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FUNCTIONAL, BIOMECHANICAL, AND THERMOGRAPHIC EVALUATION OF UPPER LIMBS IN BRAZILIAN JIU-JITSU PRACTITIONERS

Luan Fernando Pereira Soares[1], Rômulo Bahia dos Reis[1], Tiago Costa Esteves[2], Erielson dos Santos Bossini[3], José Maria Furtado Júnior[3], Danusa Neves Somensi[4], Ismari Perini Furlaneto[5] and João Sérgio de Sousa Oliveira*[1]

[1]Luan Fernando Pereira Soares. Universidade do Estado do Pará -Departamento de Ciências do Movimento Humano, Belém-PA. [2]Rômulo Bahia dos Reis. Universidade do Estado do Pará - Departamento de Ciências do Movimento Humano, Belém-PA. [3]Tiago Costa Esteves. Faculdade Inspirar - Curso de Especialização em Fisioterapia em Traumatologia e Ortopedia, Belém-PA. [4]Erielson dos Santos Bossini. Universidade da Amazônia - Curso de Fisioterapia, Belém-PA. [5]José Maria Furtado Júnior. Universidade da Amazônia - Curso de Fisioterapia, Belém-PA. [6]Danusa Neves Somensi. Universidade do Estado do Pará - Programa de Pós-Graduação em Biologia Parasitária na Amazônia, Belém-PA. [7]Ismari Perini Furlaneto. Centro Universitário do Pará - Mestrado Profissional em Ensino em Saúde/Educação Médica, Belém-PA. [8]João Sérgio de Sousa Oliveira. Universidade do Estado do Pará - Departamento de Ciências do Movimento Humano, Belém-PA. Endereço: Universidade do Estado do Pará, Centro de Ciências Biológicas e da Saúde, Campus II. Travessa Perebebuí, 2623 – Marco, CEP 66087-662, Belém

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Corresponding author:
João Sérgio de Sousa Oliveira, PhD

ABSTRACT

This is a cross-sectional study with the aim of evaluating the upper limbs of Brazilian jiu-jitsu practitioners. Fourteen athletes completed the Disabilities of the Arm, Shoulder and Hand questionnaire, and assessed using hydraulic dynamometry and infrared thermometry. The mean scores were as follows: physical functions and symptoms: 5.6 ± 7.2; sports practice: 10.6 ± 17.6; ability to work: 5.6 ± 6.5; and total score: 18.7 ± 23.9; mean grip strength: right, 44.0 ± 8.2 kilograms-force and left, 42.6 ± 7.7 kilograms-force; mean of thermograms in the posterior region of the right forearm was 33.5 ± 1.3degree Celcius, higher than in the left 33.3 ± 1.2 degree Celcius (p = 0.0205). Practitioners showed mild impairment of functionality, good handgrip strength, and bilateral changes in posterior forearm temperatures.

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INTRODUCTION

Brazilian Jiu-Jitsu (BJJ) is a widely known martial art practiced worldwide, which uses complex strategies and is taught via various teaching methods. The practitioners are classified by age, the use or not of *kimono*, and belt colors, which represent their level. The practice includes projections, bottlenecks, joint blocks, and finalizations, involving intermittent efforts of low and high intensity (Andreato *et al.*, 2017a). It requires good aerobic capacity and power, flexibility, and static and dynamic muscle forces, especially in upper limbs, and exerted using hand grip strength (Andreato *et al.*, 2011). Biomechanical aspects of the BJJ result in frequent upper limb injuries due to the movements and forces required by the techniques, resulting in overloads during training or competitions (Petrisor *et al.*, 2019).

These injuries involve complex phenomena encompassing nonlinear interactions between physiological, technical, biomechanical, and psychological factors. A proper understanding of these interactions requires broad approaches, include evaluations of functionality (McDonald *et al.*, 2017), biomechanical aspects (Andreato *et al.*, 2011), and more recently, infrared photometry (Moreira *et al.*, 2017). Functional evaluations of upper limbs are usually performed in a segmented fashion, while only a few approaches evaluate the upper limbs as a whole. An example is *The Disabilities of the Arm, Shoulder, and Hand Questionnaire* (DASH), which features psychometric characteristics used by the *American Academy of Orthopedic Surgeons* (AAOS) and the *Institute of Labor and Health* (Canada) (Hudak *et al.*, 1996). The DASH questionnaire analyzes the upper limb in terms of symptoms and function, while also considering the physical, social, and psychological dimensions, translated and adapted for use in Brazil (Orfale *et al.*, 2005). Biomechanical evaluations for determining muscle strength level are fundamental to the BJJ practitioner, and hydraulic dynamometer is an instrument widely used in individuals with upper limb dysfunction (Jones e Ledford, 2012). This instrument is recommended by the *American Society of Hand Therapists* as a simple, valid, and easy-to-apply clinical instrument (MacDermid *et al.*, 2015). It is used to evaluate maximal isometric hand grip strength, which is related to the ability to hold and control the opponent (Lopes *et al.*, 2019). Thermography is a non-invasive technique whichuses an infrared camera to capture body radiation by thermograms, measuring and mapping the distribution of temperature in regions of interest. Body temperatures vary according to local blood flow and clinical abnormalities, which can be evaluated and analyzed at temperature intervals (Viegas *et al.*, 2020). Thermography can be used in sport science as a complementary clinical examination in the follow-up of athletes for evaluating physiological responses to exercise or for preventing injury (Quesada, 2017). Therefore, this study aimed at evaluating the functionality, grip strength, and thermography of upper limbs in BJJ practitioners.

METHODS

Study design and setting: A cross-sectional study was conducted with BJJ practitioners in the months of October and November 2019 at the *Broca Fight Team*, a federal martial arts academy located in the city of Belém, state of Pará.

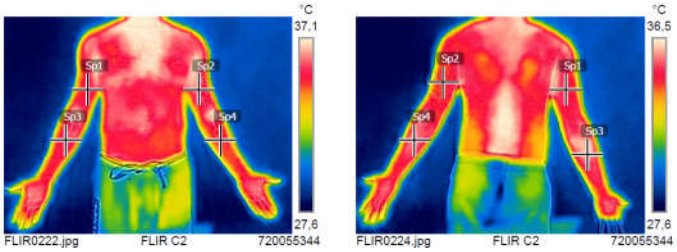

Figure 1. Thermograms of the regions of interest in the upper limbs of the participants in the anterior (left) and posterior (right) positions.Sp1A: anterior right arm. Sp2A: anterior left arm. Sp3A: anterior right forearm. Sp4A: anterior left forearm. Sp1P: posterior right arm. Sp2P: posterior left arm. Sp3P: posterior right forearm. Sp4P: posterior left forearm. ºC, degree Celsius

Participants: The convenience sample included male individuals aged 18 to 60 years, with a minimum time of sport practice of one year and a training frequency of at least three times per week. The Brazilian Confederation of Jiu-Jitsu criteria of classifying practitioners by belts and fight categorieswere adopted. Those who exhibited bruises, wounds, and acute or chronic pain at the time of evaluation, fever in the prior seven days, and those who used ergogenic substances, antipyretic drugs, or diuretics, were excluded.

Data sources and measurement: The participants were evaluated to characterize the socio-demographic and practical aspects of BJJ.

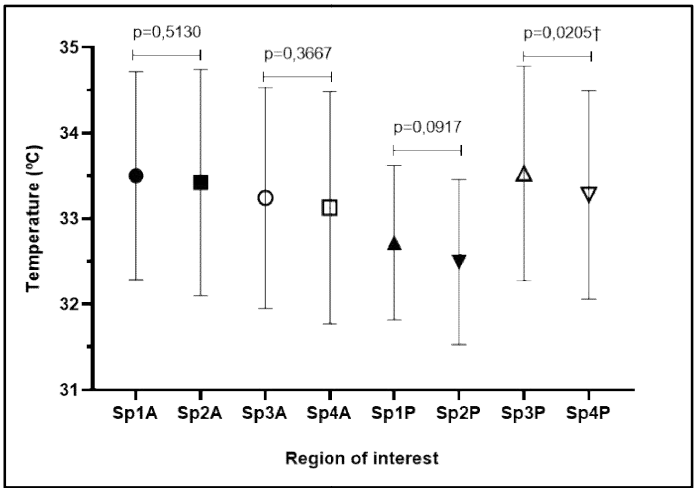

Figure 2. Comparison of the mean values of thermogram readings in the regions of interest of the upper limbs of Brazilian Jiu-Jitsu practitioners. Paired Student's t-test. †Statistically significant. Sp1A: anterior right arm. Sp2A: anterior left arm. Sp3A: anterior right forearm. Sp4A: anterior left forearm. Sp1P: posterior right arm. Sp2P: posterior left arm. Sp3P: posterior right forearm. Sp4P: posterior left forearm. ºC, degree Celsius

The upper limbs were functionally evaluated by the DASH questionnaire using the *Physiotherapy Questionnaires* software version 1.3 on the *Android* platform. This questionnaire contained 30 questions to evaluate physical function and symptoms, and two modules (musical or sports performance, and work) of four questions. A score was calculated using a formula established for the first 30 questions, and second score was calculated for the optional modules. The score for each question within the domain ranged from 1 to 5 points, resulting in a final score with possible values between zero (no disability) and 100 (severe disability) (Orfale *et al.*, 2005). The following classification of functional impairment was adopted based on the final scores: 0-20 (no limitation), 21-40 (slight limitation), 41-60 (moderate limitation), 61-80 (severe limitation), and 81-100 (very severe limitation) (Pinho *et al.*, 2014). Hand grip strength was measured using a *Saehan*® hydraulic dynamometer (SH5001), with a sensitivity of 0.5 kilogram-force (kgf) and a maximum capacity of 90 kgf.

The recommendations of the American Society of Hand Therapists were followed, with the participant in the following posture: sitting in a chair without arm support, hip and knee flexed at 90º and feet supported on the floor; shoulders adducted and neutral without rotation, elbow flexed at 90º, and forearms and wrist in the neutral position (MacDermid *et al.*, 2015). The test was performed on both hands, with the strap being adjusted to fit the size of the hand. Maximum force was exerted for five seconds in three interval measurements with one minute of rest, and the mean peak value was obtained (César *et al.*, 2016). Infrared Thermography was performed using a FLIR digital camera (model C-2), with a resolution of 320x240 pixels, wavelength sensitivity of 7.5 to 14 µm, recording temperatures ranging from -50 °C to 150 °C, and a thermal resolution of 0.05°C. The *FLIR Tools software* version 5.13 was used for identifying anatomical reference points, and the analysis and interpretation of thermograms (means and maxima). An Incoterm® digital thermometer was used to monitor and help control the temperature and relative humidity of the ambient air. The measurements followed the standards of the *European Association of Thermology*; the room in which measurements were made was artificially lit with a fluorescent lamp, and no refrigerated airflow was allowed towards the participant; the room temperature was maintained between 18 and 25°C (Ammer e Ring, 2013). Relative humidity was set at 50%. The participants were instructed to not perform vigorous physical activities in the preceding 24 hours, to not consume alcohol or caffeine, and to not use skin creams or dermatological ointments.

The participants rested for 15 minutes in the room, without making sudden movements, crossing arms, or scraping the skin, to stabilize the body temperature (Cortê *et al.*, 2019). They were placed in an orthostatic position at a distance of 1.50 meters from the tripod-supported camera. The regions of interest were created by the *FLIR Tools Software*, using two anterior and posterior thermograms, and four rectangular sites in each of the following (Figure 1): anterior right arm (Sp1A), anterior left arm (Sp2A), anterior right forearm (Sp3A), and anterior left forearm (Sp4A); posterior right arm (Sp1P), posterior left arm (Sp2P), posterior right forearm (Sp3P), and posterior left forearm (Sp4P). The following anatomical reference points in the anterior and posterior sides were considered: middle third of the arm and the forearm.

Statistical methods: Results were analyzed using a *Microsoft Excel*® 2013 spreadsheet and the *Bioestat*® software 5.3. Normality of the data was determined by the D'Agostino-Pearson test, and the comparison of the two means was obtained using a paired Student's t-test. Multiple asymmetric distributions were compared by the Kruskall-Wallis analysis of variance method. Data were expressed as mean, standard deviation, 95% confidence interval (CI), or median and percentiles as appropriate, using a significance level of 0.05.

Ethics statement: This study was approved by the Research Ethics Committee of the University of the State of Pará (no. 19346219.0.0000.5174). Participant data were kept confidential and anonymous, in conformity with resolution 466/12 of the National Health Council.

RESULTS

Fourteen BJJ practitioners were included. The practitioners were all male, 13 were right-handed and onewas ambidextrous. The mean age was 36.8 ± 9.9 years [95% CI 31.1 - 42.5] (range: 25 to 59 years), and the mean weight was 96.4 ± 15.7 kg [95% CI 87.3 - 105.4] (range: 75 to 125 kg). Training time ranged from 1 to 28 years, with a mean of 9.6 ± 9.3 years [95% CI 4.2 - 14.9].

Table 1. Statistical analysis of *Disabilities of the Arm, Shoulder and Hand* (DASH) questionnaire in Brazilian Jiu-Jitsu participants

Statistics	Dimension DASH			Total score
	Physical function and symptoms	Practical sports	Ability to work	
Mín. – Max.	0,0 – 27,0	0,0 – 56,0	0,0 – 18,0	0,0 – 83,0
Mediam	4,0	0,0	0,0	10,5
P25 – P75	0,0 – 7,5	0,0 – 19,8	0,0 – 0,0	1,5 – 28,3
p-value*	<0,0001†	0,0057†	0,0003†	0,0024†

*D'Agostino-Pearson Test. †Statistically significant. DASH: *Disabilities of the Arm, Shoulder and Hand.*

Table 2. Bilateral dynamometry of upper limbs of Brazilian Jiu-Jitsu practitioners

Laterality	Mean ± standard deviation [IC95%] Kgf	p – value*
Right	44,0 ± 8,2 [39,3 – 48,7]	0,2402
Left	42,6 ± 7,7 [38,2 – 47,0]	

*Paired Student's t-test. Dynamometry in kilogram-force (kgf).

At least half of the participants had been training for at a minimum of 5.5 years. Among them, 28.6% (04/14) were classified as 'black belt', 28.6% (04/14) as 'white belt', 21.4% (03/14) as 'purple belt', 14.3% (02/14) as 'brown belt', and 7.1% (01/14) as 'blue belt' holders. Among the participants, 35.8% (05/14) were categorized into 'very heavy', 28.6% (04/14) into 'heavy', 21.4% (03/14) into 'medium', and 7.1% each into 'medium heavy' (01/14) and 'light' (01/14) categories. The total score obtained using the DASH questionnaire (functional evaluation) ranged from 0 to 83 points, with a mean of 18.7 ± 23.9 points [95% CI 4.9 – 32.5].

At least 75% of participants achieved a maximum score of 28.3 points. Table 1 shows the other dimensions of the DASH questionnaire. The scores obtained reveal that most of the participants did not have any limitation related to functional activities, symptoms, the practice of sports, or ability to work; as for the overall score, most of the participants had at the most a limitation classified as slight. Table 2 shows the comparison between the means of hand grip strength in the dominant and the non-dominant hands. No statistical difference was observed between these values (p = 0.2402). Figure 2 shows the comparison of the mean values of the thermograms by regions of interest. Except for the comparison between the mean temperatures of the right and left posterior forearms in which the former was significantly higher (p = 0.0205), no other significant differences were found.

DISCUSSION

The present study aimed at evaluating functionality, hand grip strength, and upper limb thermography in BJJ practitioners. We did not find support in the literature for evaluating functionality in BJJ practitioners using the DASH questionnaire. However, we observed that this tool was used in a few studies where BJJ practitioners were part of the study sample. In these studies, the practitioners were investigated for musculoskeletal disorders due to biceps injury (Garcia Júnior *et al*., 2012; Winston *et al.*, 2017).and radio-ulnar joint injury (Kouwenhoven *et al.*, 2013). In the above mentioned studies, the upper limbs were studied as a whole, and thus these studies serve as a basis for the present study. Although this study did not observe differences among scores of the variousdimensions of the DASH questionnaire, a higher frequency of scores representing slight limitations was observed when analyzing the mean of the overall score. This result can be explained by the fact that although upper limb injuries are frequent in BJJ practitioners, they are less severe when compared to lower limb injuries. This observation was also madein a study conducted with 166 BJJ academies in the United States[4]. Another justification for the results relies on the neuromuscular demands of BJJ, where static strength seems to be essential for the upper limbs, while dynamic actions are performed predominantly by the lower limbs (Silva *et al.*, 2014). The biomechanics of the sport in different practice environments also seems to have influence, because in competitions stress factors are applied at higher intensity and speed, while they may be lower in training sessions (Scoggin3rd *et al.*, 2014).

There were no differences in hand grip strength between the dominant and non-dominant hands; the grip strength values were close to those expected for black and white belt holders, who were the majority participants in this study. Grip strength was also evaluated in a study by Costa e Oliveira (2011) who investigated BJJ athletes at the state level by belt classification. The kinetic characteristics of the BJJ require bilateral grip strength, which is essential during sustained manual gripping. This type of gripping is required for exerting maximum force in immobilizations, and for making the required rapid and intense movements essential for dominating the opponent. Oliveira *et al*. (2006).stated that Jiu-Jitsu practitioners develop greater grip strength when the grip is sustained in the right and left hands, as both are necessary for gripping the opponent. A study by Diaz-Lara *et al*. (2014) investigated hand grip strength among international BJJ novice and experienced competitors, and showed that the more experienced practitioners had better neuromuscular adaptations and higher isometric hand grip strength than did the novices. However, within these groups, no differences were observed between the hand grip strength of the right and left hands. However, Andreato *et al*. (2013) stressed that in the course of a BJJ fight there are significant reductions in the hand grip strength, corresponding to mean reductions of 11% and 16% in the right and left hands, respectively, at the end of the fight. Thermographic analysis revealed a significant bilateral increase in mean temperature in the posterior region of the forearm, suggesting tissue overload in the extensor muscles of the wrist and the fingers.

This can be explained by the persistence of high temperature for 24 hours after the end of an activity (Bandeira *et al.*, 2014). The thermograms of these regions of interest may be associated with the specific characteristics of the muscular actions of this sport, which uses static and dynamic hand grip to catch the kimono or the body regions of the opponent while attacking or defending (Jones e Ledford, 2012). Andreato *et al*. (2017b) found that after BJJ fights, athletes reported greater perception of effort and fatigue in the forearm regions. Diaz-Lara *et al*. (2015). Highlighted that during BJJ fights, high-intensity muscular actions are required, with strong concentric and eccentric dynamic contractions of the muscles in the forearm. Follmer *et al*. (2017).stressed that these intense eccentric muscle actions can result in mechanical damage to the sarcomeres of skeletal muscle fibers and can modify biochemical substrates, causing inflammatory responses. Such inflammatory responses generally involve the production of cytokines, immunoglobulins, acute-phase enzymes, and other proteins, in addition to causingleukocytosis (Ide *et al.*, 2019). Increased serum levels of markers such as creatine phosphate kinase (CPK) and lactic dehydrogenase (LDH) are generally observed in muscle damage (Lopes *et al.*, 2019). These events identify possible inflammatory responses which may trigger thermal variations in the posterior region of the forearm, and increase local temperature by increasing blood flow in the affected area and surrounding regions. The limitations of the study are related to the use of a non-probabilistic sample, and that of unmatched training times and competitive levels. We sought to minimize these limitations with methodological rigor while performing the functional, biomechanical, and thermo graphic evaluations.

CONCLUSION

The male participants in this study were right-handed, and had undergone almost ten years of training. Most were black beltor white belt holders, and were included in the 'very heavy' fighting category. Although functional evaluations of the upper limbs did not reveal differences in any of the dimensions of the DASH questionnaire, the mean of the total score showed impairments which can be classified as slight. Hydraulic dynamometry showed no difference between the hand grip strength of the dominant and the non-dominant hands. Thermographic analysis showed a significant bilateral increase in temperature in the posterior regions of the forearms.

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