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Investigation of Dynamic Balance, Limb Asymmetry and Flexibility in Jiu-Jitsu Athletes: A Preliminary Exploratory Study

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Abstract

This preliminary exploratory study is the first to thoroughly examine dynamic balance, inter-limb asymmetry, and flexibility in jiu-jitsu athletes, focusing on differences by fighting style, competition level, gender, and limb dominance. A total of 25 jiu-jitsu fighters participated in this cross-sectional study, which used repeated measures to ensure the reliability of the findings. Participants underwent measurements for limb lengths and were assessed for dynamic balance using the Lower and Upper Quarter Y Balance Test (LQYBT and UQYBT) and for flexibility with the Sit and Reach Test (SR). The analysis included evaluating the reliability of these tests, as well as comparing outcomes based on gender, fighting styles, competition levels, and limb dominance. The results showed that the LQYBT and UQYBT tests were reliable (ICC=0.74–0.93). There were no significant differences in dynamic balance and flexibility between different fighting styles. No significant differences were found in balance tests between the dominant and non-dominant limbs, but there were notable inter-limb asymmetries in certain measures. This study provides preliminary insights for coaches and researchers by offering reference values for balance, flexibility, and inter-limb asymmetry in jiu-jitsu athletes. However, future research with larger sample sizes is needed to better understand the differences among subgroups in this sport.

Keywords: *athletic training, Y-balance test, physical performance, martial arts, asymmetry*

Introduction

Jiu-jitsu originated from the ancient martial art of jujutsu, which traces its origins back to ancient Japan (Kano, 1994). Today, jiu-jitsu represents a modern self-defense martial art that has gained significant popularity in the last two decades (Andreato, Lara, Andrade, & Branco, 2017). In this sport, there are two styles of fighters – "Pass" and "Guard" fighters. "Pass" fighters aim to break through the guard, earning points or positional advantages, while guard fighters defend the guard and attack from that position (Báez et al., 2014). During matches, fighters utilize various choking, joint-locking, and submission techniques, and a match ends either by the opponent's submission or through scoring by judges (IBJJF, 2016). Match durations vary from 5 minutes for white belt holders (beginners) to 10 minutes for black belt holders (elite athletes; Del Vecchio, Bianchi, Hirata, & Chacon-Mikahili, 2007; IBJJF, 2016), and athletes may have an average of 4 to 6 matches in competitions, requiring good physical preparation (Andreato et al., 2017).

In order to achieve success in jiu-jitsu competitions, fighters must invest various efforts that require motor coordination, strength, flexibility, and good balance abilities (de Paula Lima et al., 2017; James, 2014). For jiu-jitsu fighters, maintaining proper joint stability and postural balance is crucial for achieving successful performances, as it is a factor that can affect the effectiveness of attack and defense techniques among fighters (Sterkowicz, Lech, Jaworski, & Ambrozy, 2012). During each action in combat, the competitor must

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maintain a stable body position that enables them to not lose or disturb their balance (das Graças et al., 2017). Postural stability represents the body's ability to maintain a stable position in a state of balance under the influence of various factors (Krištofič, Malý, & Zahálka, 2018). The level of postural stability reflects an individual's ability to minimize fluctuations in the center of gravity, which means maintaining an upright body position and properly responding to changes in external and internal forces (Angyan, Teczely, & Angyan, 2007). Dynamic balance is defined as maintaining a balanced support base during movement execution. In clinical situations, the Star Excursion Balance Test (SEBT) and its Y-balance version are often used to assess dynamic balance because they are practical tools for identifying deficits in dynamic balance (Gribble, Hertel, & Plisky, 2012). Additionally, the Y-balance test has been used to assess inter-limb asymmetries and related injury risk in both upper and lower extremities (Bubić, & Kozinc, 2023; Fusco et al., 2020; Ribnikar, Maguša, & Kozinc, 2024). Therefore, this test could be very relevant to jiu-jitsu because forced joint loading techniques often increase the incidence of knee, shoulder, and elbow injuries (Kreiswirth, Myer, & Rauh, 2014). Previous research has highlighted athletes showing limb asymmetries in jumping greater than 15% have a higher frequency of injuries (Impellizzeri, Rampinini, Maffiuletti, & Marcora, 2007). However, less is known about the role of inter-limb asymmetries and their impact on physical performance (Bishop, Turner, & Read, 2018). Some studies have shown that inter-limb asymmetries of around 10% result in reduced jump height (Bell, Sanfilippo, Binkley, & Heiderscheit, 2014) and slower change of direction times (Hoffman, Ratamess, Klatt, Faigenbaum, & Kang, 2007), but contradictory results have also been observed (Lockie et al., 2014).

Additionally, flexibility is a relevant physical component of jiu-jitsu, especially in the thoracolumbar spine and posterior chain, which are necessary for performing specific attacking or defensive situations (Andreato et al., 2011, Andreato et al., 2016). High levels of flexibility can assist jiu-jitsu athletes in executing positions and also facilitate the learning of new motor skills (Andreato et al., 2011). A practical and reliable test for assessing the flexibility of hip, back, and posterior lower limb muscles is the sit-and-reach test (Mier, 2011).

While various studies have examined postural balance in fighters such as karatekas (Kocahan, Guraslan, Kabak, Hasanoglu, & Akinoglu, 2022), judokas (Fatih, Çakir, Çavusoglu, Akyurek, & Haykir, 2022; Kilic, Karakoç, & Karakoç, 2022), and taekwondo practitioners (Aldhabi, Albadi, Alnajjar, Fasihudden, & Vincent, 2024; Fatih et al., 2022; Tayshete, Akre, Ladgaonkar, & Kumar, 2020), there is only one study that focused on jiu-jitsu athletes (Leszczak et al., 2022). The authors examined static body balance of fighters according to body mass status, reporting better stability compared to a control group and possible influence of body mass. When it comes to inter-limb asymmetry, research has mainly focused on its impact on injuries in jiu-jitsu athletes (Sarro et al., 2022). On the other hand, there are studies that have investigated flexibility in sit and reach tests among jiu-jitsu senior athletes (Andreato et al., 2011; Del Vecchio et al., 2007), however, differences among groups were not examined; instead, the level of flexibility among jiu-jitsu athletes was determined.

To the best of our knowledge, there are no studies that have examined the dynamic balance and inter-limb asymmetries of jiu-jitsu athletes. This is the first study to investigate differences in dynamic balance, limb asymmetry, and flexibility among fighters. Accordingly, the aim of this study was to preliminarily explore differences in balance, inter-limb asymmetry, and flexibility according to fighting style and competition level, gender differences, asymmetry between dominant and non-dominant legs, and inter-limb asymmetry among jiu-jitsu athletes. Based on these objectives, we can gain a broader insight into dynamic balance, inter-limb asymmetry, and flexibility in jiu-jitsu fighters. This research will have practical significance for fitness coaches in jiu-jitsu sport, providing them with reference values of the given abilities in relation to gender, competition level, and fighting style. It will also be significant for researchers because, as the first study to thoroughly investigate this area, it will contribute to a better understanding of dynamic balance and inter-limb asymmetry in jiu-jitsu athletes.

Methods

Participants

The study involved a convenience sample of 25 jiu-jitsu fighters (8 women, 17 men), representing the maximum feasible recruitment from the available population within the constraints of the study period and resources. The demographic characteristics of the study sample were as follows: the mean height was 177.32 cm (SD=9.46), mean mass was 75.74 kg (SD=11.88), and the mean age was 30 years (SD=8.62). Ten participants (3 women) were "Pass" fighters and 15 (5 women) were "Guard" fighters. The group comprised of 9 participants with purple belts (3 women), 5 with white belts (2 women), 4 with blue belts (2 women), 3 with brown belts (1 women), and 4 with black belts (0 women). The participants reported to perform 4.1±2.2 jiu-jitsu sessions per week (range =2–9) and to have 5.4±4.24 years of jiu-jitsu experience (range =2–15). The dominant arm was right for 22 participants (7 women) and left for 3 participants (1 women). The dominant leg was right for 21 participants (7 women) and left for 4 participants (1 women). To qualify for participation, individuals were required to be free from any upper or lower extremity, or spinal injuries, as well as surgeries in these areas within the previous six months. The exclusion criteria included recent concussions, any conditions that hindered work or sports participation in the last six months, limb amputations, vestibular disorders, active pregnancy, current illnesses or injuries that could affect physical performance or balance, and those receiving treatment for inner ear, sinus, or respiratory infections. Before initiating the study procedures, participants were thoroughly informed about the study's objectives and procedures, provided consent on a voluntary basis, and were assured of their right to discontinue participation at any time. A consent form was signed by each participant prior to the commencement of testing, and they were guaranteed access to their personal results upon completion of the study. Ethical approval for the study was granted by the National Medical Ethics Committee under the reference number 0120-690/2017-8.

Procedures

The study was structured as a cross-sectional investigation incorporating repeated measures to evaluate reliability. Measurements were taken on two separate occasions, with the follow-up visit arranged for 10 to 14 days after the initial session. All assessments were carried out by an examiner with BSc and MSc degrees in kinesiology and ample experience in motor ability testing. To control for potential variations due to the circadian rhythm, all sessions were conducted in the afternoon, and at similar specific time (±1h) for each individual. Participants were instructed to avoid any intense physical activity or training 24 hours prior to their scheduled testing sessions. This precaution was intended to minimize fatigue and other acute effects of exercise that could affect performance and physiological measurements during testing. Additionally, they were advised to maintain their usual dietary habits and ensure adequate hydration to avoid any nutritional imbalances that could impact the study results. Participants completed a structured questionnaire consisting of demographic information and engagement in jiu-jitsu practice. Body weight was assessed using a calibrated digital scale and body height was self-reported.

The warm-up consisted of a 10-minute session involving dynamic stretches and low-intensity cardiovascular exercises, such as jogging and jumping jacks, designed to gradually increase heart rate and muscle temperature, thereby preparing the athletes for the subsequent physical performance tests. This protocol was standardized across all participants to ensure consistency in pre-test conditions. Subsequent measurements involved determining the length of participants' upper and lower limbs to an accuracy of 0.5 cm using a measuring tape. The measurement of the lower limb was conducted in a supine position, extending from the anterior superior iliac spine to the medial malleolus. The upper limb measurement was taken in a standing position, with the arm abducted at 90 degrees, stretching from the seventh cervical vertebra to the tip of the middle finger. Limb measurements were followed by assessment of LQYBT, UQYBT and SR tests, which were conducted sequentially in this order for all participants.

For LQYBT, we followed the procedure was implemented following the methodology outlined by Plisky et al. (2009), where participants executed reaches in anterior, posterolateral, and posteromedial directions from a unilateral stance on a designated device, with allowances for trunk and arm movements and a rest period of 30 seconds between each direction. The YBT-UQ was carried out based on the protocol by Gorman et al. (2012), with participants performing reaches in medial, superolateral, and inferolateral directions from a push-up stance, allowing for pelvic adjustments and a 60-second rest between attempts. Three warm-up attempts were allowed per test, followed by three repetitions. The outcomes of both tests were initially recorded as the absolute lengths to the nearest centimeter. For analysis, the mean of the three reach distances for each direction was calculated. The reach measurements were then normalized to the limb lengths, presented as a percentage.

The SR test was conducted using a measuring tape that was placed and secured on the floor with a starting line marked on it. The test subjects removed their shoes and sat on the floor with the measuring tape positioned between their legs. The soles of their feet were set just behind the marked starting line, with heels approximately 20 cm apart. The palms were touching or slightly overlapping with thumbs interlocked, turned downwards, and placed on the measuring tape. With legs extended, the subjects slowly reached forward along the measuring tape as far as possible. The furthest reach that could be maintained for 2 seconds was measured by the tester. The test was performed twice, with a short break (30 seconds) between attempts. The results were recorded based on the zero-point marked by a line under the heels of the extended legs. If the test subjects did not reach the starting line, the results were recorded as negative values of the distance from the line; if they reached beyond it, the positive values of the reach were recorded in centimeters (Cuberek, Machová, & Lipenská, 2013). The mean value of the two repetitions was taken for further analysis.

Statistical analysis

The collected data were analyzed using the IBM SPSS software (version 25.0). Descriptive statistics are presented as mean and standard deviation. The normality of data distribution was checked with the Shapiro-Wilk test and a visual assessment of histograms. The repeatability of tests across visits was analyzed using the intra-class correlation coefficient (ICC (3,1); absolute agreement model) and the typical error, which we expressed as a percentage of the mean value or the coefficient of variation (CV). ICC values <0.5 were considered indicative of poor repeatability, values between 0.5 and 0.75 as moderate repeatability, values between 0.75 and 0.9 as good repeatability, and values above 0.90 as excellent repeatability (Koo & Li, 2016). Absolute repeatability was considered acceptable if CV was <10% (Hopkins, 2000). The relationships between the test results (both Y-tests and the seated reach test) were examined using Pearson's correlation coefficient. These relationships were interpreted as negligible (<0.1), weak (0.1–0.4), moderate (0.4–0.7), strong (0.7–0.9), or very strong (>0.9) (Akoglu, 2018). The comparison between fight styles was carried out using an independent samples t-test. The comparison between the dominant and non-dominant side was conducted using a paired samples t-test. In the t-tests, the effect size was expressed with Cohen's d, according to which the effect size is interpreted as trivial (<0.2), small (0.2–0.5), medium (0.5–0.8), and large (>0.8) (Cohen, 1988). The differences in inter-limb asymmetry magnitudes across tests and directions were tested with 1-way analysis of variance for repeated measures. Statistically significant differences were accepted at a confidence level of $\alpha<0.05$.

Results

Reliability

Table 1 contains the repeatability analyses of the measurements. The results of LQYBT were found to have good or excellent reliability (ICC=0.84 to 0.95). A similar observation applies to most results of the UQYBT (ICC=0.83 to 0.91), with the exception of moderate reliability in the medial reach with the non-dominant arm (ICC=0.74) and the superolateral reach with the dominant arm (ICC=0.73). The repeatability of the SRT was excellent (ICC=0.93). Absolute repeatability was acceptable for all the tests examined, as the typical error (expressed as CV) was below the 10% threshold for all tests. Despite good relative and absolute repeatability, there were statistically significant systematic errors in 3 out of 8 variables related to the LQYBT (p=0.014 to 0.042) and one variable related to the UQYBT (p=0.038), as well as SRT (p=0.049) (Table 1). In all cases, the test result on the second visit was slightly higher (difference of 1 to 3% of leg length).

Table 1. Reliability of the measurements

Test / Limb	Direction	Visit 1		Visit 2		Reliability		
		Mean	SD	Mean	SD	ICC (95% CI)	CV (95% CI)	Systematic error (p-value)
LQYBT – non-dominant (% leg length)	Anterior	0.71	0.06	0.73	0.05	0.84 (0.59 - 0.93)	3.26 (2.39 - 5.14)	0.014*
	Posterolateral	1.15	0.12	1.16	0.10	0.90 (0.75 - 0.96)	3.11 (2.28 - 4.91)	0.276
	Posteromedial	1.13	0.13	1.14	0.09	0.88 (0.69 - 0.95)	3.67 (2.69 - 5.79)	0.373
	Composite	0.99	0.09	1.00	0.07	0.87 (0.67 - 0.95)	3.18 (2.33 - 5.02)	0.127
LQYBT – dominant (% leg length)	Anterior	0.72	0.07	0.72	0.08	0.93 (0.81 - 0.97)	2.84 (2.08 - 4.48)	0.064
	Posterolateral	1.14	0.11	1.15	0.08	0.92 (0.79 - 0.97)	2.65 (1.94 - 4.17)	0.042*
	Posteromedial	1.12	0.11	1.13	0.09	0.95 (0.87 - 0.98)	2.16 (1.58 - 3.41)	0.079
	Composite	0.99	0.09	1.00	0.07	0.95 (0.88 - 0.98)	1.85 (1.35 - 2.91)	0.014*
UQYBT – non-dominant (% arm length)	Medial	1.06	0.10	1.07	0.08	0.74 (0.37 - 0.89)	4.62 (3.38 - 7.29)	0.884
	Superolateral	0.79	0.13	0.82	0.10	0.88 (0.68 - 0.95)	5.37 (3.93 - 8.47)	0.884
	Inferolateral	0.93	0.11	0.93	0.10	0.88 (0.69 - 0.95)	4.2 (3.08 - 6.63)	0.888
	Composite	0.93	0.09	0.94	0.06	0.85 (0.63 - 0.94)	3.45 (2.52 - 5.44)	0.961
UQYBT – dominant (% arm length)	Medial	1.03	0.10	1.06	0.09	0.83 (0.57 - 0.93)	3.88 (2.84 - 6.11)	0.038*
	Superolateral	0.76	0.12	0.79	0.10	0.85 (0.63 - 0.94)	5.87 (4.3 - 9.26)	0.182
	Inferolateral	0.89	0.10	0.92	0.07	0.73 (0.36 - 0.88)	5.24 (3.84 - 8.27)	0.078
	Composite	0.89	0.08	0.92	0.07	0.91 (0.75 - 0.96)	2.79 (2.04 - 4.39)	0.007*
Sit & Reach test (cm)	/	51.1	10.1	54.5	9.3	0.93 (0.81 - 0.97)	5.21 (3.81 - 8.22)	0.049*

SD – standard deviation; ICC – intra-class correlation coefficient; CV – coefficient of variation; CI – confidence interval; * - significance at the 0.05

Table 2. Fighting styles comparison

Variable		Guard (n = 15)		Pass (n = 10)		Difference		
		Mean	SD	Mean	SD	t	p	d
Body height (cm)		178.0	8.7	176.3	10.9	0.43	0.669	0.15
Body mass (kg)		76.5	10.4	74.5	14.3	0.40	0.691	0.23
Age (yrs)		29.5	9.8	30.7	6.8	-0.33	0.748	0.24
LQYBT – non-dominant (% leg length)	Anterior	0.71	0.05	0.71	0.07	-0.19	0.848	0.05
	Posterolateral	1.15	0.10	1.14	0.15	0.25	0.806	0.10
	Posteromedial	1.14	0.11	1.11	0.15	0.42	0.680	0.19
	Composite	1.00	0.08	0.99	0.11	0.26	0.800	0.12
LQYBT – dominant (% leg length)	Anterior	0.72	0.06	0.71	0.09	0.55	0.589	0.16
	Posterolateral	1.14	0.08	1.14	0.15	0.02	0.988	0.01
	Posteromedial	1.13	0.10	1.10	0.13	0.70	0.493	0.31
	Composite	1.00	0.07	0.98	0.11	0.45	0.658	0.17
UQYBT – non-dominant (% arm length)	Medial	1.09	0.08	1.02	0.12	1.71	0.101	0.57
	Superolateral	0.81	0.10	0.76	0.16	1.00	0.330	0.44
	Inferolateral	0.93	0.10	0.93	0.14	0.09	0.927	0.04
	Composite	0.94	0.06	0.90	0.12	1.13	0.270	0.45
UQYBT – dominant (% arm length)	Medial	1.04	0.08	1.01	0.12	0.73	0.472	0.24
	Superolateral	0.77	0.08	0.75	0.17	0.44	0.667	0.23
	Inferolateral	0.88	0.09	0.90	0.11	-0.46	0.647	0.18
	Composite	0.90	0.06	0.89	0.11	0.31	0.756	0.00
Sit & Reach Test (cm)		53.48	9.26	47.63	10.81	1.45	0.161	0.63

SD – standard deviation.

Differences between fighting styles

We compared the results of 15 "guard" and 10 "pass" fighters. There were no differences between representatives of these fighting styles in terms of body weight (p=0.691), height (p=0.669), and age (p=0.748). There were no differences in styles of fighting in the Y-balance tests (both versions), and likewise, no differences in the seated reach test. The detailed results are displayed in Table 2.

Additionally, we examined the correlations between Y-test results and experience in jiu-jitsu (years of training), as well as the weekly frequency and belt. We found no statistically significant correlations (all r≤0.31; all p≥0.099).

Limb dominance

In Figure 1, the results of the analysis of the difference between the non-dominant and dominant sides are shown. In the analysis of results for the LQYBT, no statistically significant differences were recorded between the non-dominant and dominant leg (p=0.171–0.532) (Figure 1A). Conversely, in the test for the UQYBT, statistically significant higher values were found in the non-dominant arm (p=0.001–0.0015; Figure 1B). The effect size was small for individual directions (d=0.31 for the sideways reach, d=0.21 for the superolateral reach, and d = 0.36 for the inferomedial reach). However, for the overall result, the difference between the non-dominant and dominant arm was large (d=1.48).

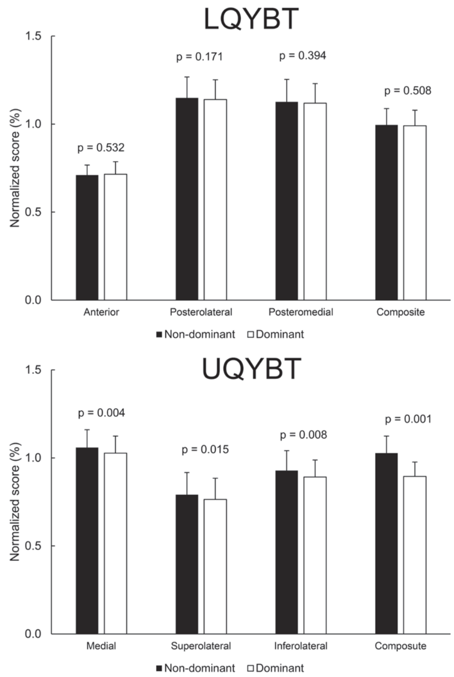

FIGURE 1. Differences between dominant and non-dominant limbs across tests and directions.

Inter-limb asymmetries

We examined whether the inter-limb asymmetries recorded in each test were correlated. We observed a moderate and statistically significant relationship between the asymmetry in the superolateral reach with the arm and the posterolateral reach with the leg (r=0.55; p=0.004), and between the asymmetry in the superolateral reach with the arm and the composite score asymmetry for the leg (r=0.48; p=0.015). No other correlations were found between the two tests. Within the lower body test, there was only a moderate correlation between the posteromedial reach and the posterolateral reach (r=0.46; p=0.019). Within the UQYBT test, there were no correlations between asymmetries in different reach directions.

Table 3 presents the descriptive statistics of the absolute inter-limb asymmetry values for each task and direction of reach. An analysis of variance revealed statistically significant differences in asymmetry values among the three directions of reach in the LQYBT (F=7.19; p=0.002). Post-hoc tests showed that the significant differences were only between the forward reach and the backward-sideways reach (p=0.004). In the UQYBT there were no differences in the size of asymmetries among the reach directions (F=0.55; p=0.578). Additionally, we compared inter-limb asymmetries in the total score between the two tests. It turns out that inter-limb asymmetry was significantly higher in the UQYBT (p=0.022; Table 3).

Lastly, we checked whether the magnitude of inter-limb asymmetries differed between men and women, and between fighters of different styles. A statistically significant difference

Table 3. Mean inter-limb asymmetry values across tests and directions

Test	Direction	Mean	SD	Minimum	Maximum
LQYBT	Anterior	4.52	3.13	0	10.85
	Posterolateral	2.19	1.72	0	5.41
	Posteromedial	3.35	2.29	0	9.52
	Composite	2.29	1.91	0	7.82
UQYBT	Medial	4.34	3.30	0	12.44
	Superolateral	5.69	4.94	0	17.48
	Inferolateral	5.49	5.47	0	24.49
	Composite	3.94	3.01	0.25	11.93

SD – standard deviation

between men and women was observed only in the anterior reach in the LQYBT, where men had significantly lower average asymmetry values (2.79±2.49%) compared to women (5.33±3.13%) (p=0.044; d=0.90). Among fighters of different styles, significant differences were also observed only in one variable, namely the medial reach in the UQYBT. Inter-limb asymmetry was higher in "Guard" fighters (5.43±3.62%) than in "Pass" fighters (2.68±1.89%) (p=0.022; d=0.99).

Discussion

The aim of this study was to thoroughly investigate differences in balance, limb asymmetry, and flexibility according to fighting style, competition level, and gender of Jiu-Jitsu fighters, as well as to determine the asymmetry between the dominant and non-dominant legs and inter-limb asymmetry among them. In this regard, this study had several significant findings: i) there were no differences among groups according to fighting styles in the dynamic balance, flexibility, and body composition; professional athletes had significantly higher results in the inferolateral reach in the UQYBT, both on the non-dominant arm and dominant arm; ii) comparing limb dominance, significantly higher values were found in the UQYBT test on the non-dominant arm, while in LQYBT, there were no differences between the limbs; iii) significant association was found between asymmetry in superolateral reach with the arm and posterolateral reach with the leg, as well as between asymmetry in superolateral reach with the arm and asymmetry in composite result for the leg; iv) within the lower body test, a moderate correlation was found between posteromedial reach and posterolateral reach; significant differences were only between forward reach and backward-lateral reach; v) inter-limb asymmetry was significantly higher in UQYBT; men had significantly lower average asymmetry values than women in anterior reach in LQYBT; inter-limb asymmetry was greater in "Guard" style fighters than in "Pass" style fighters in medial reach in UQYBT.

Reliability of tests

Good to excellent reliability was established for LQYBT (ICC=0.84 to 0.95), and for most UQYBT tests (ICC = 0.83 to 0.91), except for the medial reach with the non-dominant arm (ICC=0.74) and the superolateral reach with the dominant arm (ICC=0.73). In addition, reliability for SRT was excellent (ICC=0.93). These results are consistent with previous studies reporting good to excellent reliability of the LQYBT test (ICC=0.85-0.93; Shaffer et al., 2013), excellent reliability of the UQYBT test (Gorman, Butler, Plisky, & Kiesel, 2012; Westrick, Miller, Carow, & Gerber, 2012), as well as excellent reliability for SRT (ICC=0.95; Ayala, de Baranda, Croix, & Santonja, 2012). In summary, the reliability of all tests on a sample of jiu-jitsu athletes has been confirmed in our study, confirming previous findings. Therefore, LQYBT, UQYBT, and SRT are suitable for use within jiu-jitsu populations, providing a valid foundation for the subsequent analytical processes detailed within this paper.

Differences between groups

There were no differences among groups according to fighting styles in the dynamic balance, flexibility, and body composition. This corresponds to a previous study (de Paula Lima et al., 2017) which also found no differences between styles in jiu-jitsu athletes in dynamic postural balance, flexibility, and isometric handgrip strength, as well as the study (Del Vecchio, Gondim, & Arruda, 2016) in which no differences were found in joint mobility, stability, proprioception, strength, and flexibility. Regarding body composition, in a study (Báez et al., 2014), "Guard" fighters were taller than "Pass" fighters, but there was no difference in body mass and BMI. Based on the recent studies, it is evident that our findings are consistent with previously mentioned studies (Báez et al., 2014; de Paula Lima et al., 2017; Del Vecchio et al., 2016), which can be explained by the fact that jiu-jitsu athletes, regardless of their different fighting styles, participate in the same sport, which imposes relatively similar demands on them. Although, based on the analysis of different styles of jiu-jitsu fighters, it can be observed that "Pass" fighters attack more frequently and require greater strength and power for certain actions (Stock, Mota, Hernandez, & Thompson, 2017), it is important to note that jiu-jitsu is a dynamic sport and jiu-jitsu fighters must rely on other combat strategies depending on various competitive factors. For example, "Guard" fighters sometimes have to fight in a standing position, which is common for "Pass" fighters, and vice versa (Spencer, 2016). Given this information, it is clear why no differences were found between different fighting styles among jiu-jitsu fighters.

Limb dominance, and inter-limb asymmetries

Comparing limb dominance, significantly higher values were found in the UQYBT test on the non-dominant arm. However, although there are no studies with jiu-jitsu athletes, in studies on throwing athletes, there were no differences between the limbs in the UQYBT test (Borms, Maenhout, & Cools, 2016; Bullock et al., 2018; Taylor, Wright, Smoliga, DePew, & Hegedus, 2016). On the other hand, in LQYBT, there were no differences between the limbs, which is in line with previous research (Bressel, Yonker, Kras, & Heath, 2007; Fusco et al., 2020; Gribble & Hertel, 2003). Association was found between asymmetry in superolateral reach with the arm and posterolateral reach with the leg, as well as between asymmetry in superolateral reach with the arm and asymmetry in composite result for the leg. Within the lower body test, a moderate correlation was found between posteromedial reach and posterolateral reach. Therefore, while some correlations were found, asymmetries tend to be test- and outcome-specific, which is consistent with previous studies concerning strength and power asymmetries (Cuthbert et al., 2021; Pérez-Castilla et al., 2021). Therefore, it is crucial to consider a multitude of tests and to compressively assess the presence of inter-limb asymmetries.

Mean asymmetries for our studies were mostly in ~2-5% range, with maximal values at 5–10% in LQYBT and 11-24% in UQYBT. This shows that specific thresholds for meaningful asymmetry for each outcome will likely need to be established. Previous studies have established such benchmarks for other sports. For example, in female cross-country runners, an LQYBT inferolateral reach difference of less than 4 cm was associated with a 75% lower probability of a running-related injury (Ruffe, Sorce, Rosenthal, & Rauh, 2019). In addition, elite football players with high posteromedial asymmetry had a 2.69-fold increased risk of injury (3.26-fold in subgroup with a past injury; Bennett, Chalmers, Milanese, & Fuller, 2022). Future research should focus on investigating inter-limb asymmetries and their correlation with injury risk among jiu-jitsu practitioners. This will lead to the development of reliable thresholds that can be utilized in the development of injury prevention programs. This approach will enable practitioners to design more targeted and effective interventions aimed at reducing the incidence of injuries in this population.

Practical implication

This study is very important as it extensively examined flexibility, dynamic balance, and asymmetries among jiu-jitsu athletes. Based on the findings, reference values for these abilities have been provided, allowing practitioners to adjust training programs according to the gender, level, and style of jiu-jitsu athletes, all aiming to achieve an optimal level of physical preparedness. Furthermore, it will be significant for researchers as the first study to thoroughly investigate this area, contributing to a better understanding of dynamic balance and asymmetry among jiu-jitsu athletes. It can serve as a starting point for further exploration in this field.

Limitations and future suggestion

In the context of this study, one significant limitation is the small sample size, especially regarding the smaller sub-groups within the study. Therefore, future research needs to ensure a large sample of jiu-jitsu athletes, which will also provide a sufficiently large sub-sample to expand on our preliminary findings. Additionally, besides the given abilities, there is a need to examine other motor abilities that are important in jiu-jitsu, primarily muscle strength and muscle endurance, as well as their relationship with dynamic balance and asymmetry, which will provide a broader insight into the motor skills of jiu-jitsu athletes. While intra-rater test-retest reliability was established specifically for the rater in our study to ensure the robustness of the results, inter-rater reliability of the administered tests remains to be established.

Conclusion

This study investigated dynamic-balance (Y-balance test) and flexibility (SR test) among Jiu-Jitsu fighters, focusing on variations by fighting style, competition level, and gender. Key findings include female athletes displaying superior flexibility to males without differences in dynamic balance. No distinctions were observed in dynamic balance, flexibility, or body composition across fighting styles. Professional athletes outperformed in UQYBT for both arms, with notable asymmetry in limb performance. Interestingly, inter-limb asymmetry was more pronounced in the upper body tests, with gender and fighting style influencing specific asymmetry patterns, suggesting tailored training might benefit performance optimization.

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Conflicts of interest
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Ethical approval
The research adhered to the principles of the Helsinki Declaration and received approval from the National Medical Ethics Committee (approval number: 0120-557/2017/4).

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