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THE EFFECT OF ANAEROBIC FATIGUE ON PROPRIOCEPTION IN ADOLESCENT FEMALE BASKETBALL PLAYERS

ORIGINAL ARTICLE

ABSTRACT

Purpose: Muscle fatigue is known to alter the proprioceptive system, the central proprioception process, and power generation capacity. This study aims to determine the effect of anaerobic fatigue on lower-extremity proprioception in adolescent female basketball players.

Methods: The study included licensed female basketball players (n=30) between the ages of 12 and 16. Their dominant lower extremities were evaluated for knee joint position-sense measurements. Active and passive knee joint position senses were measured with an isokinetic dynamometer at 30° and 60° degrees prior to, immediately after anaerobic fatigue, and finally after 10 minutes of the recovery period. The Wingate Anaerobic Strength Test was used to induce anaerobic fatigue. We documented the knee joint position sense of each participant.

Results: Following a 30-second anaerobic fatigue, a significant reduction in the sense of active joint perception at 30° and 60° knee flexion was observed compared to baseline values (p> 0.017). The knee joint's proprioception at 30° and 60° flexion returned to baseline levels after a 10-minute recovery from fatigue. The passive joint perception did not show any statistical changes.

Conclusion: Anaerobic fatigue reduces knee proprioception in adolescent female basketball players. Moreover, proprioceptive sensitivity can return to baseline levels with a recovery time of as little as 10 minutes.

Keywords: Adolescent, Basketball, Fatigue, Proprioception

ANAEROBİK YORGUNLUĞUN ADÖLESAN KIZ BASKETBOL OYUNCULARINDA PROPRIOSEPSIYON ÜZERİNDEKİ ETKİSİ

ARAŞTIRMA MAKALESİ

ÖZ

Amaç: Kas yorgunluğunun proprioseptif sistemi, merkezi propriosepsiyon sürecini ve güç üretim kapasitesini değiştirdiği bilinmektedir. Bu çalışma, adölesan kız basketbol oyuncularında anaerobik yorgunluğun alt ekstremite propriosepsiyonu üzerindeki etkisini belirlemeyi amaçlamaktadır.

Yöntem: Çalışmaya 12-16 yaşları arasında lisanslı kız basketbol oyuncuları dahil edildi (n=30). Dominant alt ekstremiteleri, diz eklemi pozisyon hissi ölçümleri için değerlendirildi. Aktif ve pasif diz eklemi pozisyon duyusu, izokinetik dinamometre ile istirahatte (test öncesi), anaerobik yorgunluktan hemen sonra ve 10 dakikalık dinlenme döneminden hemen sonra 30° ve 60° derecelerde ölçüldü. Anaerobik yorgunluk oluşturmak için Wingate Anaerobik Güç Testi kullanıldı. Her katılımcı için test öncesi diz eklemi pozisyon algıları kaydedildi.

Sonuçlar: 30 saniyelik anaerobik yorgunluktan sonra, istirahat değerlerine kıyasla 30° ve 60° diz fleksiyonunda aktif eklem pozisyonu algısında önemli bir azalma gözlendi (p>0,017). Yorgunluktan sonra 10 dakikalık bir iyileşmenin ardından, 30° ve 60° diz fleksiyonunda aktif eklem pozisyonu algısı istirahat seviyelerine döndü. Pasif eklem algısında istatistiksel bir değişim gözlenmemiştir.

Tartışma: Anaerobik yorgunluğun adölesan kız basketbol oyuncularında diz proprioception'ını azalttığı belirlendi. Ayrıca, proprioseptif duyarlılığın 10 dakikalık kadar kısa bir iyileşme süresi ile bazal seviyelere döndüğü gözlemlenmiştir.

Anahtar Kelimeler: Adölesan, Basketbol, Yorgunluk, Propriyosepsiyon

INTRODUCTION

Several variables combine to cause fatigue, which decreases muscle contraction strength or power and impairs sports performance (1,2). Muscular fatigue is defined as the inability to generate or sustain a specific force through muscular contraction, which contributes to musculoskeletal problems. On a molecular level, fatigue can be caused by an imbalance of K+ ions in the sarcolemma, the amount of oxygen in the muscle, and the rates at which oxygen is lost and gained (3,4). However, in broad terms, a key indicator of fatigue is a decline in proprioception ability, which leads to a decrease in performance (5). The level of weariness in different sports directly impacts competition outcomes.

Proprioception is the body's ability to sense its position and movement in space. It is essential for maintaining balance, coordination, and joint stability (6,7). Proprioceptors are located throughout the body, including in the muscles, tendons, ligaments, and joints. These receptors send signals to the brain, which uses them to create a map of the body's position and movement (8).

Proprioception is crucial for sports performance. Athletes with strong proprioception exhibit enhanced movement control and injury prevention (9). For instance, a basketball player with proficient proprioception may safely land after a jump shot, even with their eyes closed.

Injuries, fatigue, and other factors can diminish proprioception (10). A sprained ankle can damage the proprioceptors in the ankle joint, making it more difficult to balance and walk. Muscle fatigue, which impairs proprioception, makes athletes more susceptible to injuries (8).

Proprioception training can help to improve joint stability, reduce the risk of injury, and enhance athletic performance (9). There are many different types of proprioception exercises, such as balance board training, wobble board training, and plyometric exercises.

Basketball is a team sport with repetitive transitions between offense and defense and involves movements on several planes (11). It has a high risk of injury among team sports, as it involves running, cutting, jumping, and landing (12,13). Reports particularly highlight the high frequency of injuries in the lower extremities (14,15), including the Women's National Basketball Association (WNBA) (16). Female adolescent athletes are more prone to injuries due to anatomical variables such as a wider pelvis and greater knee valgus, as well as biomechanical variations during physical activities such as running, jumping, landing, and sudden changes in direction. The control of the dynamic movements in basketball involves not only alpha motor neurons and the muscle fibers, but also muscle spindle receptors and gamma motor neurons in the fusiform muscles, which are components of proprioception for both dynamic and static movement control, as well as Golgi tendon organs that are sensitive to muscle tension (17).

In part due to the ongoing developmental process of adolescent girls, it is critical to examine the risk factors for injury in adolescent female athletes (18). Studying the effects of anaerobic strain on proprioception in basketball is essential for planning effective proprioception training programs and thus minimizing the risk of injury (19-21). Therefore, this study aims to examine the impact of anaerobic fatigue on lower extremity proprioception in adolescent female basketball players, with a 30° and 60° knee flexion angles that have not been previously investigated.

METHODS

Study Design and Participants

The research was conducted between 03.02.2020 and 17.02.2020 in Bezmi Alem University Athlete Health Centre laboratories. Athletes were tested prior to fatigue, immediately after, and finally following a 10-minute rest. The study was approved by the Istanbul Okan University Clinical Research Ethics Committee (No. 37/31.01.2020).

To determine the sample size, we used the G-Power 3.1 software (Universität Düsseldorf, Germany). Based on previous research (22), which found a significant increase in knee fatigue-induced angular error (effect size: Cohen's d = 1.16), we anticipated a similar effect in our study. Aiming for 80% power and 95% confidence, we calculated a minimum sample size of 26 participants. This study included 30 licensed female basketball players aged between 12 and 16 years of age. 'Parental Consent Forms' were collected after informing the participants and parents of the study and the tests.

Participants with chronic metabolic disorders, cardiac or respiratory system conditions, and those with a history of surgery or a lower-limb injury during the previous six months were not admitted to this study. Each participant initially underwent an orthopedic evaluation of the hip, knee, and ankle joints. Based on the test findings, the participants who did not have any health conditions that would prevent them from participating in the study were admitted. The participants were asked not to join training programs the day before and on the day of evaluation. Initial proprioception data of participants were collected prior to anaerobic exhaustion, which was followed by an immediate proprioception data collection, and then, following a 10-minute recovery phase, a third data collection was completed. The participants were asked to use their dominant legs for the evaluation for proprioception.

Outcome Measure

Proprioception assessment was performed by measuring active and passive joint position sense at target angles of 30° and 60° of knee flexion with an isokinetic dynamometer (CSMI, Cybex Humac Norm, USA). The 30° and 60° knee angles are frequently used in activities such as jumping, running, and sudden direction changes, especially among athletes. Therefore, evaluating proprioception at these angles helps to more accurately predict athletes' performance and injury risk (23). The participants were seated in the dynamometer chair with their eyes closed and used headphones. The evaluated leg was fixed with a belt from the distal portion of the tibia by a Velcro strap, and the opposite limb was strapped to the axis of the dynamometer (24). During the measurement, the participant's knee joint was passively brought from 90° of knee flexion to the target angles and held in this position for 5 seconds before returning to its original position. For active joint position sense, participants actively moved the knee joint to reach the target angle, while for passive measurement, the knee joint was passively moved and participants were asked to identify the target angles. Measurements were taken in triplicate, and joint position sense was reported as the absolute angular error (AAE), defined as the difference between the target position and the reproduced position without considering the direction of the difference (25,26).

Anaerobic Fatigue Procedure

A Wingate anaerobic test protocol was implemented to induce anaerobic fatigue using a bicycle ergometer with magnetic and air resistance, calibrated according to body weight (Wattbike Ltd., Nottingham, England) (27-29). Participants received a briefing about the exhaustion strategy and completed a 5-minute warm-up (60–70 rpm) before the anaerobic test. The test lasted for 30 seconds with a resistance of 0.075 kg/body mass, during which participants were encouraged to exert maximum effort. Heart rate was collected at rest, immediately after the Wingate test, and during recovery using a pulse oximeter to indicate physiological stress. The workload was calculated with the formula: 100×pulses/maximal heart rate

Statistical Analyses

Data analysis was performed using SPSS version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics for categorical and continuous variables (mean, standard deviation, median, minimum, maximum, count, and percentage) were reported. Homogeneity of variances was tested with Levene's test, and the normality assumption was assessed using the Shapiro-Wilk test. For normally distributed data, parametric analyses were used, and non-parametric analyses were applied to non-normally distributed data. Active and passive repeated measurements were analyzed with the Friedman test, and pairwise analyses were conducted with the Wilcoxon test using the Bonferroni correction for statistical significance. Significance was set at $p < 0.05$.

RESULTS

The participants had an average of 4 years in sports (min 2–max 5 years). Demographic characteristics are outlined in Table 1. Comparisons of active and passive joint position sense at 30° and 60° knee flexion, heart rate, and workload at rest, post-fatigue, and recovery periods are presented in

Table 1. Demographic Characteristics of Female Adolescent Participants

	Mean ± SD	**Min-Max**
Age (years)	13.96 ± 0.88	13.00 ± 16.00
Height (cm)	171.23 ± 7.29	158.00 ± 185.00
Weight (kg)	58.21± 9.37	37.00 ± 76.00
BMI (kg/m²)	19.71 ± 2.14	14.80 ± 23.60
Muscle mass (kg)	43.66 ± 6.19	30.90 ± 57.60
Fat mass (kg)	11.71 ± 3.75	3.80 ± 18.40
Fat rate (%)	19.74 ± 4.32	9.40 ± 26.00
Year of sport	4.03 ± 0.96	2.00 ± 5.00

Summary Statistics are Presented as Mean±Standard Deviation and Median (Minimum, Maximum) for Numerical Data; BMI: Body Mass Index, SD: Standard Deviation

Table 2. The average fatigue heart rate was 171.9 ± 4.2 bpm, with workload calculated as 83% of the maximum heart rate. Using the Karvonen formula (31), the percent workload during fatigue was 72.70 ± 2.90%.

Significant differences were found between initial and post-fatigue measurements, as well as post-fatigue and recovery measurements, for active joint position sense at both 30° and 60° knee flexion ($p < 0.017$). No significant differences were found between initial and recovery parameters. However, passive joint position sense did not differ significantly between the two angles. The pairwise analysis also showed statistically significant differences in heart rate and workload between initial, post-fatigue, and recovery periods ($p < 0.017$).

DISCUSSION

The purpose of this study was to examine the effect of anaerobic fatigue on lower extremity proprioception in adolescent female basketball players, focusing on knee joint proprioception at 30° and 60° knee flexion angles. The findings revealed that anaerobic fatigue led to a significant decrease in knee joint proprioception in terms of position sense at 30° and 60° knee flexion in adolescent female basketball players. Suggesting that fatigue negatively impacts proprioceptive accuracy in this population.

Fatigue impacts proprioception in both sedentary and athletic individuals, with muscle exhaustion causing neuromuscular deficits that heighten injury risk and reduce sports performance. We may express that the anaerobic fatigue on the lower extremity may threaten knee joint proprioceptive accuracy among adolescent female basketball players. Notably, proprioception was restored to resting levels following a 10-minute recovery period, and it may be feasible to express the importance of rest periods after bouts of anaerobic ex-

Table 2. Active and Passive Knee Joint Position Sense Measurements for 30° and 60° Angles using the Isokinetic Dynamometer

		X ± SD	**Rest**	**Immediately post-fatigue**	**Recovery**	**P¹**	**P²**	**P³**
			X ± SD	**X ± SD**				
AAE	**30°**	**Active**	1.38 ± 0.88	2.55 ± 1.09	1.66 ± 1.27	**<0.001***	0.220	**0.009***
		Passive	1.12 ± 0.79	1.39 ± 0.75	1.18 ± 0.93	0.019	0.954	0.074
	60°	**Active**	1.33 ± 0.90	2.41 ± 0.94	1.31 ± 0.71	**<0.001***	0.756	**<0.001***
		Passive	1.15 ± 0.88	1.31 ± 0.94	1.05 ± 0.68	0.123	0.762	0.051
%MHR			79.90 ± 9.50	171.90 ± 4.20	91.80 ± 2.90	**<0.001***	**<0.001***	**<0.001***
38.70 ± 4.60 **83.30 ± 2.10**			44.50 ± 5.00	**<0.001***	**<0.001***	**<0.001***		

*: Wilcoxon Sign Test, Statistical Significance Level P<0.05; AAE: Absolute Angular Error, MHR: Maximal Heart Rate. P¹: Between Rest and Post-Fatigue, P²: Between Rest and Recovery, P³: Between Post-Fatigue and Recovery.

ercises for preventive measures among adolescent female basketball players. This outcome may also present the uniqueness of this study since the previous proprioception studies primarily involved participants aged 20 or older as 30-33 years old, while this study focused on adolescent female basketball players who are in growing age and open for risks of injuries (Harris et al., 2021). Therefore, this study contributes to the existing body of research by focusing specifically on adolescent female basketball players that are having a critical period for neuromuscular development, and the findings of this study highlight the vulnerability of young female athletes to fatigue-induced proprioceptive deficits. On the other hand, the impact of anaerobic fatigue on proprioception of soccer and football players has also shown similar findings, where fatigue due to lower extremity muscle exhaustion reduced proprioceptive accuracy (7, 28).

Thus, these results align with previous studies indicating that fatigue impairs proprioception in athletes (7,28). Specifically, it has been shown that muscle fatigue, especially from anaerobic exercises, can cause temporary deficits in proprioception, which increases the risk of injury. Our findings echo those of Miura et al. (2004), who demonstrated that fatigue impairs proprioception in knee joint repositioning accuracy, which could lead to greater susceptibility to injuries (34).

Similarly, decreased proprioception after lower extremity fatigue has been reported in uninjured male football players (31) and following quadriceps muscle exhaustion in healthy young people (29). Miura et al., compared the effects of local and general fatigue on knee joint proprioception in healthy males (34, 35). They reported no change in proprioceptive sense after local fatigue but a decrease after general fatigue, indicating temporary impairment of muscle spindle function (34).

Another important aspect of our study is the use of anaerobic fatigue induced by the Wingate test, a common method for evaluating short-burst exertion in basketball and other high-intensity sports. Since it mimics the type of anaerobic exertion players may experience during actual competition, it provides a realistic context for understanding how fatigue may affect proprioception during a game. Therefore, the strength of our study is that it supports the notion that proprioception plays a vital role in injury prevention and players' performance, particularly in sports involving anaerobic movements with frequent changes in direction and intense physical demands, like basketball.

However, there are certain limitations to this study that must be considered. First, the sample size was limited to players from a single club, which may restrict the generalizability of the results to other populations of adolescent female basketball players. Future studies should aim to include a larger, more diverse sample to confirm these findings across different settings. Additionally, although the study assessed the effects of anaerobic fatigue on knee proprioception, it did not measure blood lactate levels or other physiological markers, which could have provided a more comprehensive understanding of the fatigue-induced changes in proprioception. Future research could include these measures to offer a more complete picture of the physiological responses to anaerobic fatigue.

In conclusion, this study provides valuable insights into how anaerobic fatigue affects proprioception in adolescent female basketball players. The findings suggest that fatigue-induced changes in proprioception can increase the risk of injury, highlighting the importance of incorporating recovery periods and fatigue management strategies into training regimens. Further research is needed to explore the long-term effects of repeated fatigue on proprioception and to develop effective strategies for mitigating these effects to improve athlete performance and safety.

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