

Seasonal variation of strength and power magnitude and asymmetry, and injury profile of Brazilian jiu-jitsu athletes

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Abstract:

Brazilian jiu-jitsu is a high-intensity intermittent combat sport and self-defense technique in which the strength and power of the upper and lower limbs and grip strength are essential to achieve success. Beyond the importance of muscle strength and power for Brazilian jiu-jitsu athletic performance, these capacities can also be related to injuries, mainly considering agonist/antagonist imbalances and interlimb asymmetry. This study aimed to obtain variation data for strength and power interlimb asymmetry and intralimb strength imbalances and to describe injury characteristics and frequency during a competitive season of Brazilian jiu-jitsu. Thirteen high-performance Brazilian jiu-jitsu athletes (19.38 ± 2.12 years old, 8.6 ± 2.4 years of training) underwent pre- and postseason evaluations of power of lower and upper limbs, strength of the hip, knee and shoulder muscles, and interlimb asymmetries. The number and characteristics of injuries were self-reported: 46.2% of the athletes suffered one or more injuries, 88.9% of which were recurrent. Small pre- and postseason intralimb strength imbalances, significant small decrease in peak torque (effect size between 0.04 and 0.09) and small increase in the magnitude of interlimb asymmetry (effect size between -0.30 and -0.28) were found considering knee and shoulder. There was good agreement of direction of asymmetry considering shoulder strength and strength balance (kappa between 0.56 and 0.81). The results reinforce the need to periodically monitor strength balance and interlimb asymmetry in terms of direction during the season to better adapt the training sessions to avoid strength imbalances and favoring always the same limb, as well as to be aware of proper recovery after the occurrence of injuries.

Key Words: Sport. Torque. Isokinetic. Martial arts

Introduction

Brazilian jiu-jitsu (BJJ) is a high-intensity intermittent combat sport, also used as a self-defense technique, which involves taking your opponent to the ground, obtaining positional control, and applying locks or strangulations on the joints in order to reach the opponent's submission (Da Silva et al., 2014). To achieve this goal, the strength and power of the upper and lower limbs, as well as grip strength are essential.

The upper limbs and grip strength play an important role in controlling the opponent and applying takedowns and submission techniques, while the lower limbs strength and power are required to achieve a more advantageous position (James, 2014; Jones & Ledford, 2012; Vidal Andreato et al., 2011). Besides, decisive actions during BJJ matches are mainly dependent on muscular power (Andreato et al., 2017), and expert BJJ athletes achieve higher height, peak power, velocity at peak power and average power than novices (Diaz-Lara et al., 2014).

Beyond the importance of muscle strength and power for BJJ athletic performance, these capacities can also be related to injuries, mainly considering agonist/antagonist imbalances and interlimb asymmetry. Injury prevalence is quite high in BJJ: 90% of athletes sustain at least one injury, usually during training, and subjects requiring surgical treatment and/or required to take more than 4 months off training were more likely to consider quitting BJJ (Petrisor et al., 2019). The demand on both upper and lower limbs during BJJ practice is extremely high when attacking and controlling the opponent and intense training can subject the locomotor system to exaggerated overloads, which can increase the risk of injury, especially in the case of athletes who already present risk factors.

Although the majority of injuries sustained are sprains and strains (Petrisor et al., 2019), there is no consensus about the most affected region. Different studies show that BJJ athletes are prone to sustain orthopedic and musculoskeletal injuries to various body locations, such as hand and fingers (McDonald et al., 2017), elbow (McDonald et al., 2017; Petrisor et al., 2019; Scoggin et al., 2014), shoulder (Da Silva Junior et al., 2018; Petrisor et al., 2019; Scoggin et al., 2014), low back (Moriarty et al., 2019; Reis et al., 2015), knee (Da Silva

Junior et al., 2018; Moriarty et al., 2019; Petrisor et al., 2019), foot and toes (McDonald et al., 2017), alerting to the need of monitoring them for injury risk factors and, consequently, implementing injury prevention programs. Although injury is the result of a complex combination of multiple factors, discrepancies of muscle force and power between muscles on the same limb have been pointed out as risk factors, since they can be associated with imbalances of neuromuscular control and load, thus increasing the risk of sustaining an acute or chronic overuse injury. For example, higher injury risk was associated with preseason imbalanced muscular strength profile of the internal and external rotator muscles of the shoulder in handball athletes (Edouard et al., 2013), and strength imbalances were associated with lower extremity injuries in female collegiate athletes (Knapik et al., 1991).

Bilateral asymmetry was also considered a strong predictor for injuries in both clinical and sport contexts, due to the reduced physical capacity of the weaker limb to produce and absorb force during the motor task (Fort-Vanmeerhaeghe et al., 2020). Team-sports athletes with greater interlimb asymmetry during the performance of the single leg countermovement jump (Fort-Vanmeerhaeghe et al., 2020) or demonstrating asymmetrical movement control during the preseason (Chalmers et al., 2017) were more likely to sustain an injury than players without asymmetry. Additionally, previous injury was also associated with increased risk of future injury due to probable residual interlimb deficits, since pre-injured athletes who were cleared to return to sport showing no deficiencies in jump performance still present significant interlimb asymmetries in force and power (Hart et al., 2019).

Unlike team-sports, in which athletes use more one side of the body due to sport specificity, asymmetry may not be expected for combat sports, that are intermittent activities requiring full body and then, considered symmetrical sports. However, asymmetries in knee flexor strength were common among wrestlers and judokas (Drid et al., 2009), sports similar to BJJ.

In addition to their possible relationship with a higher risk of injury, interlimb asymmetries were also associated with decrements in physical performance in youth team-sports players, and, thus, assessing inter-limb asymmetries would be recommended to improve training interventions (Fort-Vanmeerhaeghe et al., 2020; Michailidis et al., 2020).

Asymmetry depends on the sport (Šarabon et al., 2020) and is subject to a large within-group variation in both magnitude and direction (considering dominant and non-dominant limbs, or right and left sides) (Bishop, Lake, et al., 2021), reinforcing the importance of providing information on the presence or absence of imbalances at certain times of the season in order to establish the most appropriate training program.

Considering the crucial role of muscle force and power to BJJ athletic performance and injury risk, it is extremely important to know their variation and the presence of asymmetries as well as to classify the most common injuries throughout a season, then targeted training could be prescribed to potentially improve performance and help reduce the incidence or severity of injury. Therefore, this work aimed to provide variation data for magnitude and asymmetry of strength and power of BJJ athletes during a competitive season, as well as to describe injury characteristics and frequency. We hypothesize that a significant variation would be presented, which could alert about the need for training adaptations.

Material & methods

This exploratory study used a repeated measures design in a convenience sample of high-performance BJJ athletes during a competitive season of 6 months. Strength and power tests were conducted at pre- and postseason time points. There were seven competitions during the period, including the International Brazilian Jiu-Jitsu Federation World Championship. The athletes underwent 2-3 training sessions a day from Monday to Saturday, alternating between technical, tactical, and physical training (exercises of joint mobility and muscle strength), planned by the technical committee of the athletes' BJJ training center.

Participants

The participants were 13 high-performance BJJ athletes (11 men and 2 women) from an internationally renowned training centre, with 19.38 ± 2.12 years of age, 1.71 ± 0.16 m, 71.15 ± 26.87 kg, and 8.6 ± 2.4 years of training. Their training load consisted of twelve hours of specific training and two and a half hours of physical training per week.

The investigations were carried out following the rules of the Declaration of Helsinki. Informed signed consent was obtained from all subjects and from parents or guardians (in the case of athletes under 18 years of age) after they had been informed about the benefits and risks of the investigation. The study was approved by the Human Research Ethics Committee of the university where the study was conducted (approval number 3.955.462, CAAE 29532120.6.0000.5404).

Procedures

The athletes underwent a battery of tests at the beginning of the year and 6 months afterwards. All tests were conducted on the same day and in the same order, in a climate-controlled indoor area. The subjects wore comfortable clothing and were barefoot. Before the beginning of the tests, the athletes warmed up with treadmill jogging during five minutes at a speed of 8 km/h with their habitual sneakers. Power of the lower and upper limbs was evaluated by a single leg vertical jump test and a medicine ball throw test, respectively. Isokinetic evaluation of shoulder internal/external rotation muscles and knee flexor/extensor muscles was conducted to

obtain muscle force as well as the ratio between agonist and antagonist muscles. The force of hip muscles (abductors, extensors, and adductors) was obtained by a handheld dynamometer and handgrip strength was measured by a handgrip dynamometer.

Lower limb power was assessed using the single-limb vertical power hop protocol. The subjects performed 10 consecutive single-limb vertical jumps, with each side, on a force plate (OR6-2000, AMTI Inc., Watertown, USA). The athletes were asked to perform at their best in all jumps. Lower limb power and jump height were calculated according to Bosco et al. (Bosco et al., 1983).

Upper limb power was tested by a single-arm seated throw put with a 3 kg medicine ball (Negrete et al., 2010), testing the right and left upper extremities separately. Seated on the ground with the back supported, the subject was instructed to throw a medicine ball horizontally as far as possible, without taking the back off the wall. Upper limb power was characterized by the distance achieved by the ball, measured with a measuring tape. A Cybex isokinetic dynamometer (HUMAC NORM Extremity System - Henley Healthcare, serial no. A8814, Stoughton, MA) was used to assess the peak torque of knee flex-or/extensor muscles (Kim & Hong, 2011) and shoulder internal/external rotation muscles (Shklar & Dvir, 1995). All isokinetic measurements were conducted with five concentric repetitions at 60°.s-1 and 20 concentric repetitions at 180°.s-1.

The knee extension/flexion test was conducted in a sitting position with a flexed knee. The range of motion was between 100 and 0 degrees of flexion. The axis for extension/flexion was assumed to be a horizontal line through the femur condyles. The subject was secured with a Velcro band around the pelvis and with a thigh cushion on the test leg.

The shoulder internal and external rotation test was conducted with the athletes standing with the shoulder at 30 degrees of abduction and the elbow with 90 degrees of flexion. The range of motion of 90 degrees was set between 45 degrees of internal rotation and 45 degrees of external rotation. The other hand held a sideboard next to the isokinetic chair so there would be no trunk rotation.

A handheld dynamometer (Lafayette model 01163, Lafayette Instrument Company, Lafayette, Indiana) was used to obtain the peak isometric torque of hip abductor, extensor (de Oliveira et al., 2018), and adductor muscles (Thorborg et al., 2010). Muscle force was measured during a three-second isometric contraction, with three repetitions without interval. The mean of the three repetitions was used for statistical analysis. For the evaluation of hip abductor muscles, the subject remained lying in lateral position with the dynamometer positioned superior to the lateral malleolus, while hip extensors were assessed with the subject in prone position with the dynamometer positioned on the distal posterior thigh region. In both tests the tested limb was fixed to the table by a rigid strap. Hip adductors were assessed with the subject lying in supine position with the dynamometer positioned superior to the medial malleolus. All values were normalized by body weight.

Hand grip strength was measured by a hand grip dynamometer (Bausch & Lomb), with the subject seated, shoulder in neutral position with the arm touching the thorax, elbow with 90 degrees of flexion, and wrist in neutral position.

During the period of the study, the subjects had to respond to an injury incidence survey every two months. The survey, adapted from Pastre et al. (Pastre et al., 2004), sought information on the occurrence of injury in the two previous months, the anatomical region of the injury, injury mechanism (with or without contact), site of injury (physical training, specific training, competition), severity of injury according to consequent days away from training (minimal – 1 to 2 days, mild – 4 to 7 days, moderate – 8 to 28 days, severe – higher than 28 days), return to training symptom status (asymptomatic, symptomatic, has not yet returned), injury recurrence, and affected side.

Considering that all variables were obtained by unilateral tests, and that it is essential that the calculation used to quantify between-limb differences matches the specifics of the test method (Bishop et al., 2018), interlimb asymmetry (IA) was evaluated by a standard percentage difference equation: $100/(\text{max value}) * (\text{min value}) * -1 * 100$, according to Bishop et al. (Bishop et al., 2019). To determine the direction of asymmetry and indicate limb dominance, positive values of asymmetry were adopted for dominant limb, and negative values for non-dominant limb.

Statistical analysis

Data normality and homogeneity of variance were tested using the Shapiro-Wilk and Levene tests, respectively. Sphericity of data was verified through Mauchly's test, and when the condition of sphericity was not met, the Greenhouse-Geisser correction was used. The significance of differences between pre- and postseason tests was assessed with paired Student's t-tests. When a significant difference was found, Cohen's d for paired test was used to determine the effect size. The effect size was classified according to Rhea (Rhea, 2004) as trivial (<0.25), small (0.25–0.50), moderate (0.50–1.0), and large (>1.0).

Considering the sample size and the heterogeneous nature of asymmetry, IA was presented individually. The Kappa coefficient was used to analyze the agreement of the direction of the asymmetry between the pre- and postseason tests, where ≤ 0 = poor, 0.01–0.20 = slight, 0.21–0.40 = fair, 0.41–0.60 = moderate, 0.61–0.80 = substantial, and 0.81–0.99 = almost perfect (Viera & Garrett, 2005).

Results

Comparing the pre- and postseason test conditions (Table 1), we found a significant increase with trivial effect size in the left upper limb power ($P = 0.007$, $d = 0.07$), and in the handgrip strength of both sides (right: $P < 0.001$; $d = 0.15$; left: $P < 0.001$; $d = 0.10$). A significant decrease with trivial effect size was found in the peak torque of the right knee extensors at $180^\circ.s^{-1}$ ($P = 0.016$, $d = 0.04$), in the peak torque of the right and left shoulder internal rotators at $180^\circ.s^{-1}$ (right: $P = 0.025$, $d = 0.04$; left: $P = 0.021$, $d = 0.09$), and in the abduction isometric torque of the left hip ($P = 0.02$, $d = 0.07$).

Considering interlimb asymmetry results (Table 1), significant differences were found for the ratio of quadriceps and hamstring peak torque at 60 and $180^\circ.s^{-1}$ ($P = 0.02$, $d = -0.30$) and for the ratio of shoulder internal and external rotator muscles peak torque at $60^\circ.s^{-1}$ ($P = 0.00$, $d = -0.28$), with increased asymmetry of small effect size in the postseason evaluation.

Table 1. Results (mean $\pm$ standard deviation) obtained in pre- and postseason test conditions for lower limb power ($POWER_{LL}$), jump height (HEIGHT), peak isokinetic torque of knee extensor (EXT_{Knee_60} , EXT_{Knee_180}) and flexor muscles (FLE_{Knee_60} , FLE_{Knee_180}) at 60 and $180^\circ.s^{-1}$, ratio of quadriceps and hamstring peak torque at 60 and $180^\circ.s^{-1}$ ($RATIO_{Knee_60}$, $RATIO_{Knee_180}$), isometric torque of hip abductor (ABD_{Hip}), extensor (EXT_{Hip}) and adductor muscles (ADD_{Hip}), handgrip strength (GRIP), upper limb power ($POWER_{UL}$), peak isokinetic torque of shoulder internal ($IR_{Shoulder_60}$, $IR_{Shoulder_180}$) and external rotator muscles ($ER_{Shoulder_60}$, $ER_{Shoulder_180}$) at 60 and $180^\circ.s^{-1}$, and ratio of shoulder internal and external rotator muscles peak torque at 60 and $180^\circ.s^{-1}$ ($RATIO_{Shoulder_60}$, $RATIO_{Shoulder_180}$). Asymmetry values are in percentage.

	RIGHT		LEFT		ASYMMETRY	
	Preseason	Postseason	Preseason	Postseason	Preseason	Postseason
$POWER_{LL}$ (W/kg)	12.8(± 4.4)	10.8(± 3.2)	12.9(± 3.6)	10.5(± 2.8)	12.70 $\pm$ 9.85	15.27 $\pm$ 9.36
HEIGHT (cm)	18.1(± 6.9)	15.8(± 5.6)	18.6(± 6.2)	15.6(± 5.1)	14.41 $\pm$ 11.35	18.47 $\pm$ 11.44
EXT_{Knee_60} (N.m)	199.4(± 38.2)	188.2(± 39.2)	189.9(± 41.0)	177.0(± 28.6)	8.80 $\pm$ 6.95	9.00 $\pm$ 8.32
EXT_{Knee_180} (N.m)	134.3(± 29.3)	124.4(± 27.1)*	129.0(± 25.5)	125.5(± 33.3)	8.14 $\pm$ 6.55	9.20 $\pm$ 5.74
FLE_{Knee_60} (N.m)	124.4(± 28.8)	119.2(± 33.6)	111.6(± 27.7)	105.9(± 23.8)	11.45 $\pm$ 9.32	12.41 $\pm$ 10.67
FLE_{Knee_180} (N.m)	88.8(± 22.3)	84.7(± 22.3)	80.2(± 18.3)	74.3(± 18.5)	10.13 $\pm$ 8.81	13.05 $\pm$ 10.08
$RATIO_{Knee_60}$ (%)	62.2(± 8.2)	63.4(± 12.0)	58.8(± 6.9)	60.6(± 9.2)	10.03 $\pm$ 6.01	12.34 $\pm$ 10.75
$RATIO_{Knee_180}$ (%)	66.1(± 9.1)	67.9(± 10.9)	62.2(± 8.5)	59.8(± 8.6)	8.60 $\pm$ 5.93	15.14 $\pm$ 10.66*
ABD_{Hip} (kgf)	23.9(± 3.5)	23.4(± 3.1)	24.1(± 2.7)	21.9(± 3.2)*	7.77 $\pm$ 5.98	9.48 $\pm$ 5.13
EXT_{Hip} (kgf)	32.4(± 7.5)	31.6(± 8.8)	32.9(± 7.1)	32.0(± 8.7)	9.25 $\pm$ 9.01	7.38 $\pm$ 6.43
ADD_{Hip} (kgf)	26.4(± 5.9)	28.5(± 6.5)	25.7(± 5.6)	28.1(± 5.0)	9.97 $\pm$ 7.82	12.36 $\pm$ 7.77
GRIP (kgf)	47.3(± 17.4)	69.1(± 10.3)*	49.0(± 15.6)	64.2(± 13.9)*	12.39 $\pm$ 6.64	8.34 $\pm$ 8.15
$POWER_{UL}$ (m)	3.7(± 0.5)	4.0(± 0.8)	3.2(± 0.5)	3.6(± 0.6)*	13.70 $\pm$ 9.43	10.89 $\pm$ 8.15
$IR_{Shoulder_60}$ (N.m)	69.5(± 14.4)	70.1(± 12.6)	64.5(± 14.3)	63.5(± 13.2)	9.73 $\pm$ 5.74	12.26 $\pm$ 6.52
$IR_{Shoulder_180}$ (N.m)	59.6(± 12.3)	55.0(± 10.7)*	55.7(± 14.4)	51.5(± 10.9)*	13.39 $\pm$ 9.25	8.85 $\pm$ 6.43
$ER_{Shoulder_60}$ (N.m)	47.5(± 10.9)	50.1(± 12.4)	42.9(± 10.2)	46.6(± 10.7)	11.90 $\pm$ 7.71	13.31 $\pm$ 6.92
$ER_{Shoulder_180}$ (N.m)	37.7(± 9.9)	37.8(± 10.0)	33.9(± 8.5)	35.2(± 7.6)	10.89 $\pm$ 10.33	12.46 $\pm$ 9.50
$RATIO_{Shoulder_60}$ (%)	67.8(± 9.4)	71.6(± 8.3)	66.2(± 10.2)	71.9(± 12.6)	8.30 $\pm$ 7.85	16.00 $\pm$ 9.46*
$RATIO_{Shoulder_180}$ (%)	63.5(± 8.9)	72.7(10.6)	61.6(± 11.2)	66.5(± 10.6)	11.36 $\pm$ 7.52	16.67 $\pm$ 13.12

*Significant different from preseason measurement ($P < 0.05$)

The level of agreement between the direction of interlimb asymmetry, represented by the Kappa coefficient (Table 2), was moderate for the peak isokinetic torque of shoulder external rotator muscles at $180^\circ.s^{-1}$, substantial for the peak isokinetic torque of knee flexor muscles, ratio of quadriceps and hamstring peak

torque at 60°.s⁻¹, and ratio of shoulder internal and external rotator muscles peak torque at 180°.s⁻¹, and almost perfect for the peak isokinetic torque of shoulder internal and external rotator muscles at 60°.s⁻¹. For the other variables there were no statistical significance for the level of agreement.

Table 2. Kappa coefficients (*P*-value) and kappa classification, and Kendall's Tau Correlation Coefficient (□□value□□between injury occurrence (yes or no) and asymmetry index considering lower limb power (POWER_{LL}), jump height (HEIGHT), peak isokinetic torque of knee extensor (EXT_{Knee_60}, EXT_{Knee_180}) and flexor muscles (FLE_{Knee_60}, FLE_{Knee_180}) at 60 and 180°.s⁻¹, ratio of quadriceps and hamstring peak torque at 60 and 180°.s⁻¹ (RATIO_{Knee_60}, RATIO_{Knee_180}), isometric torque of hip abductor (ABD_{Hip}), extensor (EXT_{Hip}) and adductor muscles (ADD_{Hip}), handgrip strength (GRIP), upper limb power (POWER_{UL}), peak isokinetic torque of shoulder internal (IR_{Shoulder_60}, IR_{Shoulder_180}) and external rotator muscles (ER_{Shoulder_60}, ER_{Shoulder_180}) at 60 and 180°.s⁻¹, and ratio of shoulder internal and external rotator muscles peak torque at 60 and 180°.s⁻¹ (RATIO_{Shoulder_60}, RATIO_{Shoulder_180}).

	<i>Kappa coefficients (P)</i>	Classification	Kendall's Tau Correlation Coefficient (σ)
POWER _{LL} (W/kg)	-0.315 (0.21)	poor	0.105 (0.668)
HEIGHT (cm)	-0.512 (0.05)	poor	0.070 (0.775)
POWER _{UL} (m)	0.316 (0.12)	fair	0.245 (0.317)
EXT _{Knee_60} (N.m)	0.217 (0.43)	fair	0.314 (0.199)
EXT _{Knee_180} (N.m)	0.152 (0.51)	slight	0.175 (0.475)
FLE _{Knee_60} (N.m)	0.395 (0.14)	fair	0.454 (0.063)
FLE _{Knee_180} (N.m)	0.649 (0.01)*	substantial	0.369 (0.133)
RATIO _{Knee_60} (%)	0.690 (0.01)*	substantial	0.280 (0.253)
RATIO _{Knee_180} (%)	0.350 (0.10)	fair	0.245 (0.317)
IR _{Shoulder_60} (N.m)	0.806 (0.00)*	almost perfect	0.210 (0.391)
IR _{Shoulder_180} (N.m)	0.217 (0.43)	fair	0.070 (0.775)
ER _{Shoulder_60} (N.m)	0.847 (0.00)*	almost perfect	0.211 (0.391)
ER _{Shoulder_180} (N.m)	0.562 (0.02)*	moderate	0.178 (0.473)
RATIO _{Shoulder_60} (%)	0.156 (0.57)	slight	-0.140 (0.568)
RATIO _{Shoulder_180} (%)	0.639 (0.02)*	substantial	0.175 (0.475)
ABD _{Hip} (kgf)	0.114 (0.61)	slight	0.070 (0.775)
EXT _{Hip} (kgf)	0.530 (0.05)	moderate	0.035 (0.886)
ADD _{Hip} (kgf)	0.530 (0.05)	moderate	0.105 (0.668)
GRIP (kgf)	-0.548 (0.05)	moderate	0.314 (0.199)

*Significant (*P* < 0.05)

Given the evident variability in direction of asymmetry across all tests and considering the requirement of a more individual approach to reporting asymmetries (Bishop, Lake, et al., 2021), individual asymmetry data are shown in Fig. 1 to 3. Pronounced within-subject variability can be seen, which apparently is not restricted to injured athletes.

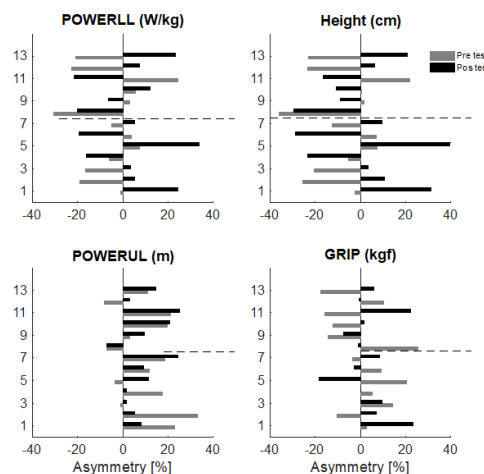


Fig 1. Individual asymmetry values for lower limb power (POWERLL), jump height (HEIGHT), upper limb power (POWERUL), and handgrip strength (GRIP) at pre- and postseason test conditions. Positive values indicate right limb dominance and negative values indicate left limb dominance. The dashed line divides the subjects without injury (1 to 7) from the subjects who suffered some injury during the period (8 to 13).

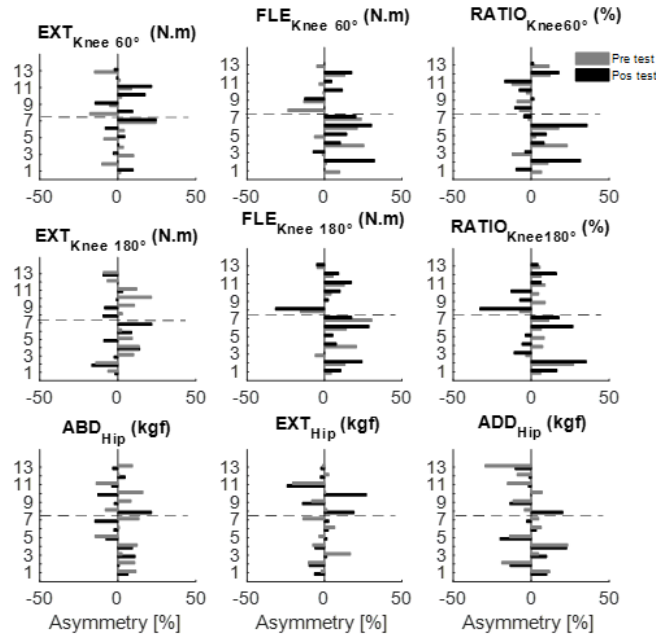


Fig 2. Individual asymmetry values of peak isokinetic torque of knee extensor (EXT_{Knee_60} , EXT_{Knee_180}) and flexor muscles (FLE_{Knee_60} , FLE_{Knee_180}) at 60 and $180^{\circ}\cdot s^{-1}$, of the ratio of quadriceps and hamstring peak torque at 60 and $180^{\circ}\cdot s^{-1}$ ($RATIO_{Knee_60}$, $RATIO_{Knee_180}$), of isometric torque of hip abductor (ABD_{Hip}), extensor (EXT_{Hip}) and adductor muscles (ADD_{Hip}) at pre- and postseason test conditions. Positive values indicate right limb dominance and negative values indicate left limb dominance. The dashed line divides the subjects without injury (1 to 7) from the subjects who suffered some injury during the period (8 to 13).

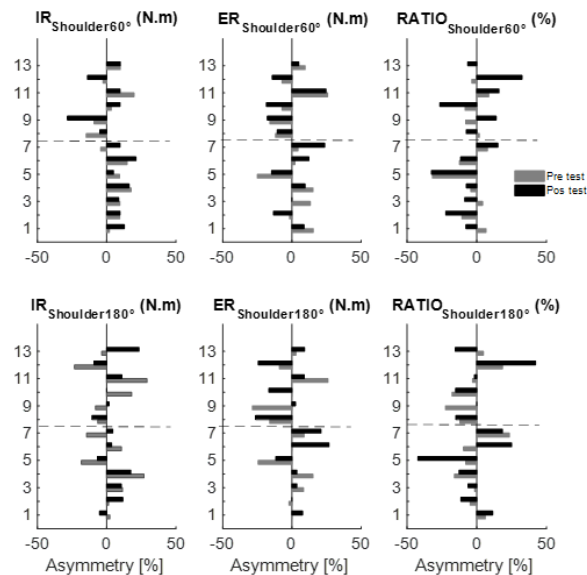


Fig 3. Individual asymmetry values of peak isokinetic torque of shoulder internal ($IRShoulder_60$, $IRShoulder_180$) and external rotator muscles ($ERShoulder_60$, $ERShoulder_180$) at 60 and $180^{\circ}\cdot s^{-1}$, and ratio of shoulder internal and external rotator muscles peak torque at 60 and $180^{\circ}\cdot s^{-1}$ ($RATIOShoulder_60$, $RATIOShoulder_180$) at pre- and postseason evaluations. Positive values indicate right limb dominance and negative values indicate left limb dominance. The dashed line divides the subjects without injury (1 to 7) from the subjects who suffered some injury during the period (8 to 13).

The injury surveillance results showed that six athletes (46.2% — 4 male and 2 female) suffered one or more injuries during the period of the study, with a total of 18 injuries, 16 (88.9%) of which were recurrent. The most injured anatomical regions were the foot, knee and wrist (3 injuries each), followed by the posterior region of the thigh, shoulder, lumbar spine, and arm (2 injuries each), and by the hand (1 injury). Considering limbs (16 injuries), 10 injuries (62.5%) affected the right side. There were 8 injuries (44.4%) during competition, 9 (50%) during training, and one absent response (5.6%). The most prevalent mechanism of injury reported was direct contact (11 injuries: 61.1%). Among injuries without direct contact, 5 (83.3%) occurred during specific training (technical training). Severity was mild for most injuries (10 injuries; 55.5%), followed by moderate (4 injuries; 22.2%), and severe (3 injuries; 16.7%) — there was one absent response (5.6%). In 17 (94.4%) injury occurrences the athletes returned to training with symptoms.

Discussion

Aiming to obtain seasonal variation data for strength and power magnitude and asymmetry, as well as to describe injury profiles, we conducted preseason force and power biomechanical evaluations with BJJ athletes. Then, the number and characteristics of injuries were registered during a competitive season and the biomechanical evaluations were repeated. The results demonstrated: a) a trivial decrease of hip abduction, knee extension and shoulder internal rotation strength as well as a trivial increase of upper limb power and handgrip strength; b) a small increase in interlimb asymmetry of knee and shoulder agonist/antagonist ratio, with evident variability in both magnitude and direction of the asymmetry index across all tests; c) a good agreement of asymmetry direction considering knee and shoulder peak torque and agonist/antagonist ratio; d) high frequency of injuries. Our results showed an increase in handgrip strength, which is essential in BJJ combats. Despite the trivial effect size found, this variable is important as it is necessary to control the opponent or to apply takedowns or submission techniques. Besides, this strength can decrease after a tournament due to fatigue, which shows the importance of training this skill (Detanico et al., 2017).

Regarding the frequency of injuries, 88.9% were recurrent. Considering the upper limb, seven (27.8%) injuries affected the shoulders, arm, wrist or hand, three without contact. Contrasting with the increase in grip strength and left upper limb power, there was a trivial decrease of the internal rotation peak torque at 180°.s-1 and a small increase of the asymmetry index of the shoulder internal/external rotation ratio at 60°.s-1. Despite the small effect size of these changes, the ratio between shoulder internal/external rotation torque found (61.1 – 72.7%) was slightly below the expected values of 66–75% (Ellenbecker & Davies, 2000) in some cases. The strength and balance between the rotator cuff muscles of the shoulder are essential to the dynamic stabilization of this naturally unstable joint, and weaknesses and imbalances could be dangerous, especially for athletes subjected to shoulder locks such as in BJJ. Among the 18 injuries reported by the BJJ athletes, eight (44.4%) affected the lower limbs, two without contact. The results show a decrease of the right knee extensors peak torque at 180°.s-1 and a decrease of the left hip abductors isometric torque. The hamstrings/quadriceps ratio was between 58.8 and 63.4% at 60°.s-1 and between 59.8 and 67.9% at 180°.s-1, with a small increase of the interlimb asymmetry index value. Although these changes had small effect sizes, hamstrings/quadriceps ratios below 75% measured at 180°.s-1 (Knapik et al., 1991) or below 60% measured at 60°.s-1 (Dauty et al., 2003) were already related to injuries. Therefore, these results could be related to injuries affecting the knee since they occurred without contact. One of the contributing factors to this kind of injury is dynamic knee valgus, which can be related, among other factors, to lack of strength and activation of knee extensor and hip abductor muscles (Claiborne et al., 2006; Hollman et al., 2009). Another is hamstrings and quadriceps imbalance (Kim & Hong, 2011). Thus, these asymmetries and strength imbalances should be monitored and properly addressed since the knee is one of the most injured joints according to the literature (McDonald et al., 2017; Moriarty et al., 2019). Additionally, Nadler et al. (Nadler et al., 2001) showed that hip muscle imbalance is associated with the risk of low back pain, a highly prevalent condition in BJJ athletes, especially at the professional level (Reis et al., 2015).

Except for the small changes found in the ratio interlimb asymmetry index for knee and shoulder agonist/antagonist, the magnitude of asymmetry remained consistent for all tested variables throughout the season. Although small differences between the dominant and non-dominant limb are expected for athletes that use more one side of the body due to sport specificity, such as in soccer (Logerstedt et al., 2013) and handball (Andrade et al., 2013), this may not be true for combat sports, that are intermittent activities requiring full body motion. Stradijot et al. (Stradijot et al., 2012) showed that, except for peak torque values of the knee extensors, healthy judokas and wrestlers are symmetrical considering lower limb strength and power. However, even if asymmetries are not expected in symmetrical sports, their occurrence seems not to be strictly related to the specificity of the activity. Asymmetries in kinematics and kinetics are very common in sports such as running, cycling, and swimming (Carpes et al., 2010; Sanders et al., 2011). Besides, Drid et al. (Drid et al., 2009) found that asymmetries in knee flexor strength were common among wrestlers and judokas. Side dominance could influence the reinforcement of asymmetries through preferential use of dominant limbs, but the present and past practice of other activities as well as the history of injuries should also be considered as they could influence the occurrence of asymmetries (Sanders et al., 2011). In judo, for example, which has high-intensity effort and unilateral characteristics, the magnitude of interlimb asymmetry considering hand-grip strength and single leg

jump tests did not change after four successive matches, which would be expected due to fatigue (Kons et al., 2021).

The lack of difference for interlimb asymmetry during the season found in our study can be related to the high variability of the magnitude of asymmetry, indicated by the large standard deviation relative to the mean shown in table 1. This result corroborates the assertion of Bishop et al. (Bishop, Weldon, et al., 2021) that “magnitude of asymmetry may not be the most viable measure when aiming to comprehend the inherent variability that accompanies mean asymmetry values.” McFall et al. (2022) also showed that interlimb asymmetry is very highly individual considering elite trials cyclists. Therefore, our results reinforce the highly variable nature of interlimb asymmetry and the importance of an individual approach to assess it.

Besides magnitude, our study also measured direction of asymmetry. Although many of the tests exhibited great variability in direction of asymmetry throughout the season, substantial to almost perfect agreement was found considering knee flexion peak torque and quadriceps/hamstrings ratio, and shoulder internal and external peak torque and ratio, meaning that the same limb was favored in both pre- and postseason tests. These results, added to the fact that the knee and shoulder are among the most injured regions, suggest that it could be more dangerous to maintain asymmetry direction than magnitude. Competitive combat sports are highly demanding: in BJJ, the contestants must throw each other on the ground, obtain an advantageous position and control the opponent by applying locks or strangulations. Thus, strength and power of upper and lower limbs are crucial, and the repeated preference of one of the limbs could be critical for both performance and increased risk of injury. Perhaps the reduction of asymmetrical ligament and soft tissue loading is related to the variation of limb preference throughout the season, which should be taken into consideration in the training and rehabilitation of BJJ athletes. Although it is common to assume that asymmetries and strength and power decrease and/or imbalance may increase the injury risk, it is worth mention that the opposite could also be true: the occurrence of injury or the lack of optimal recovery could lead to the appearance of asymmetries, imbalances and decrease in strength and power (ie, injury-induced strength loss), which could lead, consequently, to the decrease of the athletic performance. Considering that 88.9% of the injuries reported by the BJJ athletes studied were recurrent, and that in 94.4% of injury occurrences the athletes returned to training with symptoms, the results alert to the need of proper rehabilitation and recovery as well as the proper evaluation of the athletes before releasing them for training and competition. Some limitations should be considered in the interpretation of these results: our sample population was biased towards men, which is a potential limitation when applying the findings to women; however, this is a common limitation since the number of men is much greater than that of women in the practice of this sport.

Conclusions

The biomechanical evaluation of BJJ athletes during a competitive season showed: a) a small decrease in strength and small strength imbalances throughout the period; b) that interlimb asymmetry of force and power is highly variable in magnitude and direction; c) a high prevalence of injuries in a variety of locations. In view of the existence of strength and power variations and the high prevalence of injuries, the results show the necessity to periodically monitor strength, intralimb strength balance, and interlimb asymmetry in terms of magnitude and direction during the season, which are potential modifiable parameters related to physical training and risk of injury, in order to better adapt the training sessions to avoid strength imbalances and favouring always the same limb. A decrement in strength and strength balance during the season should not occur, and could be related to neuromuscular adaptations or to the lack of total recovery from injuries. Then, besides monitoring strength and power throughout the season to better adapt training, it is also important to be aware of proper recovery after the occurrence of injuries before returning to competition.

Conflicts of interest - The authors declared no potential conflicts of interest

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