Muscle Quality Measured by an Electrical Impedance Myography Device: Correlation with Upper Limb Muscle Mass and Strength in Brazilian Jiu-Jitsu Athletes

Original Research

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Abstract

Introduction: Maximum voluntary isometric handgrip strength (MVHIS) is important for Brazilian Jiu-Jitsu (BJJ) techniques. Muscle quality (MQ), assessed using a Skulpt Chisel® device, has demonstrated a correlation between muscle mass and leg strength. This study aimed to identify the correlation between forearm MQ (FMQ) and arm MQ (AMQ) with arm lean mass (ALM) and MVIHS in BJJ practitioners from southeastern Mexico.

Methods: Thirty-two adult male Brazilian Jiu-Jitsu (BJJ) were included. The FMQ and AMQ were assessed using a Skulpt Chisel® device, the ALM with an InBody 570® analyzer, and the MVIHS with a GRIPX EH101 dynamometer. Student's t-test for independent samples and Pearson's correlation coefficient (r) were used to statistical analysis.

Results: Significant difference was observed between ALM of both arms (right 3.87 ± 0.75; left 3.83 ± 0.74 kg; $p = 0.027$); but not between FMQ (right 114.77 ± 10.27; left 115.65 ± 9.15; $p = 0.226$), AMQ (right 119.76 ± 10.98; left 119.24 ± 11.19; $p = 0.315$) and MVIHS (right 44.07 ± 8.9; left 43.25 ± 8.62 kg; $p = 0.183$). Strong and significant correlation ($p < 0.001$) was observed between ALM and MVIHS on the right side ($r = 0.621$; 95% CI = 0.329 to 0.913) and the left side ($r = 0.623$; 95% CI = 0.332 to 0.915). No significant correlations were observed between FMQ or AMQ with ALM or MVIHS.

Conclusions: MQ measurement using Skulpt Chisel® device does not correlate with muscle mass or upper limb strength in BJJ athletes from southeastern Mexico.

Key Words: bioimpedance, muscle quality, handgrip strength, muscle mass.

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Introduction

Brazilian Jiu-Jitsu (BJJ) is a combat sport that originated in Brazil after World War I[1]. It is a sport that has undergone adaptations and modifications, gaining worldwide popularity with the emergence of the Ultimate Fighting Championships (UFC)[2]. Although the number of athletes practicing this sport is increasing, it is already not considered a sport for the Olympic

Games. In Mexico, 1280 BJJ athletes are registered with the Mexican Jiu-Jitsu Federation, and in the State of Yucatan, Mexico, only 116 BJJ athletes are registered[3].

BJJ combat employs various techniques, including grips, projections, transitions, strangulations, and submission grappling, which necessitate the development of both hand strength[4,5]. In this sense, the maximum voluntary isometric handgrip strength (MVIHS) is a simple and inexpensive test for assessing hand muscle strength with high reliability and validit[6,7]. MVIHS can be assessed with portable digital dynamometers, which have a high concordance with the JAMAR hydraulic dynamometer and are considered the gold standard. The assessment of MVIHS is crucial for BJJ athletes, as during most actions in a match, both hands are in contact with the opponent's uniform (*gi*), making a strong grip necessary to execute throwing techniques and groundwork[8].

Combat athletes aim to increase lean mass (LM), primarily composed of skeletal muscle mass (MM), while reducing body fat mass (BF) in order to compete in lower weight classes than their usual body weight. This strategy enhances their relative strength and improves their chances of competitive success[9,10]. The assessment of arm lean mass (ALM) using bioelectrical impedance (BIA) provides athletes and coaches with valuable insights into the effects of training on the upper extremities[11]. BIA is a reliable, double indirect, simple, rapid, and non-invasive method used to estimate the total and segmental body composition by combining these bioelectrical parameters with anthropometric measurements and specific predictive equations[12-14].

Furthermore, muscle quality (MQ) refers to the integration of a muscle's functional and structural characteristics[15]. MQ can be evaluated using electrical impedance myography (EIM), a type of localized bioelectrical impedance analysis (BIA) specifically designed to assess individual muscle groups non-invasively[16,17]. This technique focuses on a small body volume by applying a constant external electric current to the targeted area. EIM quantifies the passive electrical properties of muscle, which vary depending on the physical condition and presence of the disease[18]. Indeed, it has been proposed that EIM can provide valuable information on muscle composition and structure, being mainly used to assess the severity and progression of neuromuscular disorders. However, these measurements are uncommon in athletes[18-20].

In this regard, the Skulpt Chisel® is a relatively new portable EIM device that estimates MQ. The MQ score estimated by this device has correlated with muscle strength-related variables, such as muscle cross-sectional area (CSA) percentage of muscle mass (%MM), and maximum isometric strength; however, its correlation with upper extremity muscle strength in athletes has not been evaluated[21-23]. Identifying fitness indicators associated with specific physical performance measures in BJJ, such as the MVIHS, can support more targeted morphofunctional assessments to optimize training and nutrition programs. For this reason, this study aimed to identify the correlation of forearm MQ (FMQ) and arm MQ (AMQ) measured with the Skulpt Chisel® EIM device with arm lean mass (ALM) and maximum voluntary isometric handgrip strength (MVIHS) in practicing BJJ from Southeastern Mexico.

Methods

Participants

Thirty-two male BJJ athletes (29.28 ± 8.22 yrs, 1.73 ± 0.08 m, 80.48 ± 12.07 kg) were assessed. All subjects were athletes registered in the Mexican Jiu-Jitsu Federation database for the State of Yucatán, Mexico. Participants represented nearly all competitive categories: light feather (64kg, n = 2), feather (70kg, n = 3), light (76kg, n = 8), middle (82.3kg, n = 8), medium heavy (88.3kg, n = 1), heavy (94.3kg, n = 5), super heavy (97.5kg, n = 2), and ultra heavy (no maximum weight, n = 3). The rooster category (<57.5 kg) was the only division not represented in the sample. The combat athletes with at least two years of BJJ experience, training at least three times per week, and for sessions lasting 60 minutes or more, were included. Athletes who were taking medications and/or prohibited supplements according to the World Anti-Doping Agency[24], had prostheses, surgical metal implants, or pacemakers, sustained injuries that prevented them from performing tests, or experienced difficulties maintaining the correct anatomical positions required for the measurements, were excluded.

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Institutional Research Committee of the Universidad Modelo (POS-023/2). Informed consent was obtained from all individual participants included in the study.

Total and Segmental Body Composition Measurements

Height was measured using a stadiometer (SECA model 213), with a precision of 1 mm and a range of 20 to 205 cm, as indicated by the International Society for the Advancement of Kinanthropometry (ISAK) guidelines, and performed by trained personnel[25]. Body weight (BW), BF, visceral fat (VF), MM, body water (BWA), LM, and ALM for both right and left sides were measured with a BIA analyzer (InBody® model 570). This device utilizes an 8-point multifrequency tetrapolar hand-to-foot configuration (5 kHz, 50 kHz, and 500 kHz), with a weight range of 5 to 250 kg and a height range of 95 to 220 cm. The measurements were carried out according to the manufacturer's instructions. Body composition assessments and MVIHS testing were performed under the following indications[26]; all athletes arrived for the measurements tests for the first time in the morning (8:00 – 9:00 h), athletes should not engage in intense physical activity for at least 24 hours before the measurements, they should not consume caffeine or energy drinks 24 hours before, athletes should not drink alcohol, laxatives and/or diuretics in the previous week at the measurements, and athletes must go to the clinic after fasting for 8 hours.

Muscle Quality of the Forearms and Arms Measurements

FMQ and AMQ were measured using an EIM analyzer (Skulpt Chisel®) in both arms and forearms. For measurements, the Skulpt Chisel® was connected via Bluetooth™ to a smartphone for data collection. The evaluator was previously trained using images in the app, which guided the correct anatomical sites for measurements. Water was sprayed onto the muscle area, and the Skulpt Chisel® was placed on the muscle area, ensuring that the electrodes on the back were in contact with the skin of the athletes. Light pressure was applied, and the measurement was recorded on the mobile device. Before taking the measurements for the study, it was necessary to calibrate the device by applying it to other muscles[27]. Measurements of FMQ and MQ were obtained for both the right and left arms, biceps, triceps, and shoulders. AMQ for each side was calculated using the average of the respective measurements. All measurements were performed according to the instructions of the manufacturer[28].

Maximum Voluntary Isometric Handgrip Strength Measurements

Prior to the measurements of MVIHS, the dominant hand of each athlete was recorded. The MVIHS of the right and left arms was measured using a digital handheld dynamometer (GRIPX model EH101), which ranges from 0 to 90 kg. Before testing, the dynamometer opening was adjusted to ensure a comfortable grip for each athlete[29]. In a standing position with the elbow extended, three trials of 5s MVIHS with 1 minute of rest were performed for each hand. During each test, athletes were verbally encouraged to simulate a real fight[30]. The highest value recorded for each test was used for the analysis (Figure 1).

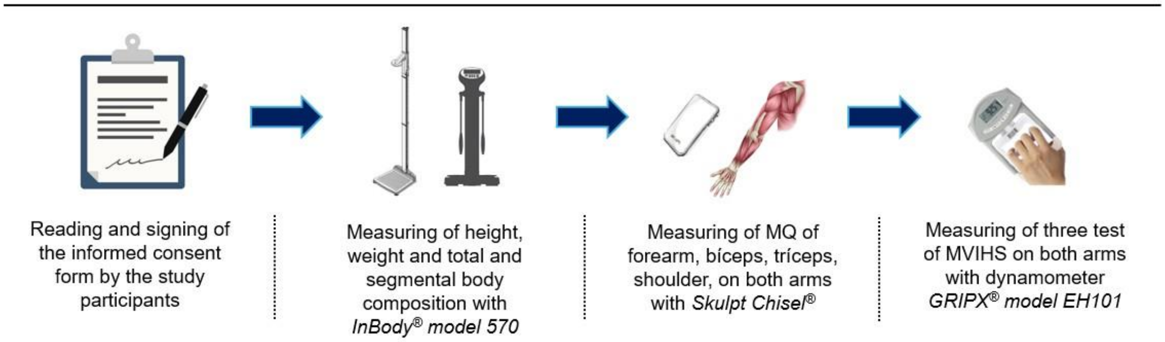

Figure 1. Procedure for the measurements of the study.

Statistical Analysis

The Shapiro-Wilks test was used to assess the normality of the variables. General characteristics and body composition measurements were represented as mean and standard deviation (SD). The Student's t-test for independent samples was used to compare the results for the right and left arms. The correlation of AMQ, FMQ, and ALM with the MVIHS, right and left, was calculated using Pearson´s correlation coefficient test (*r*) and its 95% confidence intervals (95% CI). Correlation values were considered very weak ($0.00 \leq r < 0.10$), weak ($0.10 \leq r < 0.30$), moderate ($0.30 \leq r < 0.50$), strong ($0.50 \leq r < 0.70$), very strong ($0.70 \leq r < 1.00$), and perfect ($r = 1.00$)[31]. Heatmaps were designed to graph correlations between variables. SPSS software version 26 was used for statistical analysis. Values of $p < 0.05$ were considered significant.

Results

According to the body mass index (BMI), the population was classified as overweight; however, the BF percentage values indicated that it was normal, suggesting that the excess weight is attributed to the greater development of LM. Additionally, greater ALM (p = 0.027), AMQ (p = 0.315), and MVIHS (p = 0.183) values were observed on the right side compared to the left. In contrast, a greater value of FMQ (p = 0. 226) was found on the left side than on the right (Table 1). Likewise, 84.4% (n = 27) were right-handed, 12.5% (n = 4) were left-handed, and 3.1% were ambidextrous.

Table 1. Characteristics of participants.

Variables	BJJ athletes (n = 32)	p-value
Age (yrs)		
Height (m)	1.73 ± 0.08	--
Body weight (kg)	80.48 ± 12.07	--
BMI (kg/m^2)	26.01 ± 3.21	--
BF		--
(%)	20.6 ± 6.9	
(Kg)	16.68 ± 6.41	
VF (index)	6.9 ± 2.9	--
MM		--
(%)	45.0 ± 4.2	
(Kg)	36.19 ± 5.99	
BWA		--
(%)	58.3 ± 5.2	
(L)	46.81 ± 7.41	
LM		--
(%)	75.19 ± 6.85	
(Kg)	60.37 ± 9.59	
ALM (Kg)		0.027*
Right	3.87 ± 0.75	
Left	3.83 ± 0.74	
FMQ (Score)		0.226
Right	114.77 ± 10.27	
Left	115.65 ± 9.15	
AMQ (Score)		0.315
Right	119.76 ± 10.98	
Left	119.24 ± 11.19	
MVIHS (Kg)		0.183
Right	44.07 ± 8.9	
Left	43.25 ± 8.62	

Data are Means ± SD. BMI = body mass index; BF = body fat; VF = visceral fat; MM = muscle mass; BWA = body water; LM = lean mass; ALM = arm lean mass; FMQ = forearm muscle quality; AMQ = Arm muscle quality; MVIHS = maximum voluntary isometric handgrip strength. The Student's t-test for independent samples was applied. *Significant difference $p < 0.05$.

The correlations between AMQ, FMQ, and ALM with MVIHS were performed separately for the right and left sides of the body. When we evaluated the right side, we found a strong and significant correlation between ALM and MVIHS (r = 0.621, 95% CI = 0.329 to 0.913; p < 0.001) . In contrast, no significant correlations were observed between FMQ (r = 0.216, 95% CI =-0.148 to 0.580; p = 0235) and AMQ (r =0.248, 95% CI = -0.114 to 0.609; p = 0.172) with MVIHS or ALM (Figure 2A). Similarly, when evaluating the left side, a strong and statistically significant correlation was observed between ALM and MVIHS (r = 0.623, 95% CI = 0.332 to 0.915; p < 0.001). However, no significant correlations were observed between FMQ ($r = 0.257$, 95% CI = -0.104 to 0.617; p = 0.156) and AMQ ($r = 0.332$, 95% CI = -0.019 to 0.684; p = 0.063) with MVIHS again (Figure 2B).

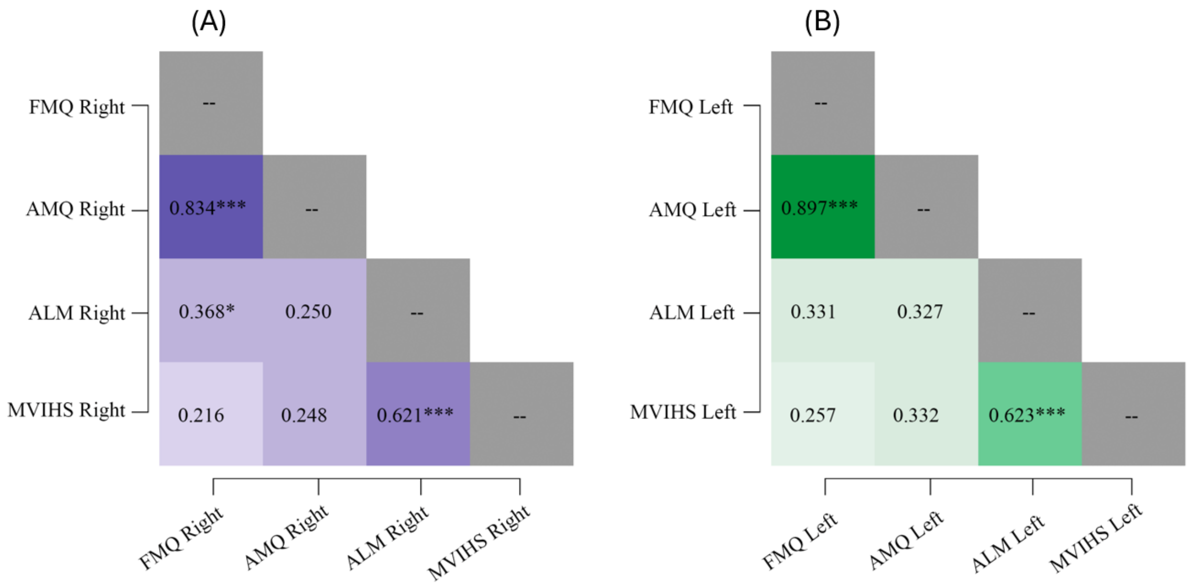

Figure 2. Correlation between variables on the right (A) and left (B) side.***Significant correlation p < 0.001.

Discussion

Brazilian Jiu-Jitsu is an emerging combat sport in the State of Yucatan, Mexico. This highlights the need for studies that enable a better assessment of body composition and physical performance in these athletes[32]. We evaluated the ALM because, although the forearm muscles are primarily responsible for handgrip[33], the upper arm muscles play a crucial role in performance, stances, and throwing techniques in grappling combat sports[34]. A strong positive correlation was observed between ALM and MVIHS on both the right and the left sides. Similarly, Tavares et al.[35] reported a very strong correlation on the right side ($r = 0.94$, $p < 0.01$) and the left side ($r = 0.82$, $p < 0.01$) between ALM and MVIHS in fifteen judokas.

The lower correlation found in our study between ALM and MVIHS can be attributed to the lower accuracy of BIA for estimating ALM. In this sense, the study by Tavares et al.[35] used dual-energy X-ray absorptiometry (DXA) to assess ALM, which is an indirect and more accurate method for evaluating body composition, while our study used an InBody brand BIA analyser[36,37]. Although InBody analyzers have demonstrated reliable performance in assessing body composition, their accuracy can vary between different populations. For instance, in a study involving sixty-six elite male wrestlers (20.6 ± 1.1 yrs), no significant differences were found when measuring ALM with DXA on the right side (p = 0.186) and the left side (p = 0.420)[38]. Lee et al.[39], for their part, found in a sample of 213 older men (64.1 ± 1.3 yrs) using the same InBody model employed by Tavares et al.[35] that it overestimated appendicular LM by 2.2 kg compared to DEXA, with greater differences ($p < 0.001$) in those with BMI ≤ 25 kg/m^2.

Furthermore, differences in the training status of participants may partially explain the lower between ALM and MVIHS observed in our study. While our inclusion criteria allowed for athletes who trained three or more times per week for a minimum of one hour per session, Tavares et al.[35] included state and national-level judokas who trained five times per week for approximately three hours per day. In this sense, Diaz-Lara et al.[40] reported a higher MVIHS in both hands ($p < 0.01$) in experts compared to novice BJJ athletes, demonstrating the relationship between MVIHS and the level of preparation in these subjects. Likewise, the results of the study by AI et al.[41] also support this idea, as they found no correlation between the ALM of the right hand ($r = 0.265$, p = 0.079) and the left hand ($r = 0.284$, p = 0.059), measured with the InBody analyzer; with the MVIHS in a group of thirty untrained young men (19.8 ± 0.83 yrs).

No correlation was observed between AMQ and FMQ with MVIHS in the present study. The MQ was evaluated using the Skulpt Chisel®, a handheld EIM device that estimates MQ through localized EIM and transmits data via

Bluetooth™ to a smartphone interface[42]. MQ is expressed in arbitrary units; higher values are claimed to reflect a greater muscle fiber size and high strength, thus indicating a healthy muscle[28]. In this sense, a few studies have evaluated the validity of this device for estimating musculoskeletal mass size reporting mixed results.

Albano D. et al.[21] found in 140 adult patients (69 male and 71 females; $\bar{x}$ = 52 ± 21 yrs) weak to moderate correlation between the CSA measured by magnetic nuclear resonance (MNR) and MQ values obtained with Skulpt Chisel® in the biceps (r = 0.234, p = 0.006), semimembranosus (r = 0.282, p = 0.001), vastus medialis (r = 0.245, p = 0.003), and sartorius (r = 0.306, p < 0.001); non-significant correlation was observed for the vastus medialis (r = 0.014, p = 0.873). Conversely, another study published by the same research group[27], involving 141 adults (63 males and 78 females; $\bar{x}$ = 57 ± 19 yrs), observed an insignificant correlation (r = 0.082, p = 0.403) between MQ measurements made with the Skulpt chisel® and the skeletal muscle index (SMI = CSA/height^2) obtained by MNR over the lumbar musculature.

Like the study of Albano D. et al. [21], Longo et al.[22] reported a moderate positive correlation (r = 0.37, p < 0.001) between MQ measured using Skulpt Chisel® and CSA of the muscle of quadriceps femoris by ultrasound in a sample of 90 physically active participants (45 males and 45 females; $\bar{x}$ = 22.9 ± 2.9 yrs). Studies seem to indicate that the reliability of the Skulpt Chisel® device in measuring muscle size and quantity may be determined to some extent by the muscle group being assessed.

One of the major limitations of the handheld EIM device is the poor electrical interface between the outer layer of the skin and the metal electrodes, which may introduce signal noise and contact artifacts that compromise the reliability of impedance values[43]. Additionally, surface EIM testing presents limitations related to the specificity of resistance and reactance measurements. These include a lack of anatomical location precision, the influence of non-muscle tissues such as skin and subcutaneous fat, and limited sensitivity to detect muscle changes[44].

This study assessed the FMQ because it encompasses key muscles involved in handgrip strength, including the flexor digitorum superficialis, flexor digitorum profundus, and flexor pollicis longus[32]. In addition, an average of AMQ was obtained by considering the QM measurements of the forearm, biceps, triceps, and shoulders in an effort to approximate a more comprehensive representation of upper limb muscle quality. Considering this, the weak to moderate correlation between FMQ and AMQ with ALM could explain the lack of correlation between FMQ and AMQ with MVIHS in both hands of the participants in our study. Similar findings were observed by Longo et al.[22], who assessed MVIHS through three separate 3-minute knee extension tests and no found no significant correlation between MQ of quadriceps femoris and MVIHS in the overall population (r = 0.29, p = 0.06) nor when analyzed by sex (males: r = –0.15, p = 0.50; females: r = 0.34, p = 0.17). Therefore, based on our results, ALM measured by a high-precision BIA device is a better indicator of MVIHS than the FMQ and AMQ estimated by a handheld surface EIM device in BJJ athletes.

Among the strengths of this study are the standardized protocols used for measurements across different devices and techniques, a sample size that allows for sufficient statistical power, and the evaluation of variables that correlate with athletic success in BJJ athletes. However, the study also has some limitations. These include the heterogeneity of the sample in terms of weight categories, levels of physical preparation, and affiliation with different BJJ academies, which may employ different training methodologies. Additionally, the study's exclusion of women is a limitation, as they were not included due to the limited number currently practicing BJJ in the Yucatan State. Furthermore, the cross-sectional design does not allow for the evaluation of the reliability, validity, or sensitivity of the Skulpt Chisel® device for assessing LM and MM.

Conclusions

In conclusion, this study found that ALM assessment with high precisions BIA analyzer showed a strong and significant correlation with MVIHS in both arms of BJJ athletes from southeastern Mexico. Furthermore, no significant correlations were observed between AMQ and FMQ, estimated using a Skulpt Chisel® EIM device, with MVIHS in either arm.

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Conflict of Interest. The authors declare no conflicts of interest.

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