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Do Elite Female Judokas Show Asymmetry in the Internal and External Rotators of the Shoulder? A One-Dimensional and Principal Component Approach

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Abstract: Background/Aims: Asymmetry of the internal (IR) and external (ER) shoulder rotators can increase the risk of injuries in judokas. Discrete analyses are usually performed in time series data, but they can have biases by removing trends, so other approaches have been proposed to avoid these biases such as statistical parametric mapping (SPM) and principal component analysis (PCA). This study analyzed the asymmetry in the shoulder rotators in female judokas, comparing dominant (D) vs. non-dominant (ND) upper limbs. **Methods:** For this, 11 elite athletes (age: 20.1 ± 2.9 yrs.; experience: 4.0 ± 0.5 yrs.; body mass: 66.0 ± 14.6 kg; height: 1.6 ± 0.1 m; BMI: 24.8 ± 4.3 kg/m^2), were evaluated in an isokinetic dynamometer (Cybex® Humac/Norm Dynamometer CSMI, 502140, Stoughton, MA, USA). All participants performed the concentric (CON/CON) isokinetic evaluations of internal and external rotation of the shoulder in 60°/s and 180°/s angular velocities. **Results**: There was no significative asymmetry between IR vs. ER at 60°/s; similar results were observed at 180°/s when analyzed by PCA or SPM methods ($p > 0.05$ for all comparison). There was no difference between peak torque at 60°/s or 180°/s ($p > 0.05$ for all comparison). **Conclusions:** no asymmetry was observed in IR and ER in elite female athletes, regardless of the analysis method.

Keywords: martial arts; isokinetics; biomechanics; athletic performance; task performance and analysis; statistical parametric mapping

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1. Introduction

Judo is an Olympic combat sport that requires a high level of technical, mental, and physical training [1,2]. To achieve maximal performance, athletes in this sport should maintain a training routine that lasts for a total of 6 h/day [1]. Therefore, daily training can lead athletes to develop lower limb [3,4] and upper limb asymmetries [5] because it is a combat sport where fighters tend to adopt unilateral postures [6]. Asymmetries in judo athletes can cause concern for coaches, physical evaluators, physiotherapists, and physicians, as they tend to increase the risk of injury [3,5,7]. According to Stradijot et al. [8], it is important to detect lower limb asymmetries in judokas and, when necessary, establish compensatory training to minimize the risk of injury. In fact, Clark [9] establishes that for lower limbs, asymmetries above 15% are considered potentially dangerous.

Although there are no injury risk indicators for upper limb asymmetries, monitoring them throughout training and establishing corrective strategies is important [10]. Specifically in competitive judo, it is very important to monitor upper limb asymmetries [5] because it is a body region where there is a high incidence of injuries [11,12]. In a recent review, Mooren et al. [11] observed that shoulder injuries account for 11–18% of injuries. Injuries to this region can be catastrophic for judo athletes, as one in four injuries require hospitalization [12] and can keep the athlete away from training and competitions for up to 6 months [13]. In this context, it is important to understand which factors are responsible for shoulder functionality and the risk of injuries. Among the factors that can increase the risk of a shoulder injury, the range of motion (RoM) of the rotator cuff in the shoulder can be influenced by physiological mechanisms, reflecting the intricate balance between muscular, tendinous, and joint factors [14]. RoM changes may stem from muscle flexibility and strength alterations, where tight or weakened rotator cuff muscles can restrict movement [14,15]. Tendon integrity also plays a crucial role; tendinopathy or tears can compromise the smooth gliding of tendons over bone, limiting motion [15]. Additionally, joint capsule and ligament stiffness, often resulting from inflammation or scar tissue formation, can impede the shoulder's range of motion [15,16]. We cannot ignore the neuromuscular control as a significant factor, as impaired proprioception or motor coordination can affect how well the shoulder joint functions within its range [14,15]. When analyzing specific studies with judo athletes, we can mention sexual differences, age [17], repetitive techniques during the training [18], and the techniques applied and suffered [12,18,19]. Barsottini and Guimarães [19] associated the levers used in hand techniques (te-waza), such as seoi-nage and tai-otoshi, with the incidence of injuries, as these require the application of force at high velocity to the internal and external rotators of the shoulder [20]. Considering those techniques like seoi-nage [21] and tai-otoshi [22] are often used in competitions, it becomes essential to monitor the asymmetry of the internal and external rotators of the shoulder [23], to minimize the risk of injuries.

Despite the topic's relevance, few studies have focused on monitoring asymmetry between shoulder rotators in judo athletes [23–25]. Even so, the results seem conflicting and, thus, in national [26] and international male judokas [23,25], no significant asymmetries were observed between the concentric strength of the rotators. On the other hand, Detanico et al. [24] observed that highly experienced athletes showed a higher rotator asymmetry when compared to beginners. Specifically in female athletes, there is a gap in the studies investigating this subject [25]. It should be emphasized that this is a relevant topic since in Brazilian under-21 judokas at the national and international levels, Madaleno et al. [27] observed that women have a higher mobility on the dominant side. However, to our knowledge, only two studies investigated this subject in female judo athletes [25,27].

Regarding the assessment of asymmetries in athletes, in recent years there has been discussion about the most appropriate analysis method [28]. Some studies on judokas have taken discrete (peak torque) measures [24–26]. However, other methods have been proposed for analyzing the biological curve, such as statistical parametric mapping (SPM) and principal component analysis (PCA). SPM was originally used for neuroscience analysis; however, Pataky [29] proposed that this method should also be applied to biomechanics because the evaluator can access the complete analysis of the force curve instead of a discrete point. However, a recent review indicated that there are few published papers in biomechanics using this method and rare sports have been investigated; furthermore, there is a lack of studies on women [30]. To our knowledge, Aedo-Muñoz et al. [23] was the only study to apply the SPM method to analyze shoulder rotator asymmetry in judo athletes.

PCA was proposed to observe patterns of variability in the data curve [31]. Unlike SPM, PCA makes a linear combination of the signals and determines the component that best explains the signal variability [32]. Given the context presented above, the present study presents, as original aspects, the comparison of concentric and isometric strength of the internal and external shoulder rotators in international-level female judokas. In addition, there will be a comparison to see whether or not there are significant differences in the asymmetries detected with the SPM or PCA methods used to analyze the strength curves. Therefore, this study aimed to investigate the levels of asymmetries in shoulder rotation at 60 and 180°/s in concentric (CON/CON) isokinetic evaluations of elite female judokas through discrete and multivariate analyses (SPM and PCA). We hypothesize that the different analysis methods (SPM and PCA) will present differences in the ability to detect asymmetries between the internal and external rotators of the shoulder at 60° and 180°/s.

2. Materials and Methods

2.1. Experimental Approach

This experimental protocol was developed to evaluate potential asymmetries in the internal and external rotators of the shoulder among elite female judokas. Before data collection, the project received approval from the ethics committee (Protocol No. 352/22) and the administration of the High-Performance Center in Chile. After this, access was requested for coaches and athletes to explain the purposes of the study. All athletes that met the inclusion criteria were invited. Those who consented signed a free and informed consent form, adhering to the Declaration of Helsinki for ethical standards in scientific research. Data collection occurred in a single session at the Laboratory of Applied Neuromechanics. Participants first completed a questionnaire detailing their age, dominant side, injury history, and tokui-waza (favorite technique) applied in training and competition (1st, 2nd, and 3rd favorites techniques. For this measure, we used self-reported data declared by the participant and we confirmed it with the coaches). The dominance side was used to compare the athletes (Dominant: D vs. Non-Dominant: ND).

2.2. Participants

The following criteria were adopted to compose the participants: (a) female athletes; (b) ≥18 yrs. old; (c) training and competing at an international level (≥South American championship) and; (d) no upper limb (shoulder, elbow, and hand) injuries in the past six months. Participants were excluded that (a) did not execute the tests at the required speed, (b) did not complete all data collection, (c) had errors occur during data recording or processing, and (d) requested to withdraw. The sample size calculation was based on two previous studies [23,24] examining asymmetry in male judokas' upper limb rotators. For this we performed a simple random sampling calculation. For this, based on these studies, asymmetry in the internal rotators was identified as the primary variable for estimating the sample size. The calculation used an alpha significance level of 0.05, a two-tailed test, a 95% confidence interval (95% CI), a power of 0.5, and an effect size of 0.2 (the effect size as rank-biserial correlation and were categorized as follows: 0.0–0.1, trivial; 0.11–0.39, weak; 0.4–0.69, moderate; 0.7–0.89, strong; and 0.9–1.0, very strong). To detect a difference of 5.0 N/m between the dominant and non-dominant upper limbs, a minimum of 11 participants was suggested. The training periodization (second of six months) and data were provided by the coaches, and all athletes trained approximately 4 h/day (50/50 physical fitness and specific judo training) and 6 times/wk. The physical fitness included sprints, strength, and power exercises targeting both upper and lower limb conditioning. The specific judo training included *uchi-komi* (repetition technical training), *tokui-waza* (repetition of favorite throw), and randori (standing and ground fight training). The final sample was composed of 11 (n = 1 left-hand domain) elite female athletes (age: 20.1 ± 2.9 yrs.; body mass: 66.0 ± 14.6 kg; height: 1.6 ± 0.1 m; BMI: 24.8 ± 4.3 kg/m^2). Table 1 displays the favorite *tokui-waza* techniques applied during training and competition with both the dominant and non-dominant sides.

Table 1. Habitual *tokui-waza* performed by dominant and non-dominant sides during training and competition.

Athlete	Dominance	1° Tokui-Waza	2° Tokui-Waza	3° Tokui-Waza
1	Right	Drop seoi-nage (te-waza)	Ko-uchi-gari (ashi-waza)	O-uchi-gari (ashi-waza)
2	Right	Uchi-mata (ashi-waza)	Ko-soto-gake	O-gochi (koshi-waza)
3	Right	Drop seoi-nage (te-waza)	O-soto-gari (ashi-waza)	Sumi-gaeshi (sutemi-waza)
4	Left	Drop seoi-nage (te-waza)	O-soto-gari (ashi-waza)	Koshi-guruma (koshi-waza)
5	Right	Drop seoi-nage (te-waza)	Ko-soto-gari (ashi-waza)	O-uchi-gari (ashi-waza)
6	Right	Harai-gochi (koshi-waza)	Uchi-mata (ashi-waza)	O-soto makikomi (sutemi-waza)
7	Right	Sumi-geshi (sutemi-waza)	Ko-uchi-makikomi (sutemi-waza)	Uchi-mata (ashi-waza)
8	Right	Harai-goshi (koshi-waza)	Uchi-mata (ashi-waza)	De-ashi-harai (ashi-waza)
9	Right	O-uchi-gari (ashi-waza)	Drop Seoi-nage (te-waza)	Morote-seoi-nage (te-waza)
10	Right	Harai-goshi (koshi-waza)	O-soto makikomi (sutemi-waza)	Ko-uchi-gari (ashi-waza)
11	Right	Ko-uchi-gari (ashi-waza)	O-uchi-gari (ashi-waza)	Harai-goshi (koshi-waza)

Gray cells represent the tokui-waza applied with the non-dominant side. Te-waza refers to throw techniques where the primary lever is the upper limbs; koshi-waza involves throw techniques where the trunk is the primary lever; ashi-waza encompasses throw techniques where the lower limbs are the main lever; and sutemi-waza denotes sacrifice techniques, which require a wrap by the tori (player executing technique).

2.3. Isokinetic Test, Signal Capture, and Asymmetry Index

Each participant was individually assessed following the institutional protocol to prevent COVID-19 established and recommended by the Chilean high-performance center. All participants received instructions about the exercise protocol, including details on the two tests (60° and 180°/s) and the isokinetic machine positioning. Prior to the isokinetic test, measurements were taken for height, body mass, corrected biceps circumference, corrected thigh circumference, and APE index according to the recommendation by Sørensen et al. [33]. Before the test, participants completed a 15 min warm-up, which included aerobic exercises on a treadmill, joint mobility work, dynamic stretching of the upper limbs and trunk, upper limb strengthening exercises, and *uchi-komi* with an elastic band (*Morote-seoi-nage and tai-otoshi*).

We assessed isokinetic internal and external shoulder rotation. The measurements were taken with the participant seated, the abductor arm positioned at 45° in the scapular plane, and at three speeds (60°/s and 180°/s) with a sampling frequency of 1250 Hz, using concentric/concentric (CON/CON) mode. The selection of speeds is based on two criteria: (i) 60°/s based on the evaluation of maximum angular force [34]; (ii) 180°/s considering the speed of the sports gesture. based on throwing technique speeds described by Imamura, Iteya [35]. Movements were performed within a range of 70° for internal and external rotation, starting with the dominant upper limb. Each participant was positioned to align the joint with the mechanical axis of the isokinetic device (Cybex® Humac Norm Dynamometer CSMI, model 502140, Stoughton, MA, USA). Participants first performed 3 submaximal repetitions for familiarization, followed by 5 maximal repetitions with standardized verbal encouragement and a 2 min rest interval between the dominant and non-dominant upper limbs. The isokinetic device was calibrated before each test, and the same evaluator conducted all measurements. Torque data were extracted from the full curve for each subject, for each velocity (60°/s and 180°/s), and for each limb (D and ND).

After completing the dynamic evaluations, all participants were positioned at a 45° of external rotation in the scapular plane to assess the torque generated by the ER isometrically. This positioning was chosen because it simulates the starting position of the *seoi-nage* technique, as described by Valenzuela et al. [34]. Each isometric evaluation lasted 5 s and was performed once for each upper limb, starting with the dominant limb, followed by the non-dominant limb. A 3 min rest was observed between attempts for each side. Figure 1 showed the start (A) and final (B) test position.

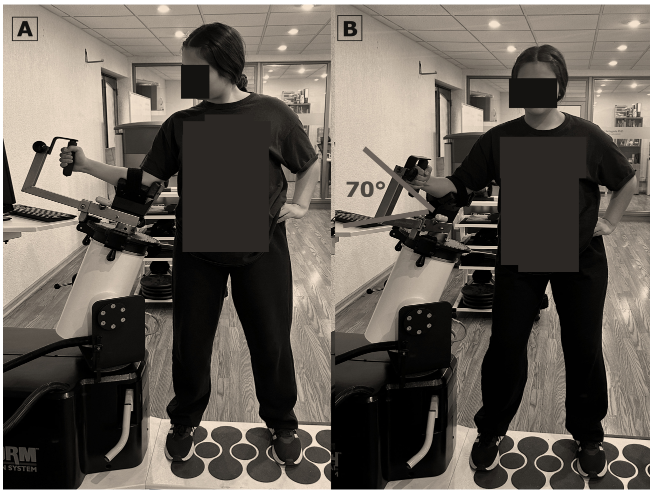

Figure 1. Start (**A**) and final (**B**) isokinetic shoulder rotator test.

2.4. Data Processing

For processing the data, we extracted all the data of each attempt in text format (.txt). These data were exported and processed using MatLab 2024b (Mathworks, Natick, MA, USA). The start and end of the torque curve were detected as the first value greater than and less than 1 Newton, respectively [23]. The signals were then resampled so that they all had the same number of samples; the signals from the 60°/s test were resampled at 1201 samples and the signals from the 180°/s test at 351 samples (*data sample* without replace function in Matlab). The signals were filtered through a 4th-order, zero-lag Butterworth filter with a cut-off frequency of 20 Hz, according to recommendations by Thompson [36]. The signals were averaged for the final analysis. Additionally, a principal component analysis (PCA) was applied to the standardized signals (mean 0 and standard deviation 1) to compare the components that explained 90% of the total variance, where the first principal component (PC1) met the requirement [31]. The first attempts at internal and external rotation were discarded because, in most subjects, they showed a large difference compared to the following attempts (visual observation by the researcher), so for the PCA and SPM analysis, the average of those attempts was used. For investigative purposes, the D vs. the ND was compared for the athletes.

2.5. Statistics

Descriptive statistics were expressed as median and interquartile range. For the discrete variables—peak torque (PT), angle of the peak torque (APT), PC1 scores, and peak rate of torque development (PRTD)—the Mann–Whitney U test was performed due to the low sample size and the effect size. Asymmetry for discrete variables was quantified using the following formula:

$$\text{Asymmetry} = \frac{[\text{Shoulder1} - \text{Shoulder2}]}{([\text{Shoulder1} + \text{Shoulder2}]/2)} \quad (1)$$

This was performed per subject and presented in tables as the mean of all subjects. A one-dimensional analysis was conducted using a parametric statistical mapping (SPM) *t*-test for independent samples according to the recommendation by Pataky [26] for comparison between D vs. ND. An alpha of 0.05 was used in all analyses. All analyses were performed using Matlab 2024b.

3. Results

Table 2 presents descriptive and inferential statistics for the discrete variables across all tests. No significant differences were observed between profiles and PC1 scores ($p > 0.05$ for all comparisons).

Table 2. Descriptive and inferential statistics of discrete variables.

Variables	D		ND		AI (%)	*p*	Rank-Biserial Correlation
	Median	IQR	Median	IQR			
PT_60°I (Nm)	36.4	11.7	33.3	10.8	4.7	0.519	0.174
APT_60°I (degree)	−20.4	20.6	−24.1	22.7	11.9	1.000	0.008
PT_60°E (Nm)	20.8	7.9	18.0	6.3	10.3	0.300	0.273
APT_60°E (degree)	−24.9	16.9	−30.0	13.5	−95.9	0.324	0.256
PT_ISO (Nm)	25.4	6.9	21.5	10.8	−1.8	0.847	0.058
PRTD_ISO (Nm/s)	195	120	185	95.0	4.0	0.949	−0.025
PT_180°I (Nm)	28.6	5.9	25.3	11.0	15.3	0.315	0.280
PT_180°E (Nm)	16.1	4.9	15.0	3.9	6.4	0.579	0.160
APT_180°I (degree)	−28.8	10.3	−24.8	10.7	17.4	0.140	−0.399
APT_180°E (degree)	−20.8	6.1	−21.9	12.1	−28.2	0.384	0.240

D—dominant side; ND—non-dominant side; PT—peak torque; APT—angle of peak torque; PRTD—peak rate of torque development; IQR—Interquartile range; AI—asymmetry index; 60°I—Internal rotation at 60°/s; 60°E—External rotation at 60°/s; 180°I—Internal rotation at 180°/s; 180°E—External rotation at 180°/s; ISO—Isometric external rotation.

Figure 2 displays the analysis for isometric external rotation at 60°/s. As observed by the overlap of the blue and red lines, as well as by the standard deviation (purple area), there was no difference between the limbs (D vs. ND) in SPM (Figure 2A,B), nor PC1 scores (Figure 2C), as showed by the boxplot ($p > 0.05$).

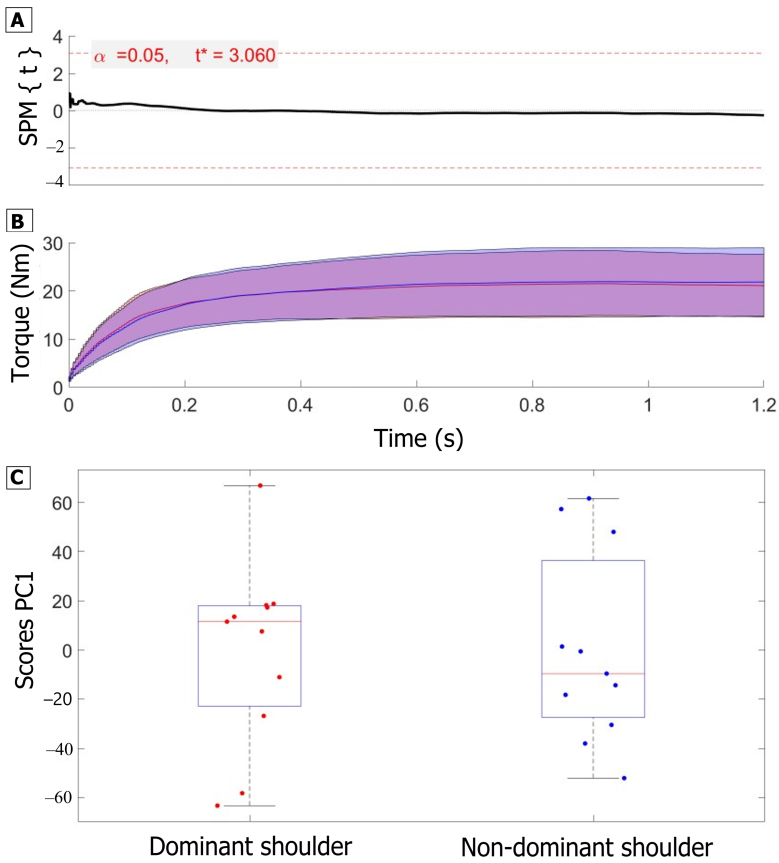

Figure 2. SPM statistic (**A**,**B**), signals of D (red line) and ND (blue line), and the standard deviation (purple area) (**C**) of isometric external rotation. t*, critical t value; α, alpha value.

Figure 3 presents the SPM curve to internal and external rotation at 60°/s and 180°/s. The red line represents the contraction of the D upper limb arm; the blue one represents contraction of ND; the pink area represents the standard deviation of D; the light blue represents standard deviation of ND; and the purple area represents the overlap of D and ND. There were no significant differences ($p > 0.05$).

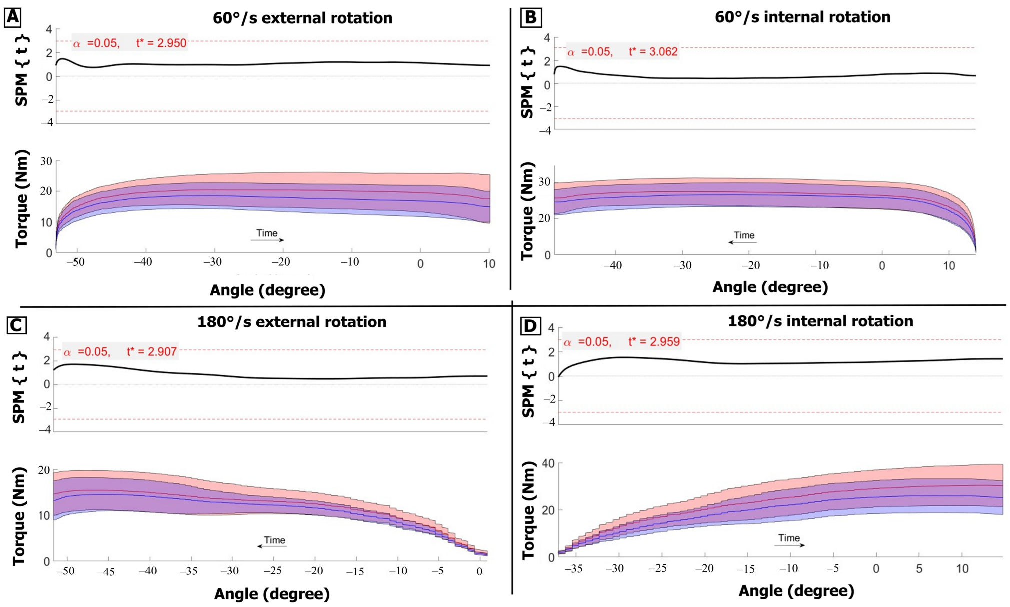

Figure 3. SPM statistic at 60°/s for external (**A**) and internal (**B**) rotation and 180°/s for external (**C**) and internal (**D**) rotation. The red line represents the signals of D and blue represents ND limbs; the pink area represents the standard deviation for D, light blue for ND, and purple the overlap D and ND. t*, critical t value; α, alpha value set a priori.

Figure 4 shows the boxplot of PC1 score for internal and external rotation at 60°/s and 180°/s. Red points represent the D limb and the blue one the ND. There were no significant differences ($p > 0.05$).

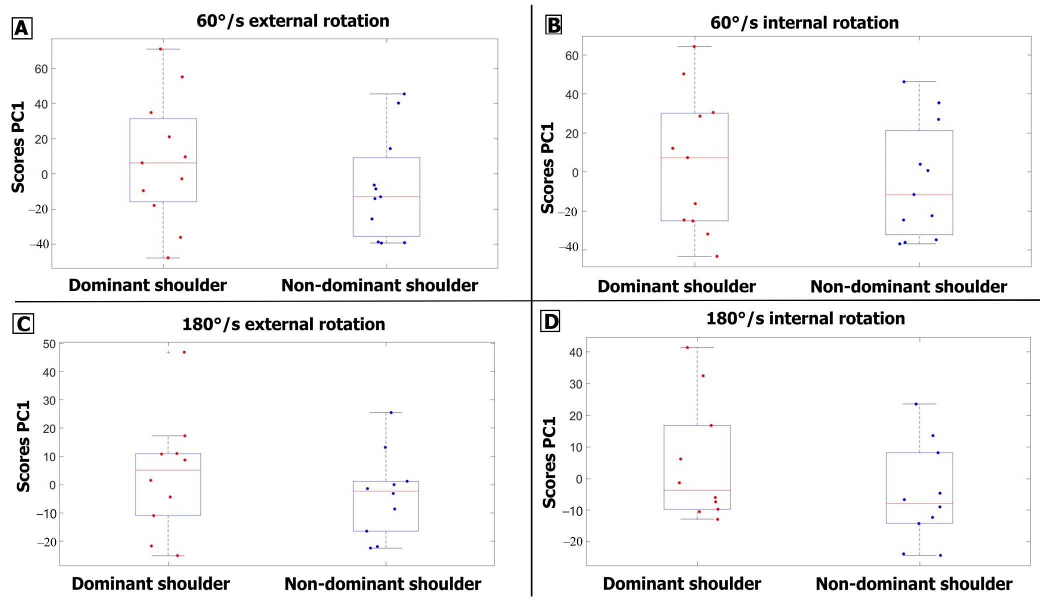

Figure 4. Boxplot and individual values of scores of the first principal component (PC1) of shoulder rotations at 60°/s for external (**A**) and internal (**B**) rotation and at 180°/s for external (**C**) and internal (**D**) rotation. The red points represent the D limb and the blue one the ND. There were no significant differences ($p > 0.05$).

Finally, Figure 5 presents the boxplot and individual PC1 analysis for peak torque (PT) (Nm) and angle of PT (degree) during internal (A) and external (B) rotation at 60°/s and internal (C) and external (D) rotation at 180°/s.

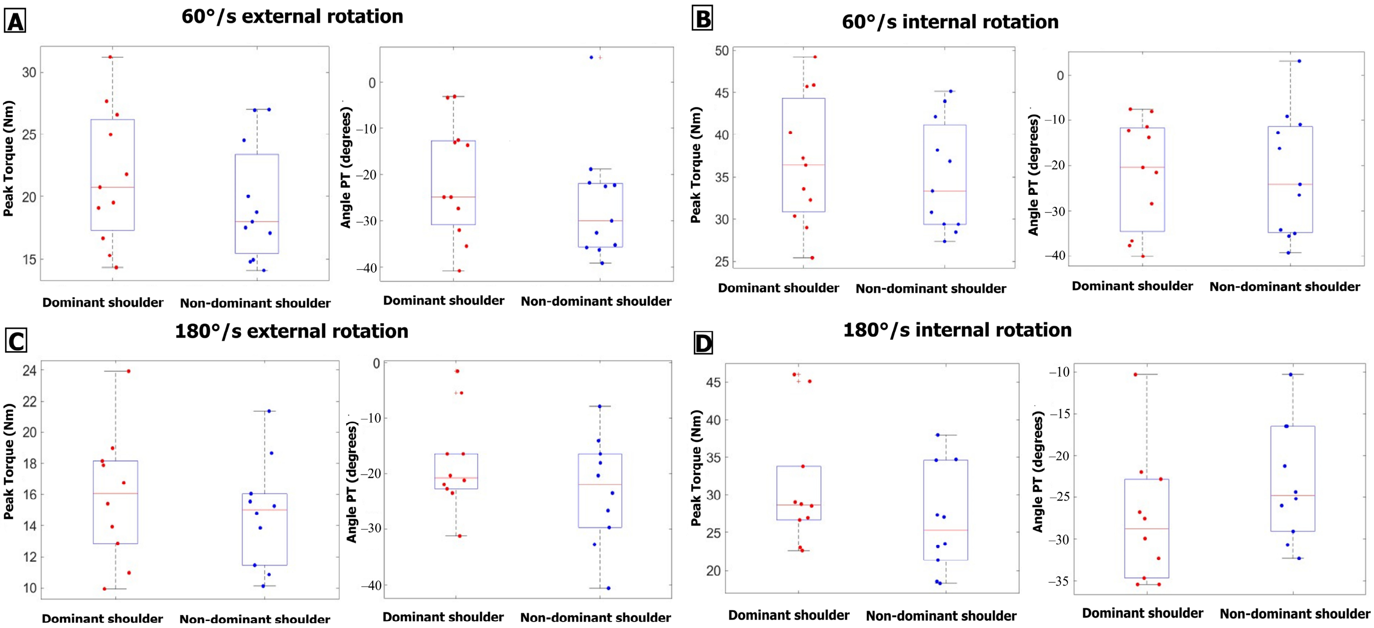

Figure 5. Boxplot and individual values of scores of first principal component (PC1) of shoulder rotations. Peak torque and Angle PT for external (**A**) and internal (**B**) rotation at 60°/s and external (**C**) and internal (**D**) rotation at 180°/s. Red points represent D limb and blue one the ND. There were no significant differences ($p > 0.05$).

4. Discussion

Assessing the strength of the muscles involved in shoulder movement is fundamental to preventing injuries in judo athletes [26]. Special attention should be paid to the rotator muscles, as there is a high frequency of techniques applied, which demand strong and fast action from the internal and external rotators, especially when applying *te-waza* [23,24]. The most recent technical-tactical analysis (Tokyo 2021 Olympic Games) indicated that *te-waza* accounts for 29.9% of the techniques applied during normal combat time and 27.5% of those during the Golden score [37]. The health of the shoulders is vital for judo performance. Studies in judo and biomechanics have focused on evaluating the shoulder rotators, whether these are aimed at performance [24,25,27] or injury risk and prevention [17,23,38]. However, in this context, there is a lack of research in female athletes. Therefore, through an isokinetic evaluation, we aimed to compare whether there are significant asymmetries between the internal (dynamic) and external rotators (dynamic and isometric) of the shoulder in international-level female athletes, through analysis by SPM and PCA.

We observe that the present results refute our hypothesis since, regardless of the method used and the angular velocity (60° and 180°/s), no statistically significant asymmetries were observed. Our results corroborate those observed by Aedo-Muñoz et al. [23] in international-level male judokas and Ruivo, Pezarat-Correia [26], in national male athletes. Ruivo and Pezarat-Correia [26], in a paired analysis, observed that judokas have a lower level of rotator asymmetry when compared to healthy subjects (≈6 h exercise/wk.). The lower asymmetry is possibly associated with the bimanual aspect preferentially adopted in the judo gripping [39] and throw techniques [22,40]. When analyzing the main *te-waza*, Tagusari, Santos [40], observed that these are techniques where the performer maintains a bimanual judogi grip at all times (from the grip to the throw) and in a throw where the performer must release the grip (e.g., ippon-seoi-nage), this action occurs only in the final moments of the throw. We believe that this bimanual characteristic adopted during training and competitions is the main determinant of the absence of asymmetries. When analyzing Table 1, it is clear that 36.4% use te-waza as their most frequent attack; furthermore, of the total preferred techniques, 78.8% are applied using a two-handed grip on the opponent's judogi. Our thesis is reinforced by other data from Table 1, which informs that less than half (45.5%) attack the ND side, and when they do, they use it as their 2nd or 3rd preferred technique. In other words, even though judo is a sport with a unilateral characteristic regarding combat and attack stances [5,12], the athletes use the strength of both upper limbs constantly (i.e., during gripping and in most attack and defense movements). Finally, it is important to highlight that athletes who present problems associated with the functionality of the shoulder rotators previously present strength deficiencies and changes in RoM, which is not observed in our female athletes [14].

Similarly to our results, absence of asymmetry between the rotators was also observed in international-level male judokas who had no history of injury in the last 6 months [23]. However, other studies with judokas with a history of injury did not observe differences in shoulder functionality [17,38]. Taken together, these studies indicate that there is no clear association between injuries and shoulder functionality in judokas. In fact, Delorme et al. [17], in male and female judokas, observed that the history of injuries significantly decreased the relative strength of the external rotators ($\approx -9\%$). However, even with this strength deficit, no functional asymmetries were observed. Green, Comfort [38] did not observe differences in shoulder joint position sense, comparing adolescents with shoulder injury history (7 months until 4 yrs. before the measurement) vs. non-injured adults. When analyzing the studies already published and reinforced by our results, we believe that the technical level of the athletes and the domain of judo technique may also be a factor contributing to the absence of asymmetries. Detanico et al. [24] observed that more advanced athletes tend to present a higher asymmetry compared to novices; however, unlike our study, the sample was composed of regional level athletes. Already, Green, Comfort [38] suggests that poor technical execution is a contributing factor in affecting shoulder functionality and increasing the risk of injury.

Finally, we also emphasize that there were no asymmetries regardless of the method used to analyze the contraction curve and angular velocity. Our results show similarity to those observed by Aedo-Muñoz et al. [23] in male judokas, but they only used SPM as a method of analyzing asymmetries and Drapšin et al. [25] with a single point analysis in the curve in male and female judokas. On the other hand, Detanico et al. [24] compared external and internal rotators and observed a significant difference ratio using a single point on the curve. However, as Ruas et al. [41] indicate, an asymmetry analysis with only one peak point on the curve could lead to erroneous interpretations of the asymmetries and the risk of shoulder injury. As with our results, a study with rowers of both sexes did not observe differences concerning peak force, when the contraction curve was analyzed by different methods [28]. Since its proposal, SPM has been widely used in biomechanic studies, yet there are gaps in the application of the method [30]. It is observed that studies have focused on lower limb analyses, and, to the best of our knowledge, our protocol was the first to analyze upper limb asymmetries by SPM and PCA simultaneously. The present study sought to investigate some scientific gaps regarding shoulder rotator asymmetry in elite female judo fighters. Regarding the practical application, we provide valuable insights for physical evaluators assessing female judokas through isokinetic tests. Since our findings indicate no significant differences between the analysis methods, evaluators can choose the method they are most familiar with for their assessments. Our results should be interpreted in light of our limitations and delimitations since we evaluated 11 international-level athletes who are undergoing the same training program as they are part of a national team. We believe that increasing the sample size would enhance the statistical power of the analysis. It is also important to highlight that we found it difficult to compare the results with other judo athletes, as there is a lack of scientific research with female judokas. Future studies should verify whether the present results will be consistent in younger or older fighters and in other tests (more ecological for example).

5. Conclusions

Given the data collection and analysis methods applied, our results allow us to conclude that there are no shoulder rotator differences in international-level female judokas in isokinetic contraction performed at 60°/s or 180°/s and isometric contraction of external rotators, regardless of whether analyzed by classic discrete, PCA, or SPM analysis in these samples at the group level. The present data could be important benchmark for these cohorts (talent detection or monitoring sport training). Trainers should be cautious about interpreting our results because individual analysis of asymmetries is crucial.

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