**CBÜ Beden Eğitimi ve Spor Bilimleri Dergisi**
*CBU Journal of Physical Education and Sport Sciences*
Volume: 18, Issue: 2, 2023
E-ISSN: 2149-1046
DOI: 10.33459/cbubesbd.1298563
URL: https://dergipark.org.tr/tr/pub/cbubesbd

# Investigation of the Relationship of Arm and Leg Volume with Anaerobic Power, Balance and Strength Characteristics in Elite Judokas*

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**Research Article**
Received: 20/05/2023 Accepted: 28/08/2023 Published: 31/12/2023

## Abstract

The aim of this study is to investigate the relationship between arm and leg volume, and anaerobic power, balance and strength characteristics in elite Judokas. 15 national Judokas participated in the study voluntarily from Burdur Municipality Sports Club. Frustum method to determine the arm and leg volumes of the athletes, Wingate anaerobic power test to determine their anaerobic performance, stabilometric balance platform test to determine the dynamic balance performances, and 1 RM method to determine the strength levels. "Spearman" Correlation Analysis was used to determine the relationship between the force, anaerobic power and balance results. Considering the results of the athletes, there was a significant relationship between peak power (Watt), mean power (Watt), average power (Watt / kg) and leg volume, while no relation was found in all other values. There was found no relation between the total leg volume and anaerobic power values in female Judokas, the total arm and leg volume and dynamic balance values of the male and female Judokas, the total arm and leg volumes of male Judokas with 1 RM. When the relation of total arm and leg volumes with 1 RM values in female Judokas was examined, positive significant relationship was found in calf raise repetition; no relation was found in all other values. To conclude, it can be suggested to sports scientists and coaches that they should plan training programs to enhance the strength and anaerobic power characteristics of Judokas.
**Keywords:** Judo, Arm-Leg volume, Anaerobic power, Balance, Strength

# Elit Judocularda Kol ve Bacak Hacminin Anaerobik Güç, Denge ve Kuvvet Özellikleri ile İlişkisinin İncelenmesi

## Öz

Bu çalışmanın amacı, elit judocularda kol ve bacak hacmi ile anaerobik güç, denge ve kuvvet özellikleri arasındaki ilişkiyi araştırmaktır. Çalışmaya Burdur Belediyesi Spor Kulübü'nden 15 milli judocu gönüllü olarak katılmıştır. Sporcuların kol ve bacak hacimlerini belirlemek için Frustum yöntemi, anaerobik performanslarını belirlemek için Wingate anaerobik güç testi, dinamik denge performanslarını belirlemek için stabilometrik denge platform testi ve kuvvet seviyelerini belirlemek için 1 RM yöntemi kullanıldı. Kuvvet, anaerobik güç ve denge sonuçları arasındaki ilişkiyi belirlemek için "Spearman" Korelasyon Analizi kullanıldı. Sporcuların sonuçlarına bakıldığında tepe güç (Watt), ortalama güç (Watt), ortalama güç (Watt/kg) ve bacak hacmi arasında anlamlı bir ilişki varken diğer tüm değerlerde ilişki bulunmadı. Kadın Judocularda toplam bacak hacmi ile anaerobik güç değerleri, erkek ve dişi Judocularda toplam kol ve bacak hacmi ve dinamik denge değerleri, 1 RM'li erkek judocularda toplam kol ve bacak hacimleri arasında ilişki bulunmadı. Kadın judocularda toplam kol ve bacak hacimlerinin 1 RM değerleri ile ilişkisi incelendiğinde baldır kaldırma tekrarında pozitif anlamlı ilişki bulunmuş; diğer tüm değerlerde ilişki bulunamadı. Sonuç olarak, spor bilimcilere ve antrenörlere judocuların kuvvet ve anaerobik güç özelliklerini geliştirmeye yönelik antrenman programları planlamaları önerilebilir.
**Anahtar Kelimeler:** Judo, Kol-Bacak hacmi, Anaerobik güç, Denge, Kuvvet

* This study is derived from Osman Ozan Çalap's Master's thesis " Investigation of the Relationship of Arm and Leg Volume with Anaerobic Power, Balance and Strength Characteristics in Elite Judokas" completed under the supervision of Mahmut Alp.

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## INTRODUCTION

Judo is a sport that uses most physical skills such as balance, endurance, strength and lifting power at a high level, combines sporting foundations with philosophy and art, provides spiritual and physical training together, improves self-confidence, motivation, comprehensive thinking, love and respect above all else. Judo is also a sport in which many motoric features such as strength, continuity in strength, endurance, balance, speed, reaction, agility, reaction speed and correct timing must be found together in a coordinated manner (Açıkada & Ergen, 1990; Güzelimdağ, 2013). In addition to all these features, judo comes to the fore with the struggle to provide where the defense and attack systems are intertwined and superior to each other, by using intelligence and technical skills directly over the opponent grip and traction techniques without using any equipment other than clothes on the mat in specified weights, by applying physical contact with each other in accordance with the rules (Bulgay & Polat, 2017; Cisa et al., 1987; Çalap et al., 2019).

Judokas must have the necessary physiological characteristics and a high level of anaerobic capacity in order to be successful in national and international competitions (Thomas et al., 1989). Anaerobic power is defined as the production of a limited number of ATP by a series of chemical reactions in an oxygen-free environment for the energy requirement of the organism in cell size (Günay et al., 2013). In other words, we can define it as the ability of athletes to work and produce energy in an oxygen-free environment during intense loads. Anaerobic power capacity is often used in sports that require short-term loads (Çavdar, 2014). Judo is a branch in which anaerobic energy and anaerobic glycolysis systems are used extensively (Degoutte et al., 2003). When examined, the lower extremities are generally used in short-term and high-intensity activities during technical trials in Judokas, while the upper extremity muscle groups are used in endurance and power actions (Demirci, 2019). Since all muscle groups in the body work intensively in different actions during judo competitions, athletes must have a very high cardiovascular system (Franchini et al., 2013).

When the studies are examined, balance in individual and team sports is one of the important factors that affect sportive success and performance at a high level (Muratlı, 2003). Balance is defined as the ability to correctly position the body's center of gravity (Erdoğan et al., 2017). The body's center of gravity is provided by the connection between the gravitational force and the support base (Balcı et al., 2013). It is one of the important motor skills that forms the basis of the movements that most harmonize the efficiency in motor skills. It is to hold the human body in a controlled manner by fixing the visual field during head movements (Coşkun, 2012). The fact that the whole body moves in harmony and coordination with each other is one of the reasons for good balance ability (Muratlı, 2003). Judo sport is also founded on the principles of balance and not resisting force (Güzelimdağ, 2013). Considering these two basic principles, balance is an indispensable element in Judo.

As in all sports, the effect of strength on success in Judo is accepted by everyone involved in sports. Determining the muscle strength with the right methods plays an important role in creating the training models to be applied, increasing the performance and preventing the injuries (Bulgay & Polat, 2017). Lower and upper extremity muscle strength is an important factor for athletes to be successful in judo competition organizations (Franchini et al., 2011; Iwai et al., 2008). Strength is defined as the ability of a muscle or muscle groups to produce maximum torque (circular force) or force. In other words, it is defined as the ability of the muscular nervous system to generate force against external resistance (Komi, 1992; Komi, 2003; Stone et al., 2007). The maximal force that athletes can produce depends on the contraction size of the muscle groups involved and the biomechanical state of the movement. During all exercises that require strength, there should be a harmonious working order between the working muscle groups (Bompa, 2015).

Physical characteristics and structure are the leading factors that determine performance in athletes. Because these features have a great effect on displaying physiological capacities. Physical characteristics and whether the structure is suitable for the sport branch to be selected are of great importance in terms of performance (Açıkada & Ergen, 1990; Özkan et al., 2005). However, it is of great importance to develop the relevant muscle groups, which are predominantly used in Judo. On the other hand, there is a positive relationship between the size of a muscle and the strength of that muscle (Kabadayı, 2005).

It is known that anaerobic performance and anaerobic power data increase as a result of the increase in arm muscle volume and leg muscle volume mass, around the thigh, around the calf, and in lean arm and leg volume and mass (De Ste Croix et al., 2001). Some research show that there is an increase in strength and performance values due to the increase in leg volume, lean leg volume, and leg muscle volume (İbiş et al., 2015). The reason for this is that the mass, cross-sectional area, volume and muscle fibers of the muscles that make up the arm and leg region show that they affect the power and strength produced by the muscles in this region (Özkan & Sarol, 2008).

In the light of this information, the aim of our research is to examine the relationship between arm and leg volume and anaerobic power, balance and strength characteristics in elite Judokas.

## METHOD

### Research Model

The study was carried out in the experimental research model.

### Study Group

A total of 15 national Judokas (5 female 10 male) from Burdur Municipality Sports Club participated in the research voluntarily. A statement was made to the Judokas participating in the research that the obtained data and personal information would be kept strictly confidential, and an "Informed Voluntary Consent Form" was received from each of them.

Mean age of Judokas was in male 19.60±1.07, in female 18.80±.44 years; mean height was in male 172.90±6.33 cm, in female 167.20±7.91 cm; mean weight was in male 71.40±9.27, in female 61.60±20.18 kg; mean BMI was in male 23.83±2.02, in female 21.71±5.02 kg/m$^2$.

**Data Collection**

***Height Measurement:*** The height measurements of the athletes were measured with the SECA brand height scale with 0.1 mm precision. The measurements were taken by positioning the athletes in an anatomical posture, with the arms hanging down and the head in a horizontal position, and recorded in “cm”.

***Body Weight Measurement:*** The body weight measurements of the athletes were recorded in “kg” with a SECA brand electronic scale with 0.5 kg sensitivity, bare feet and wearing only shorts and t-shirts.

***1 Maximum Repetition (1RM) Measurement:*** One-repeat maximum strength tests were performed with biceps curl (BC), triceps press (TP), shoulder press (SP), bench press (BP), lat pull down (LPD), abdominal crunch (AC), leg press (LP), calf raise (CR) movements on Precor brand fitness equipment, after a 20-min warm-up by determining 1 reference movement from each muscle group before the measurements were taken. Force measurements were taken. The sitting height and holding angles of each fitness equipment were adjusted according to the athletes, and a preliminary trial was made by explaining the test protocol without weight. After placing the estimated maximum load on the machine, he was asked to do the movement and the weight he lifted was recorded as "kg".

***Dynamic Balance Test:*** The dynamic balance measurements of the athletes were taken with the Stabilometric balance platform connected to the computer with the appropriate software SIGMA-18.166.014. Athletes were asked to stand in balance for 30 sec by standing barefoot on a platform with a weight of 4.5 kg and dimensions of 680 x 680 mm, and the values were recorded.

***Anaerobic Power Test:*** The Wingate Anaerobic Power Test (WAnT) was used to determine anaerobic power. In this measurement, measurements were taken using a bicycle ergometer developed for Monark 894 E (Sweden) brand WAnT, with a computer connection and working with a suitable software. The appropriate weight was determined by entering the age, height and body weight of the athletes into the computer and the device was adjusted to 90 cadence. With the start of the test, the weight dropped after 90 cadence, and the athletes completed the test by applying maximum power for 30 sec.

***Leg Volume Measurement:*** The leg volume measurement was determined as the leg volume between the formed gluteal fold and the sole of the foot. For this, it is necessary to determine the gluteal fold before starting the leg volume measurement methods.

***Determination of the Gluteal Fold:*** The subject to be measured is wearing slip shorts and the gluteal fold area of the leg to be measured is determined. While standing in an upright position, the athlete places the opposite leg of the leg to be measured on a bench or an auxiliary material with the knee flexion at 90° and the thigh at 90° with the trunk. In addition, the gluteal fold point formed on the leg to be measured was marked with a pencil so that it is clear. After determining the gluteal fold reference point, the athlete lowered his leg and stood with the feet shoulder-width apart and in an upright position. Then, one end of a 50 cm ruler was placed on the mark and the gluteal fold line was drawn after the ruler was set straight. In bilateral measurements, the gluteal fold region of the previous leg was taken as a reference in order to determine the gluteal fold region of the other leg with minimum error.

***Leg Volume Calculation:*** When calculating the leg volume, after determining the volume between the gluteal fold and the sole of the foot, the sum of the thigh and calf volumes was calculated.

$$BH = Vu + Vb$$

***Thigh Volume Measurement:*** The values were recorded by measuring the length between the tibial point and the inguinal fold with an accuracy of ± 1 mm at 10% intervals when the athlete was standing upright and in a position with legs shoulder-width apart.

***Thigh Volume Calculation:*** After measuring the length of the thigh volume with 10% intervals between the tibial point and the inguinal fold, the volume measurements of the parts determined with 10% intervals were calculated as determined by the Frustum marking method and the separately calculated calculations between the tibial point and the inguinal fold were made. The total volume of the thigh was calculated by summing all the parts.

***Calf Volume Measurement:*** The measurements were recorded by measuring the length between the tibial point and the medial malleolus points with an accuracy of ± 1 mm at 10% intervals, with the athlete standing upright in the foot position and the leg position shoulder-width apart.

***Calf Volume Calculation:*** After measuring the calf volume with 10% intervals between the tibial point and the medial malleolus point, the volume measurements of the parts determined with 10% intervals as determined by the Frustum marking method were calculated and the separation between the tibial point and the medial malleolus point was calculated. The total volume of the calf was calculated by adding the volumes of all separately calculated parts.

***Arm Volume Measurement:*** The values were recorded by measuring the length between the acromion bone and the olecranon bones with an accuracy of ± 1 mm, with 10% interval, while the athlete was standing upright and the leg position was open at shoulder width.

***Arm Volume Calculation:*** After the arm volume measurement was calculated by measuring with 10% intervals, the volume measurements of the parts determined with 10% intervals were calculated as determined by the frustum marking method and the volumes of all the parts calculated separately between the acromion bone and the olecranon bone were summed to add up the total volume of the arm volume was calculated.

***Forearm Volume Measurement:*** Values were recorded by measuring the length between the olecranon bone prominence and the ulnar styloid bones, with the subject standing upright and the leg position open at shoulder widthwith 10% interval ± 1 mm precision.

***Forearm Volume Calculation:*** After the forearm volume measurement was calculated by measuring with 10% intervals, the volume measurements of the parts determined with 10%

intervals were calculated as determined by the frustum marking method. arm total volume was calculated (Karges et al., 2003; Lund et al., 2002; Sukul et al., 1993).

**Research Publication Ethics**

The research was conducted with the approval of Süleyman Demirel University, University Ethics Committee. Additionally, all ethical elements and the Declaration of Helsinki were complied with in this study.

**Analysis of Data**

A statistical package program was used for the analysis of the data. Descriptive statistics for the demographic information of Judokas; “Kolmogorov-Smirnov” test was used to determine whether the total arm and leg volume values showed a normal distribution. Since the volume values did not show normal distribution, "Spearman" Correlation Analysis was used to determine the relationship between strength, anaerobic power and balance. The results were evaluated according to the “$p<0.05$” significance level.

## RESULTS

**Table 1.** Descriptive statistics of total arm and leg volume of Judokas

| Gender | Volumes (lt) | Min. | Max. | $\bar{X}$ | *S* |
|---|---|---|---|---|---|
| Male | Total Arm | 7399,18 | 14133,50 | 8722,12 | 1979,55 |
| | Total Leg | 16606,40 | 25193,65 | 18605,51 | 2512,59 |
| Female | Total Arm | 5276,93 | 10533,77 | 6695,61 | 2172,80 |
| | Total Leg | 14851,47 | 27207,93 | 17975,90 | 5219,19 |

The mean total arm volume of the Judokas was in male 8722.12±1979.55, in female 6695.61±2172.80 lt; total leg volume was in male 18605.51±2512.59, in female 17975.90±5219.19 lt.

**Table 2.** The relationship of total arm and leg volumes of male Judokas with 1 RM

| | | Arm Volume | | Leg Volume | |
|---|---|---|---|---|---|
| (kg) | $\bar{X}$±*S* | r | p | r | p |
| BC | 60±11,05 | ,104 | ,775 | | |
| TP | 67±7,88 | ,209 | ,562 | | |
| BP | 62,5±8,24 | ,573 | ,083 | | |
| SP | 94±10,48 | ,226 | ,530 | | |
| LPD | 73±6,32 | ,548 | ,101 | | |
| LP | 143±30,56 | | | ,328 | ,354 |
| CR | 118±14,75 | | | -,220 | ,542 |

When the relationship between the total arm and leg volumes of male Judokas and the 1 RM values, no correlation was found in all values (p>0.05).

**Table 3.** The relationship of total arm and leg volumes of female Judokas with 1 RM

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| | | Arm Volume | | Leg Volume | |
|---|---|---|---|---|---|
| **(kg)** | **X̄±S** | **r** | **p** | **r** | **p** |
| **BC** | 20±10 | ,821 | ,089 | | |
| **TP** | 31±8,94 | ,671 | ,215 | | |
| **BP** | 34±10,83 | ,872 | ,054 | | |
| **SP** | 48±9,08 | ,359 | ,553 | | |
| **LPD** | 43±7,58 | ,667 | ,219 | | |
| **LP** | 100±17,32 | | | ,224 | ,718 |
| **CR** | 84±20,43 | | | ,900 | ,037* |

*p<0.05, **p<0.01, ***p<0.001

Table 3 shows that the relationship between total arm and leg volumes of female Judokas with 1 RM values was examined, a positive significant relationship was found in calf raise (r=.900; p<0.05); no correlation was found in all other values (p>0.05).

**Table 4.** The relationship of total leg volumes of male Judokas with anaerobic power values

| | Unit | X̄±S | r | p |
|---|---|---|---|---|
| **Peak Power** | Watt | 770,03±112,70 | ,697 | ,025* |
| | Watt/kg | 10,82±1,28 | ,236 | ,511 |
| **Average Power** | Watt | 543,52±119,35 | ,721 | ,019* |
| | Watt/kg | 7,26±1,22 | ,758 | ,011* |
| **Minimum Power** | Watt | 293,75±195,68 | ,345 | ,328 |
| | Watt/kg | 3,95±2 | ,236 | ,511 |

*p<0.05, **p<0.01, ***p<0.001

When the relationship between total leg volume and anaerobic power values of male Judokas was examined, significant relationships were found in peak power (Watt) and leg volume (r=.697; p<0.05), mean power (Watt) and leg volume (r=.721; p<0,05), mean power (Watt/kg) and leg volume (r=.758; p<0.05); but no correlation was found in other values (p>0.05).

**Table 5.** The relationship of total leg volumes of female Judokas with anaerobic power values

| | Unit | X̄±S | r | p |
|---|---|---|---|---|
| **Peak Power** | Watt | 464,68±119,85 | ,800 | ,104 |
| | Watt/kg | 7,66±,52 | -,700 | ,188 |
| **Average Power** | Watt | 336,95±83,50 | ,800 | ,104 |
| | Watt/kg | 5,56±,37 | -,700 | ,188 |
| **Minimum Power** | Watt | 168,51±30,0 | ,300 | ,624 |
| | Watt/kg | 2,89±,73 | ,-700 | ,188 |

*p<0.05, **p<0.01, ***p<0.001

When the relationship between total leg volume and anaerobic power values of female Judokas was examined, no statistical correlation was found in all values (p>0.05).

**Table 6.** The relationship of total arm and leg volumes of male and female Judokas with balance values

| | | | Arm Volume | | Leg Volume | |
|---|---|---|---|---|---|---|
| | **Gender** | **X̄±S** | **r** | **p** | **r** | **p** |
| **Dynamic Balance Test ($cm^2$)** | Male | ,56±,09 | ,141 | ,698 | -,098 | ,788 |
| | Female | ,54±,03 | ,500 | ,391 | -,300 | ,624 |

*p<0.05, **p<0.01, ***p<0.001

When the relationship between total arm and leg volume of Judokas and dynamic balance values was examined, no statistical relationship was found (p>0.05).

## DISCUSSION AND CONCLUSION

The majority of studies in the fields of training science and sports physiology are conducted in order to lay the groundwork for performance sports, to maximize athletic performance, and to ensure success in national and international sports organizations, according to research and studies from the past to the present. When we examine many of these studies, strength, anaerobic power and balance, which are among the most important factors, are of absolute importance for many sports branches. For this reason, in our research, it was aimed to examine the relationship between arm and leg volume of elite Judokas and anaerobic power, balance and strength values.

In our study, when the relationship between total leg volume and anaerobic power values of male Judokas was examined, there was a significant relationship between peak power (Watt) and leg volume, average power (Watt) and leg volume, average power (Watt/kg) and leg volume, but no relationship was found in all other values. When the relationship between leg volume and anaerobic power values in female Judokas was examined, no statistical relationship was found in all values. We think that the reason for this is that male Judokas have higher leg volume on average and in parallel, strength is shown more in intensity than female Judokas in competitions and training.

When we examine other studies in the literature, Özkan and İşler (2010) found a significant relationship between anaerobic performance skill and leg volume and mass in their study. In a similar study, a significant relationship was found between leg volume and leg mass, and maximum power and average power values (Dore et al., 2001). The researchers said that the reason for these results is that the anaerobic performance of the athletes with dense muscle mass, leg volume and muscle cross-section area is much better. They think that the width around the thigh is due to the fact that the muscles that make up the thigh region, the muscle mass and the number of muscle fibers are higher, the force and power occurring in the muscle is higher and it affects the maximum power (Astrand & Rodahl, 2003).

De Ste Croix et al., (2000) stated in their study that there was a significant correlation between the muscle volume of the leg region and the maximum and average power data. In their study, Armstrong et al. (2001) revealed that even when total body weight, subcutaneous fat thickness and age factor are kept in a controlled manner, there is an increase in maximum power and average power data with the increase in leg volume and mass. Dore et al., (2001) found a relationship between maximum power and lean body mass, lean leg volume and body weight. On the other hand, some researchers argued that the reason for this result is the large number of muscles, muscle mass and muscle fiber that make up the leg region, and the strength and power generated by the muscle may be much higher (Van Praag et al., 1990; Welsman et al., 1997).

Baker and Nance (1999) stated in their study that they found a strong positive relationship between maximum power and maximum power values. According to scientists, approximately 62% of the maximum power performance values are related to strength performance, and it is one of the most dominant features affecting maximum power on rugby players. Beyaz (1997) found a positive and significant relationship between isokinetic muscle strength data and maximum strength data in his study on 15 sedentary men. The reason for this is that researchers think that as muscle strength values increase, the contraction strength of the muscles increases in high-intensity exercises performed for a short time.

In their study, Grant et al., (1996) emphasized that the strength and power in the muscle is higher in relation to the width of the thigh circumference and region, the muscles forming the thigh region, the muscle mass and the fibers in the muscles, which in turn affects the maximum power. Van Praagh et al., (1990) determined the leg volume with anthropometric measurement techniques and correlated it with maximum and average power values. Zorba et al (2010) stated in their study that they found a significant relationship between leg mass and leg volume and anaerobic performance values. They think that this is due to the fact that the muscles that make up the leg region are dense and due to this density, they reveal more strength and power. When we examine most of the studies in the literature, the results of our study on Judokas show similarities with other studies. The results we frequently encounter in studies reveal that the anaerobic power generation skills of the athletes with more leg volume and circumference are better accordingly.

In addition, Marsh et al., (1999) found a significant relationship between lean leg volume and anaerobic performance values in their study. He attributed the reason for this relationship to the increase in lean leg volumes as a result of the trainings performed by the groups of athletes participating in the studies; and they found that anaerobic power values decrease due to the loss of muscle mass and muscle cross-sectional area that make up the leg region as age progresses. Özkan (2011) found a significant relationship between both right and left leg volumes and maximum and average data. No relationship was found between leg mass and anaerobic performance WanT values. In this study, the researcher found a significant relationship between right leg volume and active jump anaerobic power and squat jump anaerobic power values, left leg volume with active jump anaerobic power and squat jump anaerobic power values. In a similar relationship, a significant relationship was found between right and left leg mass, active jumping anaerobic power and squat jumping anaerobic power values. The reason for this is that while the researcher applied 3 different measurements in regional measurements in the leg mass measurement method, he made 12 measurements in volume measurements. A small number of measurements may have reduced the predictive power of the targeted measurement model. In addition, he thinks that the low level of correlation reached in leg volume measurements and the lack of a relationship in mass may be due to the use of direct measurement method.

Martin et al., (2004) determined in their study that an increase in anaerobic power values occurred due to the increase in lean leg volume, which is why the researcher considers these performances as influencing factors due to the leg volume-mass effect. Işıldak (2018) determined peak power (Watt/kg) and average power (Watt/kg) in his research on swimmers. In total leg volume and anaerobic power relationship values, a positive significant correlation was found between total leg volume and peak power per weight and Average Power data. The researcher thinks that the reason for this is that there is an inverse relationship between the speed and load of the contraction in muscle contractions, and the decrease in the total speed applied by the subject to the weight in relation to the weight applied, this decrease is proportional to the force and as a result, the maximum power results are affected. In addition, the circumference and width of the thigh region, the greater the muscle mass and the number of muscle fibers that make up the thigh region, it is thought that the force and power produced may be higher and this may affect the maximum power (Armstrong et al., 2001; Bouchard et al., 1991; De Ste Croix et al., 2001). However, we can say that the anaerobic power performance values of athletes with more leg volume, muscle mass and muscle cross-section area are much better than others.

Özkan and İşler (2010) found a relationship between leg volume, leg mass and hamstring/quadriceps ratios, anaerobic power and isokinetic extension strength value in volleyball and basketball players. The reason for this is that the taller basketball and volleyball players in the study have longer leg lengths, along with wider thigh circumference, higher leg volume and mass, muscle density, long fibril structure, more mass and muscle fibers of the muscles that make up the thigh region. They think that it may be due to the excess. Özkan and Sarol (2008) found a significant relationship between leg volume and leg mass, peak power, and average power values in their study on mountaineers. A similar relationship was found between leg mass and peak power and average power. Based on other scientific studies, the researchers suggested that the muscles, muscle mass and muscle fibers that make up the leg region are more and the force-power generated by the muscle may be higher (Armstrong et al., 2001; Grant et al., 2001; Van Praag et al., 1990; Welsman et al., 1997).

In our study, when the relationship between the 1 RM values of the total arm and leg volumes of male and female Judokas and their strength was examined; No correlation was found in all values of male Judokas. In female Judokas, a positive significant relationship was found in calf raise repetition; No correlation was found in all other values. As the reason for this, we can say that the strength values of the Judokas are at the optimum level during the competition period and the 1 RM values are not increased during the competition period. In the increase in the calf raise values of female Judokas, we see that intense training and competitions can improve some parameters in strength during the competition period.

Zorba et al., (2010) found a significant relationship between leg volume, leg mass and leg strength in their study. They attributed this to the fact that the muscle groups, muscle mass and muscle fibers that make up the leg region are dense, and accordingly, the strength and power produced by the muscle is higher. Kabadayı (2005) found a significant relationship between the right and left arm total triceps muscle volume and strength values in his study on basketball and disabled basketball sports players. They stated that as a result of the work done with increasing weights, the muscle develops, grows and its cross-sectional area increases. In another study, Sharkey (1986) correlated muscle strength with its cross-section and diameter. He explained that large muscle volume can produce more force. Suna (2019) examined the relationship between total leg volume and maximal strength and found positive significant relationships.

In his study, Kabadayı (2005) could not find a significant relationship between the sum of the triceps arm volumes and the strength values of the football players regardless of the right and left arms. The researcher explained that the reason for this is that the triceps brachii muscle is a less used muscle group in football than in basketball. In addition, he found a high level of correlation between the strength values of the triceps brachi right and left arm total muscle volume in his study and measurements on the disabled football group. He attributes the reason for this to the fact that disabled football players play with crutches, as opposed to the rare use of the triceps muscle in his study on football players.

Özkan (2011) did not find a significant relationship between leg volume and mass and leg strength values. The reason for this is that the researcher thinks that the low muscle strength and, accordingly, the muscle fiber length, the muscle cross-section area and the low muscle mass of the muscle may be due to it. Lynch et al., (1999) found in his study that the structure of the muscles forming the leg region and the volume of the leg changed in relation to age, and the result of this change also affected the isokinetic strength values. He thinks that this is due to advancing age. As it is known, low muscle volume in the body, narrow muscle area, excess fat east, low mass and fiber ratios of the muscles that make up the leg region affect anaerobic power performance as well as strength performance negatively. De Ste Croix et al., (2000) found a relationship between lean body mass and isokinetic leg strength in the data obtained by anthropometric measurement methods, supporting these results in their study. He thinks that the reason for this should be considered as an important factor in addition to existing muscle mass, as well as gender and age. Akagi et al., (2009) found a significant relationship between leg volume and leg muscle cross-sectional area ratio and isokinetic leg strength. Still, Ste Croix et al., (2000) found no significant relationship between leg muscle cross-sectional area and isokinetic knee flexor and extensor strength in their study. In their study, they thought that the reason why there was no relationship between strength performance and other variables, the muscle strength of the football players decreased significantly when they reached the speed of 240° sec, they were tired when they reached this speed during the test and their muscular endurance levels were low.

Aktuğ (2016) determined a positive and significant relationship between leg volume and leg mass and quadriceps and hamstring muscle strength values. The researcher explains the reason for this with the correlation between isokinetic hamstring and quadriceps muscle strength and leg volume and leg mass, with the cross-sectional area of the muscle and the increase in strength parallel to each other. Özkan and İşler (2010) found a relationship between the hamstring/quadriceps ratio and isokinetic extension strength in football players in their study. They think that this is due to the characteristic features of the sports branch and the characteristics of the football players such as posture type, body weight, lean body mass, muscle mass, muscle type, leg volume, leg mass, hamstring-quadriceps ratios.

In our study, when the relationship between the total arm and leg volume values of male and female Judokas and the dynamic balance values was examined, no statistical relationship was found. We think that the reason for this is that the technical trainings are intense due to the fact that the athletes are in the competition period and the conditional characteristics of these trainings are at the optimum level.

İbiş (2015) found a statistically significant difference between leg mass and dynamic balance values in his study on volleyball players. The researcher explained the reason for this because the dynamic balance skills of athletes with high leg mass are much better, and the capacity of the flexor and extensor muscles to work synergistically and antagonistically due to the increase in intermuscular and intramuscular coordination skills with the increase in muscle strength. In two similar studies conducted by Mayson et al., (2008) and Campbell et al., (1989), they found that there was a decrease in balance skill levels as a result of decreased knee extensor and flexor muscle strength in the elderly. In the study of Paterno et al., (2004) on young male athletes, Perrin et al., (1999) on the elderly, and Young et al. (2010), they have proven that it increases. Young et al. stated that the reason for this was related to the increase in the speed of motor unit contraction and muscle coordination in the lower group extremity muscles with the increase in muscle strength.

Aktuğ (2016) did not find a significant relationship between leg volume and leg mass and static and dynamic balance performance skills in his study on football players. These results in Aktuğ's study are similar to the results in our study. Akıl et al. (2016), in their study in which they compared the leg mass and leg volume and balance performance of the athletes, they did not find a difference between the oscillation index and static balance, but they found a positive significant relationship between the leg volume, leg mass and dynamic balance. Researchers think that this is due to the relationship between mass and power.

To conclude, it was determined that arm and leg volume had an effect on some anaerobic power parameters, but had no effect on strength parameters and dynamic balance. In judo, where anaerobic power and strength are the most important factors, ensuring perfect coordination and readiness in the whole body is very important for high performance. Parallel to the findings of our study, it can be emphasized to sports scientists and coaches that studies to improve strength and anaerobic power characteristics of Judokas should be done. The reason why there is no difference in some of the findings of our research is that all judo players compete as elites and the measurements are taken during the competition period in order to reach the peak values. For similar studies to be conducted on Judokas in the future, it is recommended to establish hypotheses in the macro plan in order to consider the benefits of training programs, load intensities and scope. In addition, we think that our study can support other studies on this subject and develop new and different perspectives in the development of sportive performance in judo.

**Conflict of Interest:** There is no personal or financial conflict of interest within the scope of the study.

**Researchers' Statement of Contribution Rate:** Research Design OOÇ, MA; Statistical analysis OOÇ, MA; Preparation of the article OOÇ, MA; Data Collection was carried out by OOÇ.

**Information on Ethics Committee Permission**

**Board Name:** Süleyman Demirel University, University Ethics Committee

**Date:** 08.05.2023

**Issue/Decision Number:** 66/4

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