Akdeniz Spor Bilimleri Dergisi

Mediterranean Journal of Sport Science

ISSN 2667-5463

The Effects of Fatigue on Visual Reaction Time, Vertical Jump, and Strength in Adolescent Female Basketball Players

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DOI: https://doi.org/10.38021asbid.1742932

ORIGINAL ARTICLE

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Received:
15.07.2025

Accepted:
25.08.2025

Online Publishing:
28.09.2025

Abstract

Physical and cognitive performance in athletes is closely related to training intensity and fatigue level. In high-intensity sports, fatigue can negatively affect motor and cognitive skills. Investigating how young athletes respond to these effects is important for maintaining performance. Accordingly, the aim of this study is to examine the effects of fatigue on visual reaction time, vertical jump performance, and handgrip strength in adolescent female basketball players. Ten adolescent female basketball players (15.70 ± 1.56 years; 59.70 ± 11.90 kg; 168.10 ± 7.07 cm) who were licensed and actively playing in Konya voluntarily participated in the study. Visual reaction time (using the FitLight™ system), vertical jump (Takei jump-meter), and handgrip strength (Takei hand dynamometer) tests were administered before and after fatigue. Fatigue was induced by a standardized 20-minute full-court basketball match following official game rules, including 5 vs 5 players with continuous play. Data were analyzed using SPSS 25.0; normal distribution was assessed with the Shapiro-Wilk test, and paired samples t-test was used to compare pre- and post-fatigue values. After fatigue, visual reaction time significantly increased in both the dominant and non-dominant hands. A significant decrease was also observed in dominant handgrip strength. However, no statistically significant change was found in non-dominant handgrip strength or vertical jump performance. Fatigue has a particularly negative impact on cognitive-motor skills (reaction time and grip strength) in adolescent female basketball players, while its effect on lower extremity explosive power appears to be limited. These findings may inform the design of training loads and recovery protocols in adolescent female athletes to mitigate fatigue-related performance drops.

Keywords: Basketball, Fatigue, Handgrip Strength, Visual Reaction Time

Adölesan Kadın Basketbolcularda Yorgunluğun Görsel Reaksiyon, Dikey Sıçrama ve Kuvvet Üzerindeki Etkileri

Öz

Sporcularda fiziksel ve bilişsel performans, antrenman yoğunluğu ve yorgunluk düzeyi ile yakından ilişkilidir. Yüksek yoğunluklu sporlarda yorgunluk, motor ve bilişsel becerileri olumsuz etkileyebilir. Genç sporcuların bu etkilere nasıl tepki verdiğini araştırmak, performansın korunması açısından önem taşır. Bu doğrultuda, bu çalışmanın amacı, ergen kadın basketbolcularda yorgunluğun görsel reaksiyon süresi, dikey sıçrama performansı ve el kavrama kuvveti üzerindeki etkilerini incelemektir. Konya ilinde lisanslı olarak aktif şekilde basketbol oynayan on ergen kadın basketbolcu (15,70 ± 1,56 yaş; 59,70 ± 11,90 kg; 168,10 ± 7,07 cm) gönüllü olarak çalışmaya katılmıştır. Yorgunluk öncesinde ve sonrasında görsel reaksiyon süresi (FitLight™ sistemi), dikey sıçrama (Takei jump-metre) ve el kavrama kuvveti (Takei el dinamometresi) testleri uygulanmıştır. Yorgunluk, resmi oyun kuralları çerçevesinde, 5'e 5 oyuncuyla ve kesintisiz oyun formatında oynanan standartlaştırılmış 20 dakikalık tam saha basketbol maçı ile sağlanmıştır. Veriler SPSS 25.0 programı ile analiz edilmiş; normallik dağılımı Shapiro-Wilk testiyle değerlendirilmiş, öncesi-sonrası değerlerin karşılaştırılması için eşleştirilmiş örneklemler t-testi uygulanmıştır. Yorgunluk sonrasında hem dominant hem de non-dominant elde görsel reaksiyon süresinin anlamlı şekilde arttığı görülmüştür. Dominant el kavrama kuvvetinde de anlamlı bir azalma tespit edilmiştir. Buna karşın non-dominant el kavrama kuvveti ve dikey sıçrama performansında istatistiksel olarak anlamlı bir değişiklik bulunmamıştır. Yorgunluğun, ergen kadın basketbolcularda özellikle bilişsel-motor beceriler (reaksiyon süresi ve kavrama kuvveti) üzerinde olumsuz bir etkisi olduğu, alt ekstremite patlayıcı gücü üzerindeki etkisinin ise sınırlı kaldığı görülmektedir. Bu bulgular, ergen kadın sporcularda yorgunluğa bağlı performans düşüşlerini azaltmaya yönelik antrenman yükü planlaması ve toparlanma protokollerinin geliştirilmesine katkı sağlayabilir.

Anahtar Kelimeler: Basketbol, Yorgunluk, El Kavrama Kuvveti, Reaksiyon Süresi.

Introduction

Basketball is a team sport in which a distance of 5,500 to 6,500 meters is covered during a game (Oba and Okuda, 2008), and where short-duration, high-intensity activities such as passing, jumping, shooting, changing direction, defending, and sprinting are frequently repeated (Ivanović et al., 2022). These high-intensity physical activities can lead to physical and mental fatigue, especially toward the end of a game, negatively impacting performance.

Fatigue is defined as a temporary reduction in muscle performance and involves both central (at the nervous system level) and peripheral (at the muscular level) mechanisms (Gribble and Hertel, 2004; Barker et al., 2015). In high-tempo sports like basketball, fatigue affects many parameters such as motor control, reaction time, force production, decision-making speed, and balance. Impairments in these parameters can lead to declines in both team dynamics and individual performance (Gandevia, 2001).

Fatigue has been shown to influence several physiological functions, one of which is visual reaction time. This term refers to the interval between the appearance of a visual stimulus and the individual's motor response to it (Meng et al., 2015). It encompasses the full sequence of neural processes—from the initial registration of the image on the retina to the eventual activation of the muscles involved in the response (Patel & Rathi, 2019).

Reaction times are influenced by factors such as age (Garg et al., 2013), arousal level (Gierczuk et al., 2017), gender (Karia et al., 2012), and stimulus size (Malhotra et al., 2015). In basketball, reaction time can directly influence the score, especially in defensive situations.

In addition to reaction time, vertical jump represents another key neuromuscular component in basketball, playing a crucial role in actions such as blocking and rebounding. Basketball involves 35 to 46 jump-and-landing actions per game and includes 2 to 4 times more vertical movements than football and volleyball (Matthew and Delextrat, 2009; Nedelec et al., 2014). Therefore, a decrease in vertical jump performance can create disadvantages during critical moments of the game, such as blocking and rebounding (Izquierdo and Redondo, 2020).

Grip strength plays a crucial role in basketball, as many fundamental movements—such as catching, gripping, shooting, and passing the ball—require sustained activation of the wrist and finger flexor muscles (Cortis et al., 2011; Visnapuu & Jürimäe, 2007). In sports that heavily depend on handgrip ability, fatigue-related declines in grip strength may negatively impact an athlete's ability to control the ball effectively.

Athletes must adapt to the physical, mental, and psychological loads they are exposed to during games and training. However, this adaptation varies by gender. Female athletes differ physiologically and in recovery processes compared to male athletes. Muscle structure and hormonal fluctuations can also influence how fatigue is managed (Fort-Vanmeerhaeghe et al., 2023). It has been emphasized that the risk of injury in situations like ankle sprains (Hosea et al., 2000) and ACL tears (Paterno et al., 2010) is higher in female athletes than in males due to fatigue. Especially during adolescence, the disproportionate development of motor skills increases the risk of sports injuries. Assessing adolescent basketball players is essential, as this stage represents a critical period in their development, bridging the gap between youth potential and elite-level senior performance (Drinkwater et al., 2008; Delextrat & Cohen, 2008). Adolescent girls have unique developmental characteristics and concerns (Andreyo et al., 2024). Although numerous studies have examined the effects of fatigue on athletic performance, the majority of this research has focused on male athletes. There is a notable lack of evidence regarding how fatigue impacts cognitive and motor functions in adolescent female basketball players, despite the fact that this group represents a critical stage in both physical and skill development. Understanding these effects in young female athletes is essential for designing training strategies, injury prevention programs, and recovery protocols that are appropriately tailored to their physiological and developmental needs.

In light of the above, this study aims to investigate the specific effects of exercise-induced fatigue on visual reaction time, vertical jump, and handgrip strength in adolescent female basketball players a population largely underrepresented in the current literature.

Materials and Methods

Study design

Prior to the fatigue protocol, participants completed a five-minute warm-up session consisting of dynamic basketball-specific movements. Following the warm-up, baseline measurements were conducted in a predetermined order: first, the visual reaction times of the dominant and non-dominant hands were assessed; this was followed by the evaluation of handgrip strength, and finally, vertical jump performance was recorded.

Fatigue was then induced through a standardized 20-minute full-court basketball match, played under official game rules with 5 vs. 5 players to ensure ecological validity. The match followed a continuous play format without extended breaks, and all participants underwent the same warm-up routine and testing sequence to maintain consistency. Standardization was further supported by using the same court, refereeing the game according to regulations, and keeping environmental conditions constant. Although physiological markers such as heart rate or blood lactate were not measured to objectively confirm the level of fatigue, the match was closely monitored by the researchers to maintain a high tempo. Players were given verbal prompts and on-court instructions to sustain intensity and were discouraged from unnecessary resting periods, ensuring that the activity induced a substantial and consistent level of fatigue across all participants.

Immediately after the match, the same measurement protocol was repeated to obtain post-fatigue data. Participants were required to refrain from performing any intense physical activity for at least 24 hours before the testing sessions. Additionally, individuals who had experienced any orthopedic injury affecting the upper or lower extremities within the past three months, or who had any known neurological, cardiovascular, or musculoskeletal chronic conditions, were excluded from the study

Study Grup

This study was conducted with 10 adolescent female athletes who were actively licensed basketball players in the province of Konya. The participants had a mean age of 15.70 ± 1.56 years, a mean body weight of 59.70 ± 11.90 kg, and a mean height of 168.10 ± 7.07 cm. All participants voluntarily took part in the study, and they were recruited through a convenience sampling method from local basketball clubs in Konya.

Data Collection Tools

Visual-Motor Reaction Test

Visual-motor reaction time was measured using the FitLight™ system (Fitlight Sports Corp., Canada). The test protocol consisted of a simple motor reaction task lasting 10 seconds, responding to visual stimuli displayed on six wireless light discs. These discs were arranged in a semicircular pattern on a table. Participants were instructed to stand with the hand being tested held at the center of the semicircle (starting position). Each light disc was positioned 40 cm from the center of the semicircle, with 25 cm of space between the centers of each disc.

Before the test began, the participant placed their hand at the designated starting point. As the test started, lights were randomly activated on the discs, and the participant was required to quickly reach out and deactivate the light with their hand, then return their hand to the starting position. This process was repeated for each light that appeared within the 10-second testing window.

The FitLight system automatically recorded the participant's average reaction time during this period. The test measured the speed of hand movement and response to visual stimuli under time pressure, providing an objective evaluation of visual-motor reaction performance (Tatlıcı and Özer 2022).

Vertical Jump Test

Athletes performed the vertical jump test starting from an upright position with hands free. The movement began with a quick downward motion, immediately followed by a vertical leap. The best jump height was recorded in centimeters (cm) using a digital measurement device. A "Takei jump-meter" (Takei Scientific Instruments, Tokyo, Japan) was used for the measurements, which digitally displayed jump height with the device attached at the waist. The device has a measurement range between 5 cm and 99 cm (Tatlıcı et al., 2022).

Handgrip Strenght Test

Handgrip strength was measured using a hand dynamometer (Takei Scientific Instruments, Tokyo, Japan). Participants performed the test in an anatomical position, standing upright with their arms fully extended at their sides. Two measurements were taken for each hand (right and left) by squeezing the device with maximum effort using the fingers, and the highest value obtained was recorded (Tatlıcı et al., 2022).

Statistical Analysis

All statistical procedures were carried out using SPSS software (Version 25.0, SPSS Inc., Chicago, IL, USA). Data are presented as means along with their corresponding standard deviations. The Shapiro-Wilk test was utilized to determine whether the data conformed to a normal distribution. In cases where normality was not confirmed, skewness and kurtosis values were reviewed, and distributions falling within ±2 were deemed acceptable for normality. Differences between pre- and post-fatigue measurements were analyzed using the paired samples t-test. When relevant, 95% confidence intervals (CIs) and p-values were provided. Effect sizes (Cohen's d) and their 95% confidence intervals (CI) are reported alongside P values where appropriate. According to established benchmarks, a d value of <0.2 was interpreted as a weak effect, a d value around 0.5 as a moderate effect, and a d value >0.8 as a strong effect (Cohen, 2013). A significance threshold was set at $p<0.05$, and all findings were interpreted within a 95% confidence framework.

Ethics of Research

This study was approved by the Ethics Committee of Selçuk University, Faculty of Sports Sciences (Protocol No: 159, 12.02.2025, Konya, Turkey). Prior to the assessments, all participants were provided with standardized and detailed information about the testing procedures. Each participant signed an informed consent form. Since the participants were adolescents, written consent was also obtained from their legal guardians. It was conducted in accordance with the "Directive on Scientific Research and Publication Ethics of Higher Education Institution.

Findings

Table 1

Descriptives of Participants

	N	Minimum	Maximum	Mean	Ss
Age (year)	10	13	17	15.70	1.56
Body Weight (kg)	10	42	81	59.70	11.90
Height (cm)	10	155.00	180.00	168.10	7.07

When Table 1 is examined, it is seen that the participants' mean age is 15.70±1.56 years, their mean body weight is 59.70±11.90 kg, and their mean height is 168.10±7.07 cm.

Table 2

Comparisons of Reaction Time, Vertical Jump, and Grip Strength Before and After Fatigue

Parameters	Time	Mean	Std. Dev.	t	95% CI		p	E.S
					Lower	Upper		
Dominant hand reaction time	Pre	.506	.030	-2.665	-.0776	-.0063	.026*	0.84
	Post	.548	.043					
Non-dominant hand reaction time	Pre	.524	.033	-2.579	-.0919	-.0060	.030*	0.82
	Post	.573	.060					
Vertical jump	Pre	31.00	5.45	1.824	-.432	4.032	.101	0.58
	Post	29.20	6.32					
Dominant hand grip strength	Pre	26.80	3.95	2.662	.3225	3.9734	.026*	0.84
	Post	24.65	3.40					
Non-dominant hand grip strength	Pre	25.80	4.34	1.234	-.6411	2.1811	.248	0.39
	Post	25.03	3.87					

*p<0.05.

Table 2 indicates that, following the fatigue protocol, both dominant and non-dominant hand reaction times increased significantly ($p<0.05$) compared to pre-fatigue measurements. Additionally, dominant hand grip strength showed a significant decrease post-fatigue ($p<0.05$). In contrast, no statistically significant differences were observed in non-dominant hand grip strength or vertical jump performance between pre-fatigue and post-fatigue conditions ($p> 0.05$)

Discussion

In this study, it was investigated whether the fatigue protocol applied to adolescent female basketball players affected reaction time, vertical jump, and handgrip strength. The adolescent female basketball players were found to have a mean age of 15.70 ± 1.56 years, mean weight of 59.70 ± 11.90 kg, and mean height of 168.10 ± 7.07 cm. The findings of this study revealed that after fatigue, the duration of visual reaction increased in both the dominant and non-dominant hands, and a decrease was observed in dominant-hand grip strength ($p< .05$). However, no changes were observed in non-dominant hand grip strength or vertical jump values ($p> .05$).

In this study, it was observed that reaction time in both the dominant and non-dominant hands increased at a statistically significant level. This finding indicates that fatigue slows down motor responses and cognitive processes at the level of the central nervous system (CNS) (Gandevia, 2001). Especially in sports such as basketball that require quick decision-making and instant reactions, this extension of reaction time may negatively affect game performance and increase the risk of injury. Indeed, a study conducted with padel players also reported significant impairments in both balance and reaction time after fatigue (Bourara et al., 2023). Since reaction time represents not only physical but also cognitive reflexes in athletes, it plays a critical role in decision moments during defense, direction changes, and ball interception. Furthermore, the fact that the increase in reaction time was observed similarly in both hands suggests that central fatigue produces more pronounced effects than local fatigue (Enoka and Duchateau, 2016). This finding indicates that performance declines originating in the brain, not only the muscles, should be taken into account.

Previous research has indicated that fatigue can impair reaction time and consistency in mixed martial arts athletes following upper-body exertion, as shown in the Wingate test results (Pavelka et al., 2020). Similarly, Valayi et al. (2024) reported that fatigue led to disruptions in key psychomotor abilities including reaction speed, focus, and visual processing—among elite female volleyball players. On the other hand, some findings in the literature contradict these outcomes. For instance, Böge et al. (2022) found that fatigue induced by the Yo-Yo Intermittent Recovery Test had no measurable effect on visual-motor reaction time in young fencers competing at the national level. Likewise, Tatlıcı and Özer (2022) observed no significant changes in visual reaction times before and after acute fatigue in either the dominant or non-dominant hands of hearing-impaired male national basketball players. These results were attributed to the athletes' advanced skill level and their ability to tolerate fatigue effectively.

Although a decrease in vertical jump values was observed after fatigue in this study, this change was not found to be statistically significant. This finding is supported by results reported in some studies. Robineau et al. (2012) stated that there was no statistical decrease in vertical jump height after a simulated football match in eight amateur football players. In a similar study, professional male volleyball players showed no difference in any vertical jump measurement after a sport-specific training session (Cabarkapa et al., 2023). Cortis et al. (2011) also reported no difference in vertical jump performance after fatigue. However, the difference observed in the present study (pre: 31.00 cm, post: 29.20 cm) is noteworthy in terms of performance, even though it was not statistically significant. This situation can be explained by the fatigue protocol's intensity not being sufficient to affect lower-extremity explosive strength or by adolescent female basketball players' lower-extremity muscle groups being more resistant to fatigue. Vertical jump is considered an indicator of lower-extremity explosive strength and is a determinant for movements such as jumping, blocking, and rebounding in basketball (Izquierdo and Redondo, 2020).

This finding contradicts some literature results. For example, Delextrat et al. (2012) reported that after a typical in-season week consisting of four training sessions and a competitive match, national-level female basketball players experienced a general decrease in vertical jump performance, with significant differences noted particularly on the 2nd, 3rd, and 6th days. In a related study, Cooper et al. (2020) observed notable declines in jump height, muscular strength, and power output among recreationally trained participants following a fatiguing protocol involving repeated vertical jumps.

The significant decrease in dominant handgrip strength shows that fatigue directly affects muscle force production. Fatigue is a complex physiological phenomenon that affects multiple levels of the neuromuscular system, including the central and peripheral nervous systems, motor unit function, and the performance capacity of individual muscle fibers. Muscle fatigue occurs with prolonged or repetitive use of a muscle group. Additionally, muscle fatigue reduces the functional capacity of hand muscles through physiological mechanisms such as decreased motor unit synchronization, reduced motor neuron activity, and depletion of energy stores (Enoka and Duchateau, 2008). Especially in sports like basketball, where upper-extremity use is intense, this can negatively affect the quality of essential skills such as ball control, passing, and shooting (Li et al., 2025).

During a basketball game, fatigue is believed to have a direct impact on upper-extremity muscle performance, as handgrip strength is considered a reliable indicator of general upper limb muscular strength. Passing accuracy, in particular, is primarily influenced by the strength of the upper limbs and grip strength. Grip strength is not only linked to the muscles of the hand and forearm but is also associated with overall body strength and certain anthropometric characteristics (Balogun et al., 1991). It reflects the maximal voluntary force generated through the coordinated flexion of all finger joints under biomechanically normal conditions (Koley et al., 2009). The synchronized action between flexor and extensor muscles, as well as the interaction among various muscle groups, plays a significant role in determining grip strength. Additionally, numerous factors such as overall muscular strength, hand dominance, fatigue, time of day, age, nutritional status, mobility limitations, and pain can influence grip performance (Richards et al., 1996).

The results of this study are consistent with those of Ahmed (2013). In Ahmed's study, after upper-extremity fatigue protocols (chest press and wrist curl), at both 70% and 90% exercise intensities, fatigue was reported to have a significantly negative effect on dominant handgrip strength and passing accuracy in male basketball players under 18 years of age.

Contrary to our study's findings, there are studies that reported no effect of fatigue on handgrip strength. Cortis et al. (2011) observed no significant difference in handgrip strength in measurements taken before and after a basketball game among 10 male basketball players. Although they initially attributed the lack of difference to age, the main reason was explained as the higher training volume and intensity of younger players (i.e., three 2 hour sessions and one match per week) compared to older players (i.e., one 1.5 hour session per week), which helped preserve this skill important for gripping, holding, and passing the ball (Cortis et al., 2011).

The absence of a significant strength change in the non-dominant hand can be explained by the dominant hand bearing more load during play and the non-dominant hand being used less frequently, thus being less affected by fatigue. However, individual differences and baseline force levels may also influence this outcome. Nonetheless, Ahmed (2013) also reported strength decreases in the non-dominant hand following fatigue.

The significance of this study lies in its focus on adolescent female basketball players. Adolescence is a critical period during which neurological, hormonal, and psychosocial changes occur and growth and development progress most rapidly (Patton et al., 2016). Especially in females, increased estrogen levels during adolescence lead to increased fat tissue and relatively limited muscle mass development, which causes motor skills—such as balance, muscle strength, and coordination to develop in a gender-specific manner (Faigenbaum et al., 2009; Tenforde and Fredericson, 2011). These differences are pronounced during this period; males, due to increased testosterone, gain more muscle mass and strength, while females experience more limited development (Tenforde and Fredericson, 2011). These physiological differences also play a role in fatigue's impact on performance.

In adolescent female basketball players, fatigue may negatively affect neuromuscular transmission, muscle contraction quality, and attention level, thereby causing performance declines particularly in fine motor skills (e.g., grip strength) and reaction time. Moreover, hormonal fluctuations and growth processes affecting the nervous system suggest that female athletes in this age group may be more sensitive to fatigue (Fort Vanmeerhaeghe et al., 2023). Therefore, it is of great importance that training and recovery programs for adolescent female athletes be structured according to age and biological maturity level. In this study, fatigue was found to adversely affect visual reaction time and handgrip strength in adolescent female basketball players, with this effect being particularly pronounced in the dominant extremity. This finding indicates that in adolescent female basketball players, fatigue effects appear more rapidly in cognitive–motor tasks (reaction, grip), whereas they appear later or are less pronounced in complex tasks such as lower-extremity explosive strength. However, the relatively small sample size of this study limits the generalizability of the findings, and future research with larger participant groups is recommended to confirm and expand upon these results.

Conclusion

In adolescent female basketball players, fatigue specifically impairs cognitive–motor skills—namely reaction time and grip strength—while having minimal impact on lower-body power as measured by vertical jump performance. These findings highlight the importance for coaches, sports scientists, and young athletes to incorporate targeted training and adequate recovery strategies that address upper-body strength and cognitive-motor function, ultimately supporting sustained performance and reducing fatigue-related risks.

Ethical Approval Information

Ethics Committee: Selçuk University Faculty of Sport Sciences Ethics Committee

Date of Approval: 12 February 2025

Approval Number: 159

Author Contribution Statement

Both authors contributed equally to all stages of the study.

Conflict of Interest Statement

The authors declare that there is no conflict of interest related to this research.

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