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CORRELATION OF UPPER AND LOWER EXTREMITIES ISOKINETIC STRENGTH IN ELITE MALE JUDOKAS

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ABSTRACT

Background and purpose

Muscle strength is one of the most physically important parameters during the competition for judokas. Studies have shown that for judokas, strength in especially the knee and shoulder muscles and the strength balance between right and left sides is very important in terms of both staying in balance and doing specific techniques correctly. Our study aims to find out the correlations between isokinetic lower and upper extremity strength in elite judokas and to examine bilateral and contralateral strength ratios.

Methods

This study is designed according to cross-experimental design with randomized repeated measurements. Fifteen male (mean values: age 19.40 ± 1.24 years, height 170.55 ± 9.44 cm, weight 78.47 ± 18.55 kg, and BMI 27.02 ± 5.82 kg/m^2) elite judokas between the ages of 18 and 21 participated voluntarily in the study. Knee extension (EX) and flexion (FLX), shoulder internal rotation (IR) and external rotation (ER) isokinetic strength measurements of the subjects were measured with concentric/concentric (Con/Con) contractions at 60^{o} s^{-1} and 180^{o} s^{-1} angular velocities. Ipsilateral hamstring/quadriceps (H/Q), internal rotation/external rotation (IR/ER), contralateral Q/Q, H/H, IR/IR, ER/ER ratios were calculated through lower and upper extremity isokinetic strength. Shapiro–Wilk, Levene, paired sample t-test, and Pearson correlation test were used in statistical analyses.

Results

In terms of the ipsilateral strength ratios on dominant (DS) and nondominant (NDS) in lower and upper extremities, a significant difference was found only at 60° s^{-1} angular velocity in only the lower extremity on DS ($P < 0.05$). In contralateral strength ratios, a statistically significant difference was found between Q/Q and H/H at 60° s^{-1} angular velocity ($P < 0.05$). When the correlations between lower and upper extremities were examined, no significant difference was found only between ER and FLX on DS at 60^{o} s^{-1} angular velocity (P > 0.05). High correlations were found between all other parameters (P > 0.05).

Conclusions
In conclusion, it was found that lateral asymmetric ratios may differ in elite judokas especially at low angular velocities; however, this difference was not at a level to cause the risk of injury, DS and NDS showed similar strength in both lower and upper extremity, and there were high positive correlations between lower and upper extremity strength.

Keywords: *isokinetic strength; judoka; knee; lateral asymmetry; shoulder*

INTRODUCTION

It is a known fact that in the judo branch, in which competition is of great importance and pushes, pulls, and different techniques (throws, pins, chokes, arm bars, etc.) are intensely applied, certain specific physical and physiological characteristics should be dominant.[1–4] Studies conducted have clearly stated that especially judokas competing in elite national and international competitions should have top-level strength, power, and endurance and that all these compounds have a direct effect on success.[5] Researchers have emphasized that during competitions, the most important physical parameters for judokas are muscle strength and balance.[6] Kinesiologically, the ability to make moves specific for judo correctly and efficiently with different contractions that differ frequently depends on whether the skeletal muscles are strong enough; in addition, it is also known that skeletal muscles have great importance in terms of the stabilization of the body during training or competition.[7,8] Researchers have reported that in judokas, especially the strength in the knee, thigh, and shoulder muscles and strength balance in right and left sides are of great importance in terms of both staying in balance and being able to perform specific techniques correctly.[6,9,10]

Today, sports scientists use different methods to find out muscle strength in athletes and to show the similarities or differences between agonist and antagonist muscles. Isokinetic dynamometers are among the tools that enable us to evaluate skeletal muscles which allow different joints to make movements and the strength produced by these muscles in the most objective way.[11,12] At the same time, it is possible to find out whether muscle groups are prone to injury with isokinetic dynamometers.[13,14] Especially in combat sports, performing muscle strength tests is important in terms of revealing the possible differences and asymmetry between muscle groups.[15] When evaluated from this point of view, continuous evaluation of being prone to knee and shoulder injuries, which are of great importance in combat sports and which develop due to excessive use, with isokinetic measurements is of great importance for athletes.[6,16,17]

Asymmetric force differences for knees and shoulders in athletes is defined as muscle groups on right and left sides not being able to produce equal force or force other than specific rates in similar contraction types in isokinetic dynamometers.[18,19] This is known as the imbalance of force created by quadriceps (Q) and hamstring (H) muscles during extension (EX) and flexion (FLX) for the knee and during internal rotation (IR) and external rotation (ER) by shoulder muscles.[18,21] In isokinetic dynamometers, H/Q and ER/IR ratios increase as test speed increases, while this rate can vary between 50 and 80% for knee depending on the angular velocity, it is 60–80% for shoulder[22,23].

A 10–15% difference between dominant (DS) and nondominant (NDS) in bilateral strength ratios such as H/H, Q/Q, ER/ER, and IR/IR is considered as normal.[24] Studies conducted on judokas have reported that judokas with similar age groups and weight classes have similar body strength,[4] and that there are no big differences between DS and NDS sides in terms of shoulder strength in the absence of the history of injury.[4,6,19,20,25]

When the current literature is examined, although studies were found in which lower and upper extremity strength and asymmetries were evaluated separately in judokas, no studies were found in which both extremities were evaluated together and the correlations between one another were found. In this respect, our study is the first.

The hypotheses of the present study were that there would be no asymmetric strength balance on DS and NDS in terms of lower and upper extremity muscle strength in elite male judokas and that there would be high correlations between the two extremities.

METHODS

Experimental design

This study is designed according to a cross-experimental design with randomized repeated measurements. With this design, lower and upper extremity strength of elite judokas on DS and NDS were found, and the differences and correlations between these were also found. The subjects visited the laboratory five times at 24-hour intervals. In the first visit, the subjects were informed about the test protocols to be applied; their height, weight, and body mass index (BMI) measurements were taken and lower and upper extremity concentric/concentric (Con/Con) isokinetic test at $60^{o}\ s^{-1}$ and $180^{o}\ s^{-1}$ angular velocities which would be applied in subsequent visits were introduced. Since studies conducted on isokinetic strength in judokas are generally conducted at angular velocities of $60^{o}\ s^{-1}$ and $180^{o}\ s^{-1}$ and since movement structures of judokas are suitable for these angular velocities, isokinetic strength measurements were conducted in these two angular velocities in the present study.[6,19] In the following visits, the subjects were randomized with application cards and isokinetic lower and upper extremity strength measurements at $60°\ s^{-1}$ and $180°\ s^{-1}$ angular velocities on DS and NDS were measured randomly and with intervals of 24-hour long full rests. DS of all subjects in both lower and upper extremity were determined as the right sides and all tests were applied on both DS and NDS sides. Before the tests, the subjects performed general warm-up for lower and upper extremity muscles.[26] During the applications, the subjects were warned not to perform any exercise or physical activity. The applications were carried out at the same hour of the day (14:00–16:00). Since the subjects were elite judokas, the measurements of the study were completed between January and August 2020. The measurements were conducted in the performance laboratory of Ondokuz Mayıs University Yaşar Doğu Faculty of Sport Sciences. The study was organized and conducted in accordance with the Helsinki protocol. All of the subjects were informed about the study and consent forms were taken from all of them. The ethical approval was taken at a local ethic committee (2020/532).

Participants

Fifteen male judokas (mean values: age 19.40 years, height 170.55 cm, weight 78.47 kg, and BMI 27.02 kg/m^2) between the ages of 18 and 21 who had at least 9 years of active judo training history and who were regularly training participated voluntarily in the study (Table 1). In the G power analysis conducted to determine the number of subjects, it was determined that the study could be completed with 14 elite judokas; thus, 15 judokas were included in the study. Athletes who had a previous history of injury in the lower and upper extremities and those who had a serious injury or a chronic disease were not included in the study.

Determination of lower extremity isokinetic strength

Cybex Humac Norm Testing and Rehabilitation System, CSMI computer-controlled isokinetic

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TABLE 1 Descriptive Data of Subjects (n:15).

	Min.	Max.	Mean	SD
Age (year)	18	21	19.40	1.24
Height (cm)	154	185	172.80	9.44
Weight (kg)	56.3	137.8	80.32	18.55
BMI (kg/m^2)	20.43	39.47	27.02	5.82
Training age (year)	9	12	10.13	1.06

BMI: body mass index; Min: minimum; Max: Maximum; SD: standart deviation.

dynamometer was used to find out the isokinetic lower extremity strength of the subjects in our study. For lower extremity strength, peak torque (PT) angular velocities of the knee at EX and FLX phases were found as 60^o s^{-1} and 180^o s^{-1}. The tested subject sat on the seat of the dynamometer, with an 85° torso inclination. The range of motion was 90° (maximum extension was marked and set as "anatomic zero, 0°"). The participant's trunk and thigh of the tested limb were fixed using the dynamometer's fixing straps (tested thigh and thorax, pelvis) so that movement was confined to a single joint movement only (knee extension–flexion). Dynamometer calibration was performed in accordance with the manufacturer's instructions and torque was gravity corrected. In order to ensure the adaptation of the subjects and to protect from injury, three trials were made and a 30-second rest was given before the test at both angular velocities. Five maximal repetitions were made at 60^o s^{-1}, while 20 maximal repetitions were made at 180^o s^{-1}. During the whole test, the subjects were verbally encouraged about basic push/pull and the number of remaining repetitions to get the best performance from the subjects. The PT values found at all angular velocities were recorded in Newton-meter (Nm). In line with the results, in order to find out lower extremity strength rates, contralateral strength rates of DS and NDS were found as Q/Q and H/H, while ipsilateral strength rates were found as H/Q and they were recorded in percentage values.

Determination of upper extremity isokinetic strength

Cybex Humac Norm Testing and Rehabilitation System, CSMI computer-controlled isokinetic dynamometer was used to find out the isokinetic upper extremity strength of the subjects in our study. For upper extremity strength, peak torque angular velocities of the shoulder at IR and ER phases were determined as 60^o s^{-1} and 180^o s^{-1}. Before each test, the device is calibrated. The range of motion of the tested extremity was 90 degrees. One person performed both giving instruction to the subjects prior to testing and measurement. Dynamometers were set for each subject according to the protocol. The testing started with the warm-up and was followed by a period of rest for 2 min before performing maximal contraction. Testing the maximum muscle strength of subjects was carried out at an angular speed of 60° s^{-1} and 180° s^{-1} in the supine position. For 60^o s^{-1}, five maximal and for 180^o s^{-1}, 10 maximal contractions were performed in a row. PT values found at all angular velocities were recorded as Newton-meter (Nm). In line with the results, to find out upper extremity strength rates, contralateral strength rates of DS and NDS were found as IR/IR and ER/ER, while ipsilateral strength rates were found as ER/IR and they were recorded in percentage values.

Statistical analysis

SPSS package program (SPSS for Windows, version 21.0, SPSS Inc., Chicago, Illinois, USA) was used for statistical analysis. The data were presented as mean and standard deviation. The Shapiro–Wilk test was used to test normality, while the Levene test was used to test homogeneity. As a result of the normality test, the data were found to be normally distributed. A paired sample t-test was used in PT values of the subjects on DS and NDS, and in the comparison of H/Q, ER/IR, H/H, QQ, IR/IR, and ER/ER values. Correlations between the PT values of lower and upper extremities were found with the Pearson correlation test. Statistical results were evaluated at 95% confidence interval and $P < 0.05$ significance level.

RESULTS

When the subjects' muscle strength generated at lower and upper extremities on DS and NDS were compared, no significance was found on DS and NDS at both lower and upper extremities ($P > 0.05$) (Figure 1).

In Figure 2, when the ipsilateral strength ratios of the subjects on DS and NDS of lower and upper extremities were compared, no significance was found on both DS and NDS in upper extremity values ($P < 0.05$); however, a significant difference was found on DS at $60^o s^{-1}$ angular velocity in lower extremity ratios (P=0.049; 95% CI = -7.24 to -2.12). No significance was found at $180^o s^{-1}$ angular velocity ($P > 0.05$).

When the contralateral strength ratios of the subjects at lower and upper extremities were compared, statistical significance was found between Q/Q and H/H at $60^o s^{-1}$ angular velocity (P=0.030, 95% CI=-17.18 to -1.04); however, no significance was found in $180^o s^{-1}$ Q/Q and H/H, 60 and $180^o s^{-1}$ IR/IR and ER/ER values ($P > 0.05$) (Figure 3).

In Figure 4, when the relationship between the subjects' lower and upper extremity strength values on DS and NDS was examined, high positive correlations were found between IR and EX (r=0.651, P=0.009) at $60^o s^{-1}$ angular velocity, between IR and EX (r=0.714, P=0.003) and ER and FLX (r=0.543, P=0.036) at $180^o s^{-1}$ angular velocity on DS. On NDS, high positive significant correlations were found between IR and EX (r=0.884, P=0.001) and ER and FLX (r=0.809, P=0.001) at $60^o s^{-1}$ angular velocity and IR and EX (r=0.571, P=0.026) and ER and FLX (r=0.789, P=0.001) at $180^o s^{-1}$ angular velocity. A significant correlation was not found only between ER and FLX (r=0.432, P=0.108) at $60^o s^{-1}$ angular velocity on DS.

DISCUSSION

The present study showed several major findings related to lower and upper extremity muscle

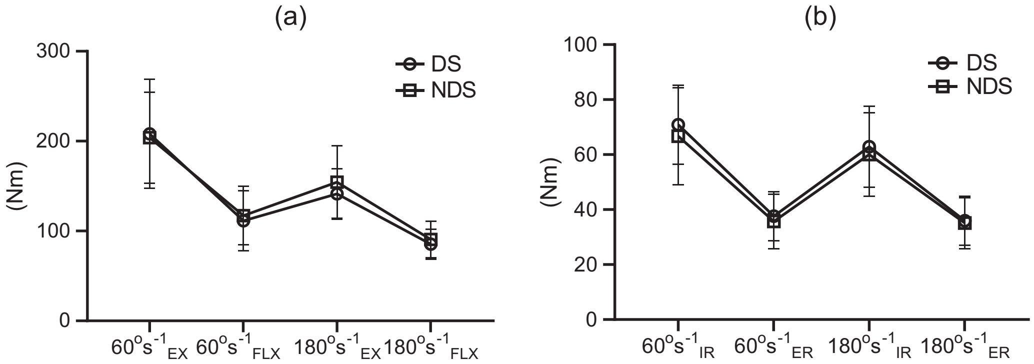

FIGURE 1 Comparison of isokinetic upper and lower extremities strength on DS and NDS. (a) isokinetic knee strength; (b) isokinetic shoulder strength. DS: dominant side; NDS: nondominant side; EX: extension; FLX: flexion; IR: internal rotation; ER: external rotation.

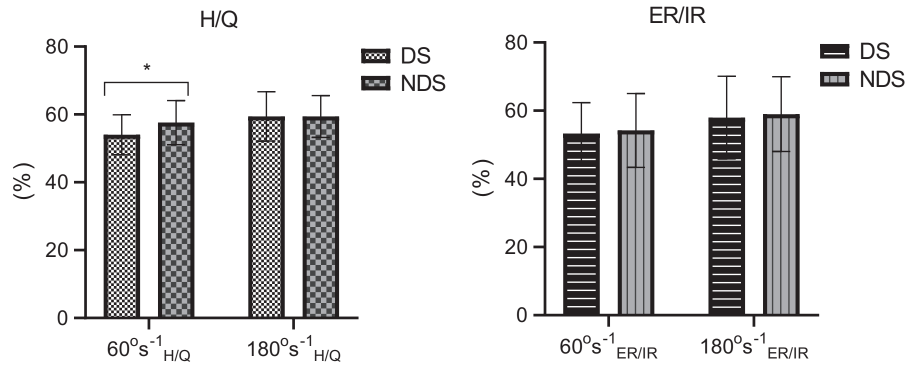

FIGURE 2 Comparison of upper and lower extremities ipsilateral strength ratio on DS and NDS. *P < 0.05. DS: dominant side; NDS: nondominant side; H: hamstring; Q: quadriceps; IR: internal rotation; ER: external rotation.

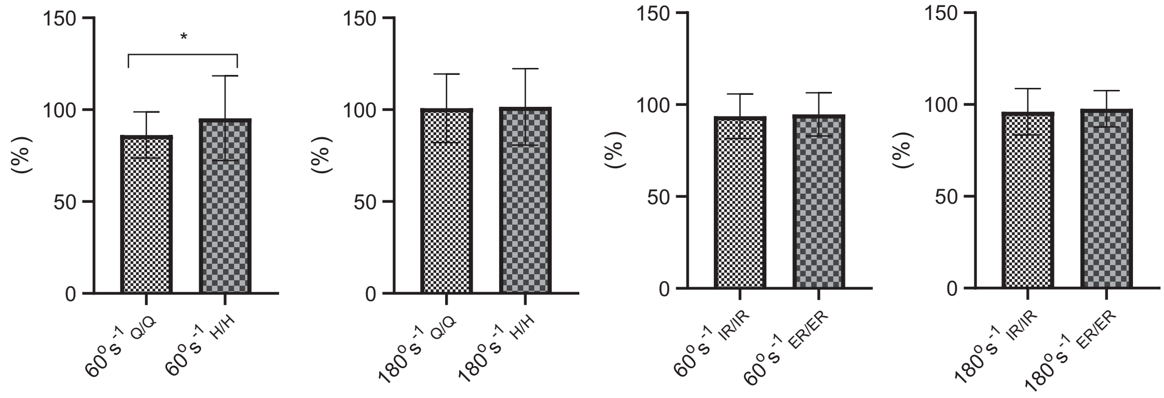

FIGURE 3 Comparison of upper and lower extremities contralateral strength ratio on DS and NDS. *P < 0.05. H/H: hamstring/hamstring; Q/Q: quadriceps/quadriceps; IR/IR: internal rotation/internal rotation; ER/ER: external rotation/external rotation.

strength in elite judokas. Of these findings, when strength and asymmetric ratios were evaluated, it was found that at $60^{o}\,s^{-1}$ angular velocity, NDS had a higher ipsilateral (H/Q) ratio when compared with DS and again at $60^{o}\,s^{-1}$ angular velocity, H/H showed higher results when compared with Q/Q among contralateral (H/H and Q/Q) ratios. When the correlations between lower and upper extremity were examined, high correlations were found between lower and upper extremity at all angular velocities except $60^{o}\,s^{-1}$ angular velocity ER and FLX (P=0.108, r=0.432) on DS and all angular velocities on NDS.

When studies about lower extremity isokinetic strength measurements of judokas were evaluated, it was found similar to the results of our study that strength decreased and bilateral and contralateral strength ratios increased as angular velocity

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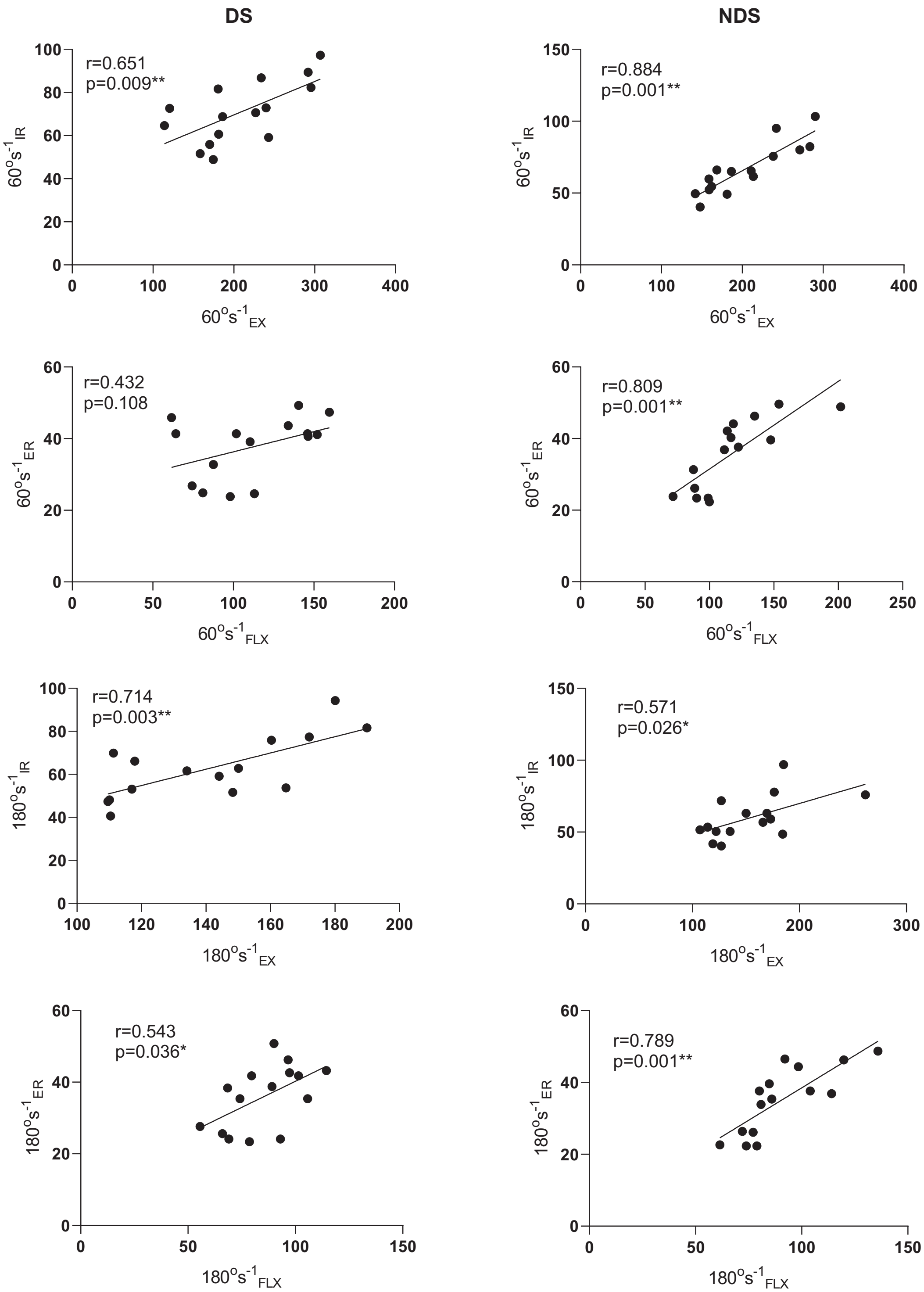

FIGURE 4 Correlation between upper and lower extremities strength on DS and NDS. $^{**}P < 0.001$; $^{*}P < 0.05$. DS: dominant side; NDS: nondominant side; H: hamstring; Q: quadriceps; IR: internal rotation; ER: external rotation; EX: extension; FLX: flexion.

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increased. In addition, researchers reported that results showed similar strength values on DS and NDS in the lower extremity of judokas and asymmetric strength differences were generally between 10 and 15% as stated in literature.[10,20,27] Researchers reported that the reason why there were similar strength values and asymmetric ratios on DS and NDS was the fact that judokas had to have good body stabilization and thus they had similar strength ratios in order to be able to perform specific movements efficiently during both training and competitions.[25,27] When evaluated in terms of isokinetic measurements, since movement is obtained first from fast twitch (FT) fibers instead of slow twitch (ST) depending on repeated measurements in ST and FT fibrils during the period movement starts in the muscle (latent period), muscle contraction period and relaxation with the stimulation of motor neurons, increase in asymmetric ratios and decrease in strength as angular velocity increases, the decrease in strength and increase in asymmetric ratios as velocity increase is a possible result. As is known, STs are fibrillar types that contract slowly but strongly, while they produce less strength than ST. In their study, Ebersole et al.[28] interpreted the results of their study as we did and in addition, they advocated that for these reasons, fatigue index (FI) decreased as angular velocity increased.

Studies in the literature evaluating the upper extremity strength in elite judokas have reported that judokas had much higher shoulder IR and ER strength when compared with many sport branches and especially with nonathlete groups.[29,30] Also, it has been reported that judokas had similar shoulder IR and ER strength on DS and NDS although differences were found in many branches.[10,31] Studies conducted have shown that similar strength ratios especially on DS and NDS are generally found in studies conducted on elite judokas, while some studies have reported that sub-elite judokas show different results.[20] It is thought that this situation results from the fact that training programs are prepared in this respect to balance strength production on DS and NDS and to remove the risk of injury caused by lateral asymmetry, as stated by Drid et al.[32] In addition, competitions last for 3–4 min in elite judokas and they do activities that require high-intensity strength up to 30 s; thus, judokas may have to show a high level of strength in, especially, push and pull movements depending on their weight class and levels of being sub-elite or elite.[5,7] Since elite judokas need a high level of strength, similar strength values on DS and NDS are important in terms of protecting body stabilization and performing the moves accurately during competition.

In the present study, when ipsilateral and contralateral strength ratios in both lower extremity and upper extremity were evaluated in elite judokas, while no difference was found in the upper extremity, a significant difference was found between H/Q ratios and Q/Q and H/H ratios on DS and NDS at $60^{o}\ s^{-1}$ angular velocity in the lower extremity. It was found that NDS had higher ratios than DS especially in H/Q ratios; however, the ratios on both DS and NDS were between 50 and 80%, as stated in the literature. In this respect, it was found that lateral asymmetry ratios of our subjects in both lower and upper extremities were not within the ranges that would pose a risk. In almost all of the studies conducted on judokas in literature, similar asymmetric ratios were found on DS and NDS.[4,6,7,10,19,20,25,27,29–31] Researchers thought that this was due to the fact that lateral asymmetry ratios depending on the knee and shoulder strength were within optimal range on both sides and thus during both training and competition, both extremities ensured body stabilization in situations contrary to the structure of movement and thus enable a top level of ability to recover.[6,32,33] Besides, too much or too little asymmetric ratio differences that may occur in both lower and upper extremities also increase the risk for different injuries or cause injuries. For example, while 0.60 is accepted as normal in H/Q ratios at $60^{o}\ s^{-1}$ angular velocity in the knee, too much increase or decrease in this ratio can be attributed to hamstring strains and anterior cruciate ligament injury.[34,35,36]

When the correlations between judokas' lower and upper extremity strength values were examined in our study, high correlations were found in all parameters except ER and FLX strength at 60º s^{-1} angular velocity (Figure 4). In our study, lower and upper extremity correlations were conducted between IR and EX and ER and FLX at all angular velocities. Evaluating the correlations of IR and EX, ER and FLX phases together is due to the fact that shoulder internal rotators and the muscles in Q muscle group work concentrically as the main agonists in IR and EX phases and shoulder external rotators and muscles in H muscle group function to protect the stability at ER and FLX phases.[10,37] Although there are studies in literature examining the lower and upper extremity isokinetic strength values of judokas together, no studies were found in which the correlations between one another were examined. However, the fact that strength values between DS and NDS in lower and upper extremities were similar in most of the studies proves that both extremities develop similarly in judokas.[10,20,38] Also, as stated by researchers, similar lower extremity and upper extremity results on DS and NDS especially in elite judokas are important in terms of keeping the body in balance during the competition, keeping the stabilization of the body during moves specific to judo (pushes and pulls) are also important in terms of performing the movement correctly and accurately.[6,10,25,39] It is thought that regular and conscious training programs applied to elite judokas keep the correlations between lower and upper extremities high.

In conclusion, it can be seen that DS and NDS show similar strength in elite judokas when considered in terms of lateral asymmetry, while the difference was found especially at 60º s^{-1} angular velocity. This difference was not within the range of injury risk and high correlations were found between lower and upper extremity strengths, as stated in our hypothesis. These results showed that lateral asymmetry rates of judokas are within safe ranges in terms of injury risk and lower and upper extremity strengths showed similar results on DS and NDS sides. It is thought that these similar results will contribute to competition performance and minimize injury risk due to sudden movements since staying in balance and applying strength equally to both sides is very important especially for judokas. However, in addition to examining the relationship between the two extremity groups in future studies, it is of great importance to evaluate trunk and hip strengths and thus examine the correlations between all strength parameters that affect balance and body stabilization, which is very important for judokas. Our study also has some limitations. The most important of these limitations is the fact that isokinetic strength measurements were made only at angular velocities of 60 and 180 degrees and that they were applied only to elite male judokas.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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