

Investigation Of The Effect Of Acute Muscle Fatigue On Static And Dynamic Balance Performances In Female Judokas

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Abstract

Judo is a dynamic martial art that combines technical, tactical, and physical performance elements, aiming to neutralize the opponent by causing them to lose balance and stability. To be successful in this sport, it is essential to develop fundamental motor skills such as muscular strength, cardiovascular endurance, agility, flexibility, reaction speed, and particularly balance. Balance plays a critical role in both offensive and defensive movements, as judokas must maintain their postural stability to effectively throw their opponents to the ground while simultaneously resisting counterattacks. The ability to control one's center of gravity during rapid, complex movements directly impacts success in judo matches. Despite the importance of balance, there is limited research, especially involving female athletes, focusing on how acute muscle fatigue—common during both training and competition—affects static and dynamic balance performances. Therefore, the primary aim of this study is to investigate the effect of acute muscle fatigue on the static and dynamic balance performances of female judokas. In this study, a total of nine well-trained female judokas, who actively practice judo and regularly participate in competitive training programs in Konya province, voluntarily took part. The average age of the participants was 14.66 ± 1.11 years, with a mean height of 158.77 ± 4.49 cm, an average body weight of 50.75 ± 4.02 kg, and an average sports experience of 2.11 ± 1.05 years. All participants underwent a standard warm-up protocol before testing. Initially, their static and dynamic balance performances were measured in a rested state using the Biodex Balance System. Subsequently, the participants performed a 30-second Wingate Anaerobic Test to induce acute muscular fatigue, which simulates the high-intensity efforts experienced during a judo match. Immediately after completing the fatigue protocol, the participants repeated the static and dynamic balance tests. The data collected before and after fatigue were analyzed using the paired sample t-test with SPSS 24.0 statistical software. The results demonstrated that there was no statistically significant difference in the participants' static balance performances between the rested and fatigued states ($p > 0.05$). However, a significant decrease was observed in dynamic balance performance, specifically in the "overall" and "anterior-posterior (ante-post)" parameters following fatigue ($p < 0.05$). No significant differences were found in the "medial-lateral (med-lat)" balance parameters. In conclusion, acute muscle fatigue has a negative impact on the dynamic balance performance of female judokas, although it does not significantly affect static balance performance. This finding suggests that fatigue impairs postural control during dynamic activities, potentially increasing the risk of performance decline or injury during competition. It is recommended that coaches incorporate targeted balance training into regular judo training programs, focusing on maintaining balance under fatigue conditions. Additionally, strategies to enhance post-exercise recovery may further improve athletes' ability to sustain high performance levels during matches.

Keywords: Judo, Static-Dynamic Balance, Acute Muscle Fatigue

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Kadın Judoculararda Akut Kas Yorgunluğunun Statik ve Dinamik Denge Performanslarına Etkisinin İncelenmesi

Özet

Judo, teknik, taktik ve fiziksel performans unsurlarını bir araya getiren, aynı zamanda zihinsel dayanıklılık gerektiren dinamik bir dövüş sporudur. Bu sporun temel amacı, rakibin dengesini ve stabilitesini bozarak onu etkisiz hale getirmek ve avantaj sağlamaktır. Judoda başarılı olabilmek için kas kuvveti, kardiyovasküler dayanıklılık, çeviklik, esneklik, reaksiyon hızı ve özellikle denge gibi temel motor becerilerin geliştirilmesi büyük önem taşır. Denge hem saldırı hem de savunma hareketlerinde kritik bir rol oynar; çünkü judocular, rakiplerini etkili bir şekilde yere düşürebilmek ve aynı zamanda karşı saldırılara direnebilmek için postüral stabilitelerini korumalıdır. Karmaşık ve hızlı hareketler sırasında vücut ağırlık merkezini kontrol edebilme yeteneği, judo müsabakalarındaki başarıyı doğrudan etkileyen önemli bir faktördür. Ancak denge unsurunun önemine rağmen, özellikle kadın sporcular üzerinde yapılan bilimsel araştırmalarda hem antrenman hem de müsabaka sırasında sıkça karşılaşılan akut kas yorgunluğunun statik ve dinamik denge performansı üzerindeki etkilerini inceleyen çalışmalar oldukça sınırlıdır. Bu nedenle, bu çalışmanın temel amacı, akut kas yorgunluğunun kadın judocuların statik ve dinamik denge performanslarına olan etkisini detaylı bir şekilde araştırmaktır. Bu çalışmaya, Konya ilinde aktif olarak judo yapan ve düzenli olarak rekabetçi antrenman programlarına katılan, toplam 9 antrenmanlı kadın judocu gönüllü olarak katılmıştır. Katılımcıların yaş ortalaması $14,66 \pm 1,11$ yıl, boy uzunluğu ortalaması $158,77 \pm 4,49$ cm, vücut ağırlığı ortalaması $50,75 \pm 4,02$ kg ve spor geçmişi ortalaması $2,11 \pm 1,05$ yıl olarak belirlenmiştir. Tüm katılımcılara testlerden önce standart bir ısınma protokolü uygulanmıştır. İlk olarak, dinlenme durumunda katılımcıların statik ve dinamik denge performansları Biodex Balance System cihazı kullanılarak objektif bir şekilde ölçülmüştür. Ardından, akut kas yorgunluğu oluşturmak amacıyla, anaerobik kapasiteyi zorlayan 30 saniyelik Wingate Anaerobik Testi uygulanmıştır. Yorgunluk protokolü tamamlandıktan hemen sonra, katılımcıların statik ve dinamik denge testleri tekrar gerçekleştirilmiştir. Yorgunluk öncesi ve sonrası elde edilen veriler, SPSS 24.0 istatistik yazılımı kullanılarak eşleştirilmiş örneklem t-testi ile analiz edilmiştir. Sonuçlar, dinlenme ve yorgunluk durumları arasında katılımcıların statik denge performanslarında istatistiksel olarak anlamlı bir fark bulunmadığını ortaya koymuştur ($p > 0,05$). Ancak, dinamik denge performansında, özellikle "genel (overall)" ve "ön-arka (anterior-posterior / ante-post)" parametrelerinde, yorgunluk sonrası anlamlı ve belirgin bir performans düşüşü gözlemlenmiştir ($p < 0,05$). "Orta-yan (medial-lateral / med-lat)" parametrelerinde ise anlamlı bir farklılık tespit edilmemiştir. Sonuç olarak, akut kas yorgunluğu, kadın judocuların dinamik denge performansını olumsuz yönde etkilemekte, ancak statik denge performansını belirgin şekilde etkilememektedir. Bu bulgu, yorgunluğun dinamik aktiviteler sırasında postüral kontrolü bozduğunu ve bu durumun, yarışmalar sırasında performans düşüşüne veya ciddi sakatlanma riskine yol açabileceğini düşündürmektedir. Bu doğrultuda, antrenörlere, sporcularının yorgunluk koşullarında da denge becerilerini koruyabilmeleri amacıyla, düzenli antrenman programlarına hedefe yönelik denge çalışmaları ve proprioseptif egzersizler eklemeleri önemle önerilmektedir. Ayrıca, antrenman ve müsabakalar sonrası toparlanma süreçlerini iyileştirmeye yönelik bilimsel temelli stratejilerin uygulanması, sporcuların yüksek performans düzeylerini uzun süre koruyabilmelerine katkı sağlayabilir.

Anahtar kelimeler: Judo, Statik-Dinamik Denge, Akut Kas Yorgunluğu

Introduction

Judo is one of the most popular martial arts, wherein numerous variables such as technical, tactical, physiological, and psychological factors play a significant role in determining the final result. Apart from strength and endurance, which are considered potential determinants of judo performance, the sport includes features such as flexibility, coordination, balance, and quickness (Mala et al., 2016).

Balance control in judo plays a crucial role in achieving success since the techniques of this martial art rely on constant displacements aimed at destabilizing the opponent to make them fall (Witkowski et al., 2014). Therefore, the ability to maintain postural stability during a fight against an opponent is considered a vital factor in judo (Maśliński et al., 2016). Previous studies have highlighted that basic judo exercises significantly influence motor characteristics and balance performance in children (Kılıç, 2018).

Balance is the result of a well-coordinated interaction within the neuromuscular system, allowing the body to adapt swiftly to gravity during both rest and movement. This harmonious integration is achieved through the processing of various sensory inputs (vestibular, proprioceptive, and visual data) in the central nervous system (Soyuer and İsmailoğulları, 2009). Balance can be assessed in two ways: statically and dynamically. Static balance refers to the ability to maintain the body's equilibrium by keeping the center of gravity stable in stationary or minimally active positions (Uzun, 2018). On the other hand, dynamic balance involves the continuous and persistent adjustments of movement based on environmental conditions to execute various actions effectively (Çebi, 2013).

Factors affecting the balance system in humans include gender, height, body weight, age, neurological disorders, as well as mental and physical fatigue (Faraldo-Garcia et al., 2012). In a judo tournament, athletes typically engage in several matches with a minimum recovery time of 15 minutes between each match (Detanico et al., 2015). The high-intensity efforts and continuous repetition of judo challenges during matches occur under increasingly unfavorable metabolic conditions (Bonitch-Dominguez et al., 2010). Physiologically, fatigue sets in after consecutive matches, leading to potential balance issues, reduced performance, and an increased risk of injury (Taşkın et al., 2015). Therefore, managing fatigue and ensuring adequate recovery become crucial for achieving successful performance (Franchini et al., 2013).

Muscle contractions in judo primarily rely on anaerobic metabolic pathways, but elite judo competitors also exhibit higher aerobic capacities, facilitating quicker recovery after short-term high-intensity training (Franchini et al., 2011a). However, there are limited studies in the literature that have investigated the balance parameters of female judokas after experiencing fatigue. Therefore, this

study was designed to examine the effect of acute fatigue on static and dynamic balance in female judokas.

Materials and Methods

Research Design

Participants arrived at the Faculty of Sports Sciences laboratory at 10:00 am and were instructed not to engage in any exercises within 48 hours prior to the test. A standard warm-up, including stretching movements, was performed by the participants. The static and dynamic balance performances of the participants were then measured in their resting state before inducing fatigue using the Biodex Balance System device. To minimize any learning effect, the initial resting measurements were taken from 5 athletes, following which the Wingate test was conducted to induce acute fatigue. Immediately after the Wingate test, the balance performances in the fatigued state were measured again. For the remaining 4 athletes, fatigue was induced first, and after measuring their balance performance, they were allowed to rest for 2 hours. Subsequently, their balance performances were measured again in the resting state.

Population and Sample/Study Group

Nine trained female athletes who practiced judo in the Konya Sports Club participated in our study. Participants were informed about the purpose and risks of the study. Written informed consent was given to all participants.

Table 1. Demographic characteristics of the participants

| | N | Minimum | Maximum | Mean | Ss |
|--------------------------|----------|----------------|----------------|-------------|-----------|
| Age (year) | 9 | 13.00 | 16.00 | 14.66 | 1.11 |
| Weight (kg) | 9 | 45.30 | 56.70 | 50.75 | 4.02 |
| Height (cm) | 9 | 152.00 | 165.00 | 158.77 | 4.49 |
| Sports Age (year) | 9 | 1.00 | 4.00 | 2.11 | 1.05 |

Data Collection Instruments

Static and Dynamic Balance Measurements

The Biodex Balance System (BBS, Biodex Medical Systems Inc, Shirley, NY) was utilized to assess balance performances. Higher scores obtained from the BBS indicate impaired balance performance. The participants' balance performance was evaluated using both dynamic balance tests with eyes open and static balance tests with eyes closed. These tests were conducted on the dominant leg, with the dynamic balance test set at "level 7" difficulty and the static balance test at the "static

level" difficulty. During the tests, participants were allowed to move the platform freely while observing the screen to determine the coordinates of their foot position and find an optimal stable position. Once they achieved a stable position, the platform was locked according to their foot position, and the coordinates of this position were recorded by the device. Subsequent tests were performed with the recorded foot position as the reference. To eliminate the influence of the arms during the tests, participants were asked to place their hands diagonally on their right and left shoulders. Each test lasted for 20 seconds, and the results were recorded for overall, anterior-posterior, and medial-lateral stability.

Wingate Test (Fatigue)

The Wingate test was carried out on a modified Monark 834 E (Sweden) bicycle ergometer with a pan. After adjusting the saddle and handlebar separately for each participant, the feet of the participants were fixed to the pedal using clips. The weights corresponding to 7.5% of the bodyweight of each participant were noted separately. After these weights were placed in the weight basket as resistance during the test, the test was started. The participant, who reached a certain pedal speed (130-150 rpm), was asked to voluntarily pedal for 3-4 seconds initially with no load, then with load, for 30 seconds at the highest possible speed and maintain this speed. Participants were verbally encouraged throughout the upload.

Statistical Analysis

SPSS program (SPSS for Windows, version 24.0, SPSS Inc., Chicago, Illinois, USA) was used to analyse the results. Data were presented as median and standard deviation, and the Shapiro-Wilk test was used to test the distribution of normality. Skewness and kurtosis values were checked for data values that were not normally distributed, and those with values between ± 2 were considered to be normally distributed. Paired sample t-test was used to compare the pre-test and post-test parameters of groups. Effect size (Cohen d) and 95% confidence intervals (CI) are given together with P values. According to this formula, a "d value of <0.2 " was defined as a weak effect size, a "d-value of 0.5 " was defined as a medium, and a "d-value >0.8 " was defined as a strong effect size. Statistical results were evaluated at a 95% confidence interval and significance level of $p < 0.05$.

Research Ethics

The study protocol was approved by the Selcuk University Faculty of Sport Sciences Ethics Committee (Protocol number 72, 19.10.2020). This study was conducted in strict adherence to the YÖK Scientific Research and Publication Ethics Directive, ensuring that all research procedures and ethical considerations were meticulously followed throughout the study.

Results

Table 2. Comparison of resting and fatigue static balance performances of judokas

| Parameters (score) | Mean | Ss | 95% CI | | t | p |
|-----------------------|------|-----|--------|-------|-------|------|
| | | | Lower | Upper | | |
| Rest – overall | 3.12 | .74 | -.70 | .43 | -.53 | 0.60 |
| Fatigue - overall | 3.25 | | | | | |
| Rest - ante-post | 2.16 | .56 | -.73 | .13 | -1.58 | 0.15 |
| Fatigue - ante-post | 2.46 | | | | | |
| Rest - med-lat | 1.78 | .48 | -.33 | .41 | .27 | 0.79 |
| Fatigue - med-lat | 1.74 | | | | | |

CI: Confidence interval, Ante-post: anterior-posterior, med-lat: medial-lateral, significant differences $p < 0.05$.

When Table 2 is examined, it is seen that static balance performances do not differ statistically in rest and fatigue in terms of overall, ante-post, and med-lat.

Table 3. Comparison of resting and fatigue dynamic balance performances of judokas.

| Parameters (score) | Mean | Ss | 95% CI | | t | p |
|-----------------------|------|------|--------|-------|-------|-------|
| | | | Lower | Upper | | |
| Rest – overall | 1.51 | .80 | -1.30 | -.06 | -2.56 | 0.03* |
| Fatigue - overall | 2.20 | | | | | |
| Rest - ante-post | 1.04 | .96 | -1.61 | -.13 | -2.73 | 0.02* |
| Fatigue - ante-post | 1.92 | | | | | |
| Rest - med-lat | 1.34 | 1.18 | -.47 | 1.34 | 1.09 | 0.30 |
| Fatigue - med-lat | 0.91 | | | | | |

CI: Confidence interval, Ante-post: anterior-posterior, med-lat: medial-lateral, significant differences * $p < 0.05$.

When Table 3 is examined, it was determined that the dynamic overall (effect size: 0.85) and dynamic ante-post (effect size: 0.91) parameters were statistically negatively affected by fatigue. Dynamic med-lat measurements did not show statistically significant changes in rest and fatigue.

Discussion and Conclusion

Balance is a critical element in judo. Fatigue during a match can result in a loss of balance, leading to a decline in performance. Hence, this study aims to investigate the balance of judo athletes under conditions of fatigue. The study results indicated that there was no statistically significant difference in the static balance performances of female judokas between rest and fatigue. However, a statistically significant difference was observed in the dynamic overall and dynamic ante-post between rest and fatigue, showing a decrease in performance ($p < 0.05$).

Two of the most fundamental principles in judo are balance and non-resistance to force. The main principle of competition is not to counter the opponent's strength directly but rather to defeat

them by utilizing their own strength. In judo, practitioners don't respond to the opponent's attack with a direct counter-attack; instead, they leverage the opponent's weight, speed, and power while constantly maintaining control over their own strength. The objective in judo is to gain an advantage by throwing the opponent to the mat. To achieve this, judokas focus on unbalancing their opponent to create the most favorable mechanical conditions for executing a successful throw.

It will be challenging for an opponent whose balance is disturbed to defend herself against the shot. Additionally, the attacker will have a significant advantage for a second attack. Balance is a fundamental principle in judo that reflects power and is essential for avoiding defeat (Maśliński et al. 2016). In a study by Güler (2015), the effect of fatigue on balance performance was examined in 16 elite male karate athletes. The results showed no statistically significant difference in the hitting foot postural stability, static overall, anterior-posterior, and medial-lateral values of the athletes. It is suggested that the lack of difference may be attributed to a 30-minute rest period after fatigue, during which the balance parameters returned to their pre-fatigue levels. This indicates that the provided rest improved the athletes' balance after the exertion. The results of this study align with our findings. It is believed that the lack of difference in static balance parameters in our study may be attributed to the fact that the short-term loading did not induce complete fatigue in the body. Göktepe (2016) conducted a study comparing the static balance of 31 soccer players, comprising both girls and boys, between their dominant and non-dominant feet. The study concluded that there was no significant difference in static balance values between the dominant and non-dominant feet of the soccer players. Furthermore, no significant difference was observed based on the gender variable. Bressel et al., (2007) conducted a study comparing the dynamic balance of female athletes participating in football, gymnastics, and basketball. They measured dynamic balance using The Star Excursion Balance Test and static balance using the Balance Error Scoring System. The results revealed that there were no significant differences in static and dynamic balance values between female football players and gymnasts. However, it was found that basketball players had lower static balance compared to gymnasts and lower dynamic balance compared to soccer players. Another study involving 58 female athletes from dance, basketball, and football branches examined Balance Error Scoring Scores and swing speeds. The findings showed no significant difference between the groups, indicating that the balance performances of female athletes in the three branches were similar (Cortes et al., 2014).

Contrary to our study findings, there are studies in the literature that fatigue affects static balance (Soslu et al., 2018; Erkmén et al., 2009). Soslu et al., (2018) in a study examining the effect of acute fatigue on static balance in 10 male boxers who do sports at the elite level, the static balance test was measured before and after the Wingate test. As a result of the study, a statistically significant difference was found in the static balance of the boxers, before and after fatigue, and with their eyes

open and closed ($p < 0.05$). It has been determined that the static balance of the boxers is better when their eyes are open and the fatigue of the athletes affects the static balance negatively. It has been observed that the reason for this may be due to the blows received by boxers on their heads, affecting the visual points of the brain, and fatigue in the leg muscles. Erkmen et al., (2009) conducted a study with 16 amateur soccer players, and fatigue was created by applying the Bruce protocol on the treadmill, and their balance performance was measured using the Balance Error Scoring System before and after this protocol. It was determined that there was a significant increase in one-leg posture error scores after fatigue ($p < 0.05$). In another study in which ankle fatigue was induced by isokinetic contractions, a significant difference was found in the time to stay in balance on one foot ($p < 0.05$) (Yaggie and McGregor, 2002). In his study, Akay (2018) found a significant difference in the balance values of the right and left feet after 8 weeks of balance training in 40 male adolescent judokas. It has been shown that balance training is effective in controlling body balance.

Ekizler et al., (2006) conducted a study investigating the effect of lower extremity muscle fatigue on balance in 55 healthy students. They evaluated the balance before, immediately after, and 5 minutes after the Wingate test. The study observed a significant decrease in the time the students could maintain balance before and after the Wingate test. However, after 5 minutes of rest, the balance time was longer than before the test. Additionally, when considering gender, men demonstrated a longer time staying in balance compared to women. Yamada et al., (2012) observed a significant difference in the dominant leg postural stability values (overall and ante-post) of soccer players before and after a 45-minute match, with a decrease in balance after the match. In another study by Baghbani et al., (2016) post-fatigue dynamic balances of both athletes and non-athlete women were examined. The Star Excursion Balance Test was conducted before and after a 20-minute fatigue protocol. While no significant difference was found in the dynamic balance values of the athletes, a significant difference was observed in the non-athletes in the posterior, medial, and posteromedial directions after fatigue ($p < 0.05$). The findings of these studies are consistent with our study results.

Çavdar (2014) conducted a study examining the impact of anaerobic fatigue on balance and strength. The study measured the balance before and after fatigue was induced using the Wingate test. However, when comparing the pre-test and post-test values of women, no significant difference was found in the dynamic ante-post and med-lat values. These findings contrast with our study results. The small sample size consisting of female judokas within a specific age range and the focus solely on the effects of short-term acute muscle fatigue limit the generalizability of the study's findings.

As a result, our study shows that acute fatigue affects the balance of female judoka athletes. Consequently, it is advisable to incorporate balance training in judo training programs for future studies.

Ethics Committee Permission Information

Ethics Committee: Selcuk University Faculty of Sport Sciences Ethics Committee

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Author Contributions Statement

Authors contributed equally to all stages of the research.

Conflict of Interest Statement

There is no conflict of interest or conflict of interest between the author(s) regarding this study.

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