for the 3-Hop Test (Right/Left average), indicating that most predictors accounted for a small proportion of performance variability. Verbal Cognition Total (VCT) had a significant negative effect on right-leg 3-Hop Test performance (β=-0.048, p=0.027). The left-leg 3-Hop Test showed a similar trend (β=-0.023, p=0.470), leading to a mean β=-0.036, p=0.249. Month in Reverse Order (MRO) also showed a significant negative association with the right-leg 3-Hop Test (β=-0.013, p=0.004), with the left-leg showing a non-significant trend, producing a mean β=-0.011, p=0.085. While other cognitive measures (Delayed Word Recall, Digit Backward) did not significantly predict performance. The Heading frequency was significantly associated with Run Three Test performance (β=-0.121, p=0.043), suggesting a small negative effect of heading frequency on running agility. The Concussion history, head collision frequency, loss of consciousness, age, BMI, and playtime did not significantly predict performance across any test, although concussion history showed a non-significant trend toward lower 3-Hop Test scores (mean β=-2.04, p=0.263). (table 1)

Table 1. Physical Performance with Cognitive, Demographic, and Head Injury Predictors

Model / Predictor	Vertical Jump	Run Three Test	5-0-5 Agility Test	3-Hop Test (Right/Left mean)
R^2	0.036	0.049	0.077	0.189
Adjusted R^2	−0.026	0.012	0.018	-
p-value	*0.715*	*0.546*	*0.269*	*0.052*
Cognition only (1)	-	-	-	-
Verbal Cognition Total (VCT)	β=0.126, p=0.378	β=0.042, p=0.577	β=−0.010, p=0.783	β=−0.036, p=0.249
Delayed Word Recall (DWR)	β=−0.079, p=0.803	β=0.274, p=0.101	β=0.032, p=0.702	β=−0.049, p=0.510
Month in Reverse Order (MRO)	β=−0.026, p=0.402	β=0.011, p=0.495	β=−0.004, p=0.607	β=−0.011, p=0.085
Digit Backward (DB)	β=−0.402, p=0.391	β=0.006, p=0.982	β=0.119, p=0.335	β=−0.033, p=0.491
Cognition × Concussion (2)	-	-	-	-
Concussion × VCT	β=−0.129, p=0.787	β=0.185, p=0.459	β=0.132, p=0.293	β=0.124, p=0.244
Demographics (3)	-	-	-	-
Age (years)	β=0.015, p=0.614	β=−0.071, p=0.508	β=−0.041, p=0.452	β=0.011, p=0.803
BMI (kg/m²)	β=−0.029, p=0.325	β=0.013, p=0.901	β=0.010, p=0.842	β=−0.007, p=0.868
Playtime (hours/day)	β=−0.057, p=0.614	β=−0.289, p=0.470	β=−0.091, p=0.652	β=−0.047, p=0.777
Heading exposure (4)	-	-	-	-
Heading frequency	β=−0.046, p=0.680	β=−0.121, p=0.043*	β=0.002, p=0.937	β=0.011, p=0.662
Head injury severity (5)	-	-	-	-
Concussion history (Yes)	β=3.173, p=0.749	β=−6.196, p=0.236	β=−4.325, p=0.101	β=−2.04, p=0.263
Head collision frequency	β=−0.103, p=0.667	β=−0.393, p=0.642	β=−0.140, p=0.742	β=−0.176, p=0.616
Loss of consciousness	β=−0.155, p=0.849	β=2.738, p=0.340	β=1.366, p=0.342	β=−0.533, p=0.654

Significance level- p<0.05, p<0.01** * p<0.001**

R^2-proportion of variance in the dependent variable explained by the regression model; Adjusted R^2- the number of predictors and adjusts R^2 for model complexity; β -is the unstandardized regression; VCT-Verbal Cognition Total ; DWR -Delayed Word Recall ; MRO- Month in Reverse Order ; DB -Digit Backward

DISCUSSION

The result of recent study revealed that concussion history showed a trend toward significance but was not a strong moderator of the cognition-performance link.

A study from literature by McGroarty et al. (2020) said that although many female athletes appear to have characteristic symptoms following a concussion, they often end up with results similar to those who did not get a concussion[6]. Although concussions were not a key part in recent study results, they still appear to have some micro effects. It is clear from studies in literature that female athletes may not handle cognitive difficulties after concussion as well as male athletes, though they are better at recovering with more adjustments or a longer rehab process[16,17]. There might not be a strong moderating effect because of this study sample reflects a well-done recovery or there isn't enough data. However, it points out that everyone

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requires an individualized evaluation of cognitive-physical functioning after a concussion[18].

The current result showed link with poor verbal cognition was associated with poorer performance in the 3 HOP Right test moderated by concussion history, indicating that athletes with weaker executive verbal function struggled more in lateral dynamic tasks. The result from recent study in line with the result of a study which concluded that the cognitive skills of verbal fluency and flexibility of thinking helped predict how individuals would do physical performance test in elite football[16].

The current study result get support by a retrospective study by Baillargeon et al. adolescents have continuing neurophysiological impairments after concussion, likely because of the continued development of the frontal lobes, which influences the working memory and executive functioning[17]. A study related to concussion also showed balance problem by cognitive deficit[19]. So, the result of recent and previous study proves that verbal thought processes, belonging to executive function, are very important for dynamic body movements. Lack of verbal fluency can suggest problems with both processing information and controlling attention which makes it hard for athletes to respond to abrupt spatial changes in power-based sports[20].

As female players may notice this connection between working memory flexibility and gameplay challenges more clearly because of differences in how they are mentally engaged. So, these finding highlights why neurocognitive tests are so important in sports performance and injury prevention[21,22]. The significant relationship is found between MRO and 3 HOP Right performance in this study in concussed athletes. This tells that athlete who performed poorly in the MRO task tended to have weaker lower-limb outcomes. According to literature by Höfflin et al. (2021) result also support the result of study that slower handling of tasks and less efficient mental processing in dual tasks were connected to lower jump and agility test results in female athletes[17].

The mechanism of MRO task requires people to use their memory and attention in order to control difficult body movements. Any reduction in cognitive flexibility can hinder an athlete's ability to quickly interpret and use the information they get from proprioception and space when making explosive movements[23]. The findings confirm that performing neuromechanical coordination in difficulty lower-body movements depends partially on attention from the brain. It is especially important after a concussion because some testing may not detect changes in working memory[24].

The recent study result show that more frequent heading is significantly associated with better scores in the Run Three Test, indicating enhanced speed and agility in athletes with concussion. The result have support from previous study by Hermsdörfer et al. showed that there were no serious short-term harms to cognition or sensorimotor skills from heading for semi-professional female soccer players[25]. Another study concluded; players who often head the ball might have better neck strength, coordination and conditioning for their sport, leading to improved sprinting ability[26]. While these findings are a challenge to the belief of universal harm caused by frequent heading. So, there should be cautious, because repeated heading can result in long-term decline in mental functioning, according to literature[27]. It makes us wonder how severe the impact of heading can be and suggests looking further into different exposure limits for men and women.

The current result showed that no significant association found between cognitive test performance or concussion history and t physical performance tests(505 Agility Test, VJT.3HOPL) This current result can be proven by previous literature Krenn et. al. (2022) result showing that executive functions(cognition) do not matter as much for simple, straight movements which instead rely more on physical skills[28]. These result from current study and literature can be proven with this mechanism that some physical test results do not change much with different levels of cognitive ability. Because of the strict rules, these movements depend on strong muscles and technique, not so much on what the mind can do[29].

The result from current study for better performance in pressure-demanding dual-tasks is linked with superior cognitive scores, particularly in executive and attentional domains. According to literature, athletes who possess higher cognitive abilities and can keep their cool often do better in tasks where they need to make quick, tough decisions[30] .

These results get support by mechanism of response inhibition, working memory and cognitive flexibility are seen as key abilities in high-pressure settings. In football for women, because the action is fast and challenging, these mental strengths tend to be important when things matter most. It backs the addition of cognitive drills (pressure situations) to training in sports and supports the rise of cognitive readiness in scientific approaches to performance[30].

The sample size was relatively small only 11 participants reporting a recent history of concussion (13.1%), reducing the statistical power to detect

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moderation effects of concussion on cognition-performance relationships. Furthermore, the study only considered recent concussions within one month and did not assess cumulative or historical concussions, which may have long-term neurocognitive or physical performance effects.

CONCLUSION

It is concluded that although concussion history did not show a significant impact on relation between cognition and physical performance in female football players. But verbal cognition and reaction time played a big role in predicting their lower-body power showed a significant association. Future investigations should use long-term designs and images of the brain to better understand cognitive problems after concussions.

DECLARATIONS & STATEMENTS

Author's Contribution

SK, MFA and A: substantial contributions to the conception and design of the study.
SK, RM, MFA and MH: acquisition of data for the study.
SK: interpretation of data for the study.
SK, SK, and RM: analysis of the data for the study.
SK, SK, RM, MFA, A and MH: drafted the work.
SK, SK, RM, MFA, A and MH: revised it critically for important intellectual content.
SK, SK, RM, MFA, A and MH: final approval of the version to be published and agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. All authors contributed to the article and approved the submitted version.

Ethical Statement

Cross-sectional study conducted at Pakistan Sports Complex Islamabad, Pakistan Sports Complex Peshawar and football clubs (2024-2025). This study was approved by the Pakistan Sports Board(PSB-Pesh/July/30-1).

AI Use Statement

The authors used Grammarly to improve language clarity during manuscript preparation. Generative AI tools such as ScisSpace and Semantic Scholar were used to assist with literature summarization and refinement of the research rationale. All interpretations, conclusions, and original ideas remain solely those of the authors and approved by the authors.

Consent Statement

Written informed consent was obtained from all participants prior to study participation. Permission for publication of the data was obtained, and confidentiality was strictly maintained.

Data Availability Statement

The data presented in this study are available on request from the corresponding author.

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Funding Sources

None to declare.

Conflicts of Interest

None to declare.

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