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Dynamic strength and muscle power in elite and non-elite Brazilian jiu-jitsu (BJJ) athletes: a systematic review with meta-analysis

Fuerza dinámica y potencia muscular en atletas de jiu-jitsu brasileño de élite y no élite: una revisión sistemática con metanálisis

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Abstract. A systematic review with meta-analysis on the dynamic strength and muscle power in elite and non-elite Brazilian jiu-jitsu (BJJ) athletes is essential to provide a comprehensive and quantitative evaluation of the physical attributes critical for performance, allowing for a better understanding of the training needs and physical characteristics that distinguish different levels of athletes in this sport. Therefore, this study endeavors to comprehensively synthesize existing literature on muscle strength and power in the context of BJJ, making a comparative analysis between elite and non-elite athletes. The research was conducted up to April 20, 2022, employing the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol to systematically search electronic databases using the keywords: "Brazilian Jiu-jitsu" or "BJJ" or "Jiu-jitsu" and "power" or "muscle power" or "physical fitness" or "muscle strength" or "strength." Following a rigorous selection process, 26 articles were included in the systematic review. Subsequently, the GRADE (Grading of Recommendations, Assessment, Development, and Evaluations) tool was employed for evidence assessment. The primary assessments of dynamic strength encompassed protocols involving the Bench press, squat, and pull-up-*gi*. In the context of muscle power, the meta-analysis considered parameters such as the countermovement jump (CMJ), standing long jump, and variables derived from jump power assessed on the force platform, including Peak velocity, peak power, mean power, and maximum force. The data showed a substantial effect size for strength [1.012 ($p \leq 0.0001$)] and a moderate effect size for power [0.619 ($p \leq 0.0001$)], indicating superior performance among elite athletes compared to their non-elite counterparts. Although power is predominant in most BJJ actions, strength emerges as a crucial element distinguishing elite from non-elite athletes in this sport. This realization carries significant implications for training and injury prevention, as both strength and power necessitate specialized training to enhance performance in the sport.
Keywords: Physical Fitness, Martial Arts, Sport Physiology, Musculoskeletal and Neural Physiological Phenomena, Judo

Resumen. Una revisión sistemática con meta-análisis sobre la fuerza dinámica y el poder muscular en atletas de jiu-jitsu brasileño (BJJ) élite y no élite es esencial para proporcionar una evaluación completa y cuantitativa de los atributos físicos críticos para el rendimiento, permitiendo una mejor comprensión de las necesidades de entrenamiento y las características físicas que distinguen a los atletas de diferentes niveles en este deporte. Por lo tanto, este estudio pretende sintetizar de manera integral la literatura existente sobre fuerza y potencia muscular en el contexto del Jiu-jitsu brasileño (BJJ), realizando un análisis comparativo entre atletas de élite y no élite. La investigación se realizó hasta el 20 de abril de 2022, empleando el protocolo PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) para buscar sistemáticamente en bases de datos electrónicas utilizando las palabras clave: "Brazilian Jiu-jitsu" o "BJJ" o "Jiu- jitsu" y "potencia" o "potencia muscular" o "aptitud física" o "fuerza muscular" o "fuerza". Tras un riguroso proceso de selección, se incluyeron 26 artículos en la revisión sistemática. Posteriormente, para la evaluación de la evidencia se empleó la herramienta GRADE (Grading of Recommendations, Assessment, Development, and Evaluaciones). Las evaluaciones primarias de la fuerza dinámica abarcaron protocolos que involucraban press de banca, sentadilla y dominadas (gi). En el contexto de la potencia muscular, el metanálisis consideró parámetros como el salto con contramovimiento (CMJ), el salto de longitud de pie y variables derivadas de la potencia del salto evaluadas en la plataforma de fuerza, incluida la velocidad máxima, la potencia máxima, la potencia media y la potencia máxima. fuerza. Los datos mostraron un tamaño de efecto sustancial para la fuerza [1.012 ($p \leq 0.0001$)] y un tamaño de efecto moderado para la potencia [0.619 ($p \leq 0.0001$)], indicando un rendimiento superior entre los atletas de élite en comparación con sus contrapartes no élite. Aunque la potencia predomina en la mayoría de las acciones en BJJ, la fuerza surge como un elemento crucial que distingue a los atletas de élite de los no élite en este deporte. Esta realización tiene implicaciones significativas para el entrenamiento y la prevención de lesiones, ya que tanto la fuerza como la potencia requieren un entrenamiento especializado para mejorar el rendimiento en el deporte.
Palabras clave: Condición Física, Artes Marciales, Fisiología del Deporte, Fenómenos Fisiológicos Musculoesqueléticos y Neurales, Judo.

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Introduction

Brazilian Jiu-jitsu (BJJ), similar to Judo and Olympic Wrestling, is a combat sport known for its grappling techniques, including throws, joint locks, chokes, and immobilizations (Carvalho, Barcellos, et al., 2022; Rufino & Darido, 2012; Dal Bello et al., 2019; Lise & Capraro, 2018). Administered by the International Brazilian Jiu-Jitsu Federation (IBJJF, 2015), BJJ adheres to specific rules, scoring systems, and guidelines for prohibited maneuvers. The sport's technical-tactical and time-motion profile is closely related to the physical fitness of its practitioners, with strength and power identified as critical success factors by esteemed researchers (Andreato et al., 2017; Coswig et al., 2018). Therefore, understanding the differences in these attributes between elite and non-elite athletes is crucial for developing tailored training programs (Norambuena et al., 2021; Santurio & Fernández-Río, 2019), effective injury prevention strategies (Santos et al., 2022; Carvalho, Rego et al., 2022), and talent identification and development. This distinction is not only vital for optimizing performance and aiding athletes in transitioning from non-elite to elite levels but also enhances the scientific understanding and evolution of BJJ (Andreato et al., 2017; Coswig et al., 2018). While there is a recognition of these aspects, a comprehensive meta-analysis is still needed to fully understand the practical implications of differentiating between elite and non-elite athletes. Furthermore, systematic reviews could offer valuable insights into training planning and injury prevention in grappling combats (Carvalho, Rego, et al., 2022; Colonna et al., 2022; Santos et al., 2022).

Grappling combat action cadence reflects the intermittent nature, with high-intensity actions heavily dependent on neuromuscular strength and power (Andreato et al., 2013; Bello et al., 2019; Diaz-Lara, Del Coso, Portillo, et al., 2016). According to Andreato et al. (2013), the cadence of actions during BJJ contests reveals that for every 117 seconds of engagement, four high-intensity (Hi) actions, lasting approximately 3 to 5 seconds, are followed by 25 seconds of low-intensity (Lo) actions, resulting in a Hi: Lo ratio of approximately 1:5 (Andreato et al., 2013). High-intensity actions directly correlate with performance and the neuromuscular component of strength and power in combat sports (Bello et al., 2019; Chaabene et al., 2014; Diaz-Lara, Del Coso, Portillo, et al., 2016; James et al., 2017). The Alactic Anaerobic System (ATP-CP) plays a key role in these short, decisive high-intensity movements, highlighting the importance of muscle power and its varied use by elite and non-elite athletes (Andreato et al., 2013). While analyzing the energy pathways during BJJ matches lasting 5-10 minutes, it becomes apparent that the ATP-CP system is not the predominant energy pathway in this sport (da Silva et al., 2014; Diaz-Lara, Del Coso, Garcia, et al., 2016; Øvretveit, 2019). However, the Alactic Anaerobic System plays a crucial role in high-intensity, short-duration movements, typically employed during pivotal moments in BJJ (Follmer et al., 2021; Villar et al., 2018). Differentiating strength and power in elite and non-elite BJJ athletes is key for creating specific training programs tailored to their respective needs, enhancing performance and efficiency in energy system utilization (Follmer et al., 2021; Villar et al., 2018). This distinction aids in targeted injury prevention strategies and provides essential insights for non-elite athletes aspiring to reach elite levels (Guillen Pereira et al., 2018. Moreover, it enriches the overall scientific understanding of the sport, offering practical guidance for performance improvement in BJJ.

The current literature on strength and power in Brazilian Jiu-Jitsu (BJJ) primarily focuses on common field tests like the medicine ball throw and various jump tests for assessing power, offering valuable yet somewhat limited insights (da Silva et al., 2014; Øvretveit & Tøien, 2018). These field tests offer accessibility and practicality, rendering them invaluable tools for efficient and cost-effective research (Silva et al., 2014). Gathering insights about the neuromuscular aspects of BJJ athletes assumes paramount importance, as muscular strength and power, within the context of combat, can be the decisive factors determining victory (Diaz-Lara, Del Coso, Portillo, et al., 2016) and establishing guidelines for enhancing competitive performance (Detanico et al., 2017; Jones & Ledford, 2012). However, there appears to be a gap in comprehensive, systematic reviews and meta-analysis that collate and analyze data specifically comparing the neuromuscular attributes of strength and power between elite and non-elite BJJ athletes. This type of research could fill that gap by integrating various studies to provide a more holistic understanding of how these physical attributes vary across different competitive levels. Such a review would be original in its approach to synthesizing existing data, thereby offering a more nuanced perspective on the specific training needs and performance capabilities of elite versus non-elite athletes in BJJ.

Considering the need for clear information, this study, focusing on dynamic strength and muscle power in elite and non-elite BJJ athletes, hypothesizes that a systematic review coupled with a meta-analysis will reveal significant differences in strength and power between these two groups. This research could provide critical benchmarks for training periodization applicable to both elite and non-elite athletes (Amtmann, 2012; Andreato et al., 2013; Del Vecchio et al., 2007). Thus, the primary objective is to comprehensively review and quantitatively analyze the variations in muscle strength and power between elite and non-elite BJJ athletes, offering insights that can significantly impact training methodologies and athlete development.

Methods

Study Design

This research employs an exploratory, descriptive documentary approach to assess the differences in dynamic maximum strength and power between elite and non-elite Brazilian Jiu-Jitsu (BJJ) athletes. The methodology includes a comprehensive, PRISMA-guided search across multiple databases such as SciELO, PubMed, BVS, and EBSCOhost, coupled with clearly defined inclusion and exclusion criteria to ensure relevant study selection and minimize bias. The quality of evidence is rigorously evaluated using the GRADE protocol, which accounts for study design, risk of bias, and inconsistencies. Key stages of the research protocol involve systematic extraction and synthesis of data, including detailed analysis of study characteristics, participant profiles, assessment protocols, and significant findings related to strength and power in BJJ. Finally, a meta-analysis conducted using the Comprehensive Meta-Analysis Version 2.0 software quantitatively assesses the effect sizes of dynamic strength and power, providing a robust and unbiased comparison between elite and non-elite athletes. This methodical approach, including the elimination of duplicates and meticulous screening and review of articles, ensures a comprehensive and reliable understanding of the neuromuscular attributes in different levels of BJJ athletes.

Criteria for Inclusion of Studies in this Systematic Review and Meta-Analysis

Inclusion criteria encompassed studies written in English, Portuguese, and Spanish, up to May 2022. Exclusion criteria consisted of: I) studies analyzing athletes from sports other than Jiu-Jitsu within the evaluated group without specifying tests for each modality; II) investigations primarily focused on adolescent or female populations; and III) works that did not provide numerical data.

Search Strategy

This systematic review exclusively considered cross-sectional observational studies evaluating muscle power and dynamic muscle strength in BJJ practitioners. Selected studies contained data related to the results of maximal dynamic strength or power assessments. For the subsequent meta-analysis phase, data were categorized into two groups: elite and non-elite, based on criteria established by Del Vecchio et al. (2014) and Diaz-Lara et al. (2014). In this context, elite athletes were defined as those holding purple, brown, and black belts, while non-elite athletes comprised white and blue belt holders.

The search process extended until April 20, 2022, on a single-researcher task and was conducted across various databases, including SciELO, PubMed, BVS - virtual health library (covering LILACS, Medline, and IBECS bases), and EBSCOhost (encompassing Sportdiscus, CINAHL, and Medline databases). Key search terms employed were "Brazilian Jiu-jitsu," "physical fitness," "muscle power," and "muscle strength." References retrieved from these databases were compiled and imported into the Excel 2018 program (Microsoft, Washington, USA).

Article selection adhered to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Liberati et al., 2009; Rethlefsen et al., 2021). Figure 1 presents the flowchart outlining the search and selection process for the review and meta-analysis.

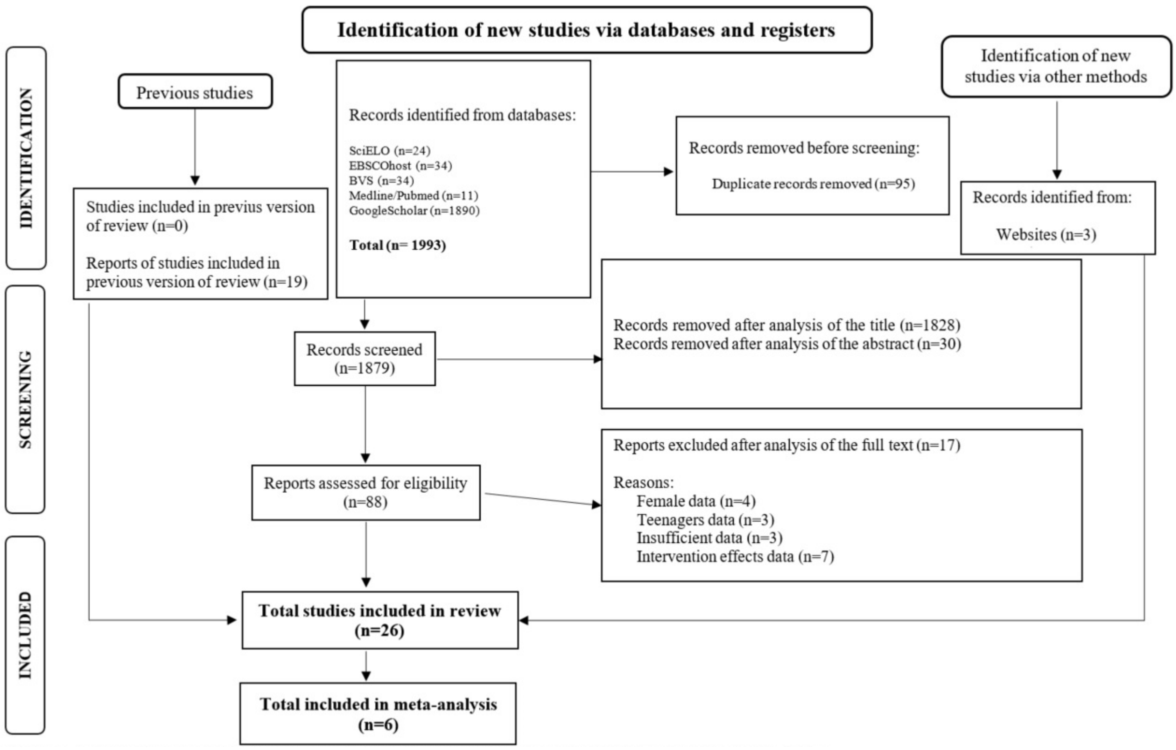

Figure 1. PRISMA flow diagram for study selection from dynamic strength and power test elite and non-elite BJJ athletes

Initially, a total of 1,974 articles were identified using the specified keywords across online databases. Subsequently, 95 duplicate articles were eliminated before screening. Afterward, 1,828 articles were manually excluded based on their titles, as they indicated populations from different combat sports, female athletes, or did not involve assessments of muscle power or dynamic strength. Among the remaining 51 articles, 30 were excluded following the abstract review, either due to supplementation content or because they pertained to different sports, leaving 21 articles eligible for the subsequent phase. Following a comprehensive examination of full-text articles, 17 studies were excluded for dealing with female data, evaluating adolescents, lacking numerical data presentation, or featuring data associated with training methodologies.

Consequently, 23 articles were retained for systematic review. Additionally, three more studies identified through alternative sources were included, resulting in a total of 26 studies for the systematic review. For the subsequent meta-analysis, three studies were selected, providing twelve comparative datasets for analysis. The primary aim of the meta-analysis was to compare performance in dynamic strength and muscle power tests between elite and non-elite athletes.

Criteria for Data Analysis and Selection

The quality of evidence was assessed using the GRADE - Grading of Recommendations, Assessment, Development, and Evaluations protocol (Atkins et al., 2004). The protocol comprises four levels of evidence qualification, namely:

- ✓ Very low: The evidence possesses minimal confidence in the effect estimate, implying that the effect size may significantly deviate from the estimate.
- ✓ Low: Confidence in the effect estimate is limited, suggesting that the true effect may considerably differ from the estimate.
- ✓ Moderate: The evidence indicates moderate confidence in the effect estimate, suggesting that the true effect is likely to be close to the estimate, although significant differences are possible.
- ✓ High: The degree of confidence that the true effect aligns closely with the effect estimate is high.

The assessment of evidence levels considers various factors, including study design, methodological limitations (risk of bias), inconsistency, indirect evidence, imprecision, publication bias, large effect magnitude, dose-response gradient, and potential confounding factors (Atkins et al., 2004).

Quantitative Meta-Analysis

Quantitative data analysis was executed using the Comprehensive Meta-Analysis Version 2.0 program. This analysis involved selected studies with a subgroup of tests used for strength or power assessment. Data were presented as sample number (N), mean (M), standard deviation (SD), and the calculation of the 95% confidence interval for the difference (CI) in tests between elite and non-elite athletes, as reported by each study. The relative weights of differences between means and effect sizes (difference between means) were summarized in forest plots.

A standardized mean model was applied for the meta-analysis, accommodating different tests of the respective physical capacities within the same analysis. Heterogeneity of effect sizes across studies was assessed using inconsistency (I2), classified as follows: <25% considered low, <50% intermediate, and <75% high (indicating questionable use of meta-analysis for evidence). The significance criterion applied was $p \leq 0.05$.

Results

Table 1 shows the result of the GRADE analysis. Table 2 shows the dynamic force data included in the systematic review of BJJ power and strength measures. Table 3 shows muscle power data included in the systematic review of BJJ power and strength measures. Table 4 shows data from dynamic strength tests included in the meta-analysis.

Table 1.
Evidence qualification data by using the GRADE protocol.

Study	Study design	Risk of bias	Inconsistency	Indirect evidence	Imprecision	Other considerations Assessment	Assesment
Nascimento (2011)	observational	not severe	not severe	not severe	not severe	None	Low
Neto & Dechechi (2010)	observational	not severe	not severe	not severe	not severe	None	Low
Diaz-Lara, et al. (2016)	observational	not severe	not severe	not severe	not severe	None	High
Andreato, et al. (2015)	observational	not severe	not severe	not severe	not severe	None	Low
Diaz-Lara, et al. (2015)	observational	not severe	not severe	not severe	not severe	None	Low
Diaz-Lara, et al. (2014)	observational	not severe	not severe	not severe	not severe	None	Low
Corrêa Da Silva, et al. (2014)	observational	not severe	not severe	not severe	not severe	None	Low
Detanico, et al. (2017)	observational	not severe	not severe	not severe	not severe	None	Low
Ribeiro, et al. (2015)	observational	not severe	not severe	not severe	not severe	None	Low
Pietraszewska, et al. (2014)	observational	not severe	not severe	not severe	not severe	None	Low
Coswig, et al. (2011)	observational	not severe	not severe	not severe	not severe	None	Low
Coswig, et al. (2018)	observational	not severe	not severe	not severe	not severe	None	Low
Detanico, et al. (2021)	observational	not severe	not severe	not severe	not severe	None	Low
Marinho, et al. (2016)	observational	not severe	not severe	not severe	not severe	None	Low
Del Vecchio, et al. (2007)	observational	not severe	not severe	not severe	not severe	None	Low
Fernandes, et al. (2010)	observational	not severe	not severe	not severe	not severe	None	Low
Lourenço-lima, et al. (2020)	observational	not severe	not severe	not severe	not severe	None	Low
Leitão da Silva (2015)	observational	not severe	not severe	not severe	not severe	None	Low
Costa, et al. (2009)	observational	not severe	not severe	not severe	not severe	None	Low
Rigatto (2008)	observational	not severe	not severe	not severe	not severe	None	Low
Øvretveit K. (2020)	observational	not severe	not severe	not severe	not severe	None	Low
Corrêa Da Silva, et al. (2015)	observational	not severe	not severe	not severe	not severe	None	Low
Kons, et al. (2017)	observational	not severe	not severe	not severe	not severe	None	Low
Andreato, et al. (2022)	observational	not severe	not severe	not severe	not severe	None	Low
Corrêa Da Silva, et al. (2014)	observational	not severe	not severe	not severe	not severe	None	Low
Corrêa Da Silva (2012)	observational	not severe	not severe	not severe	not severe	None	Low

Table 2.
Dynamic force data included in the BJJ systematic review, absolute and relative one RM in M±SD.

Study	n	Group (n)	Type of Exercise	Absolute 1RM (kg)	Relative 1RM (kg/body mass)
Marinho, et al. (2016)	18	High-level athletes (8)	Flat bench press	111±6	1.46±0.13
		State-level athletes (10)		98±6	1.36±0.11
Diaz-Lara, et al. (2016)	14	High-level athletes	Flat bench press	90.5± 7.7	1.27±0.27

Leitão da Silva (2015)	5	High-level athletes- Brown and black belt Intermediate level athletes	Flat bench press	115±16 101±13	1.48±0.15 1.32±0.14
Silva, et al. (2014)	23	High-level athletes- blue to black belt	Flat bench press	103.4±22.9	1.3±0.2
Costa, et al. (2009)	20	State-level athletes	Flat bench press	85.8±17.8	NR
Rigatto (2008)	12	(CG) State-level athletes purple to black belt (5) (TG) State-level athletes purple to black belt (7)	Flat bench press	94±24 87±31	NR
Lourenço-Lima, et al. (2020)	8	Non-experienced	Flat bench press	82±22.37	NR
Øvretveit, et al. (2020)	42	Adult athletes with practice time (5.5±3.7 years)	Flat bench press	87.6±16.5	NR
Corrêa da Silva, et al. (2015)	28	Advanced Not advanced	Flat bench press	116±16 101±13	NR
Del Vecchio, et al. (2007)	11	High-level athletes (7)	Flat bench press	109±18	1.39±0.26
Marinho, et al. (2016)	18	High-level athletes (8) State-level athletes (10)	Back squat	91±8 88±7	1.20±0.13 1.23±0.13
Del Vecchio, et al. (2007)	11	High-level athletes (7)	Back squat	110±15	1.38±0.19
Lourenço-Lima, et al. (2020)	8	Non-experienced	Back squat	82±22.37	NR
Øvretveit, et al. (2020)	42	Adult athletes with practice time (5.5±3.7 years) (CG) State-level athletes purple to black belt (5)	Back squat	113.2±20.4 90±18	NR
Rigatto (2008)	12	(TG) State-level athletes purple to black belt (7)	Open Pull	86±15	NR
Rigatto (2008)	12	(CG) State-level athletes purple to black belt (5) (TG) State-level athletes purple to black belt (7)	Dumbbell Press	56±17 57±22	NR
Rigatto (2008)	12	(CG) State-level athletes purple to black belt (5) (TG) State-level athletes purple to black belt (7)	Biceps curls	91±25 52±29	NR
Rigatto (2008)	12	(CG) State-level athletes purple to black belt (5) (TG) State-level athletes purple to black belt (7)	Triceps pulley	114±28 64±41	NR
Del Vecchio, et al. (2007)	11	High-level athletes (7)	Deadlift	138±24	0.72±0.31
Del Vecchio, et al. (2007)	11	High-level athletes (11)	Leg press	308±88	NR
Fernandes, et al. (2010)	11	High-level athletes (11)	Leg press	307.72±87.7	NR
Corrêa da Silva, et al. (2014)	28	Experienced (14) Beginner (14)	Pull-up with *judogi*	10.1±3.0 8.4±3.2	NR
Corrêa da Silva, et al. (2012)	20	Elite (10) Non-Elite (10)	Pull-up with *judogi*	15±4 8±3	NR

Note. NR - not reported; RM - repetition maximun; M – mean; SD - standard deviation; CG – Control group; TG – training group.

Table 3.
Muscle power data included in the BJJ systematic review, results in M±SD.

Study	n	Group (n)	Test	Results
Nascimento et al. (2011)	10	State-level athletes	Medicine Ball Throwing (cm)	428±33
Neto and Dechechi (2010)	5	State-level athletes - white and blue belt	Medicine Ball Throwing (cm)	380±48
Coswig et al. (2018)	24	Purple, brown and black belt athletes	Medicine Ball Throwing (cm)	430±110
Nascimento et al. (2011)	10	State-level athletes	Horizontal jump (cm)	237±23
Neto and Dechechi (2010)	5	State-level athletes - white and blue belt	Horizontal jump (cm)	237±23
Pietraszewska et al. (2014)	49	High-level athletes	Horizontal jump (cm)	234±22
Coswig et al. (2011)	14	Beginner athletes - white and blue belts (7) Experienced Athletes - Purple, Brown and Black Belts (7)	Horizontal jump (cm)	225±25 226±12
Coswig et al. (2018)	24	Purple, brown and black belt athletes	Horizontal jump (cm)	225.9 ±23.5
Coswig et al. (2018)	24	Purple, brown and black belt athletes	Sargent Jump Test (cm)	46.5±7.7
Detanico et al. (2021)	20	White and blue belt athletes	Sargent Jump Test (cm)	37.8±5.84
Andreato et al. (2015)	10	State-level athletes - brown and black belt	Countermovement jump (cm)	41.6±6
Diaz-Lara et al. (2016)	14	High-level athletes	Countermovement jump (cm)	40.6±2.6
Diaz-Lara et al. (2014)	56	Beginners - white and blue belt (24) Experts - purple to black belt (32)	Countermovement jump (cm)	29.7±5.0 34.2±5.1
Diaz-Lara et al. (2015)	26	Experienced athletes(26)	Countermovement jump (cm)	34.0±5.2
Kons et al. (2017)	28	Beginner athletes (20) Experienced athletes (8)	Countermovement jump (cm)	43.25±7.00 48.25±2.90
Silva et al. (2014)	23	State-level athletes - blue belt to black belts	Countermovement jump (cm)	40.8±5.5
Ribeiro et al. (2015)	9	State-level athletes	Countermovement jump (cm)	39.9±8.1
Andreato et al. (2021)	12	NR	Countermovement jump (cm)	41.5±10.0
Andreato et al. (2021)	12	NR	Plyometric push-up (cm)	15.7±1.9
Andreato et al. (2021)	12	NR	Squat jump (cm)	37.8±7.4
Detanico et al. (2021)	20	White and blue belt athletes	Countermevement jump(W/kg)	23.2±3.6
Detanico et al. (2021)	20	White and blue belt athletes	*Sargent Jump Test* (W/kg)	19.0±2.4
Detanico et al. (2021)	20	White and blue belt athletes	Countermovement jump (cm)	38.5±4.1
Kons et al. (2017)	28	Beginner athletes (20) Experienced athletes (8)	Maximun force (N/kg)	22.99±2.06 26.22±2.41
Kons et al. (2017)	28	Beginner athletes (20) Experienced athletes (8)	Average power (W/kg)	27.32±3.80 29.93±2.51
Kons et al. (2017)	28	Beginner athletes (20) Experienced athletes (8)	Peak power (W/kg)	49.32±5.70 51.88±3.75
Kons et al. (2017)	28	Beginner athletes (20) Experienced athletes (8)	Peak velocity (m/s)	2.56±0.27 2.87±0.14

Note. NR = not reported

Table 4.
Results of dynamic strength BJJ tests included in the meta-analysis.

		Non-elite			Elite									
Study	Test	n	Mean	SD	n	Mean	SD	DOE	SMD	SE	Hedge's g	SE	MD	SE
Marinho et al. (2016)	Absolute 1RM Back squat	10	88	7	8	91	8	Positive	0.4	0.48	0.38	0.46	3	3.54
Marinho et al. (2016)	Absolute 1RM Flat Bench press	10	98	6	8	111	6	Positive	2.17	0.6	2.06	0.57	13	2.85
Marinho et al. (2016)	Relative 1RM Flat Bench press	10	1.36	0.11	8	1.46	0.13	Positive	0.84	0.49	0.8	0.47	0.1	0.06
Silva et al. (2014)	Pull-up with *judogi*	14	8.4	3.2	14	10.1	3	Positive	0.55	0.38	0.53	0.37	1.7	1.17
Silva et al. (2012)	Pull-up with *judogi*	10	8	3	10	15	4	Positive	1.98	0.55	1.9	0.52	7	1.58

Note. RM - repetition maximun; SD - standard deviation; SDM - standard difference in the means; SE - Standard error; MD - mean difference.

The meta-analysis evaluated the tests of squat, straight supine, barbell with kimono, comparing the results between elite and non-elite groups of studies. The data exposed a significant difference in the performance of elite athletes, which suggests that the competitive level influences the performance of athletes regarding dynamic strength (Silva et al., 2014; Silva et al., 2014; Marinho et al., 2016). Table 5 displays data from muscular power BJJ tests included in the meta-analysis.

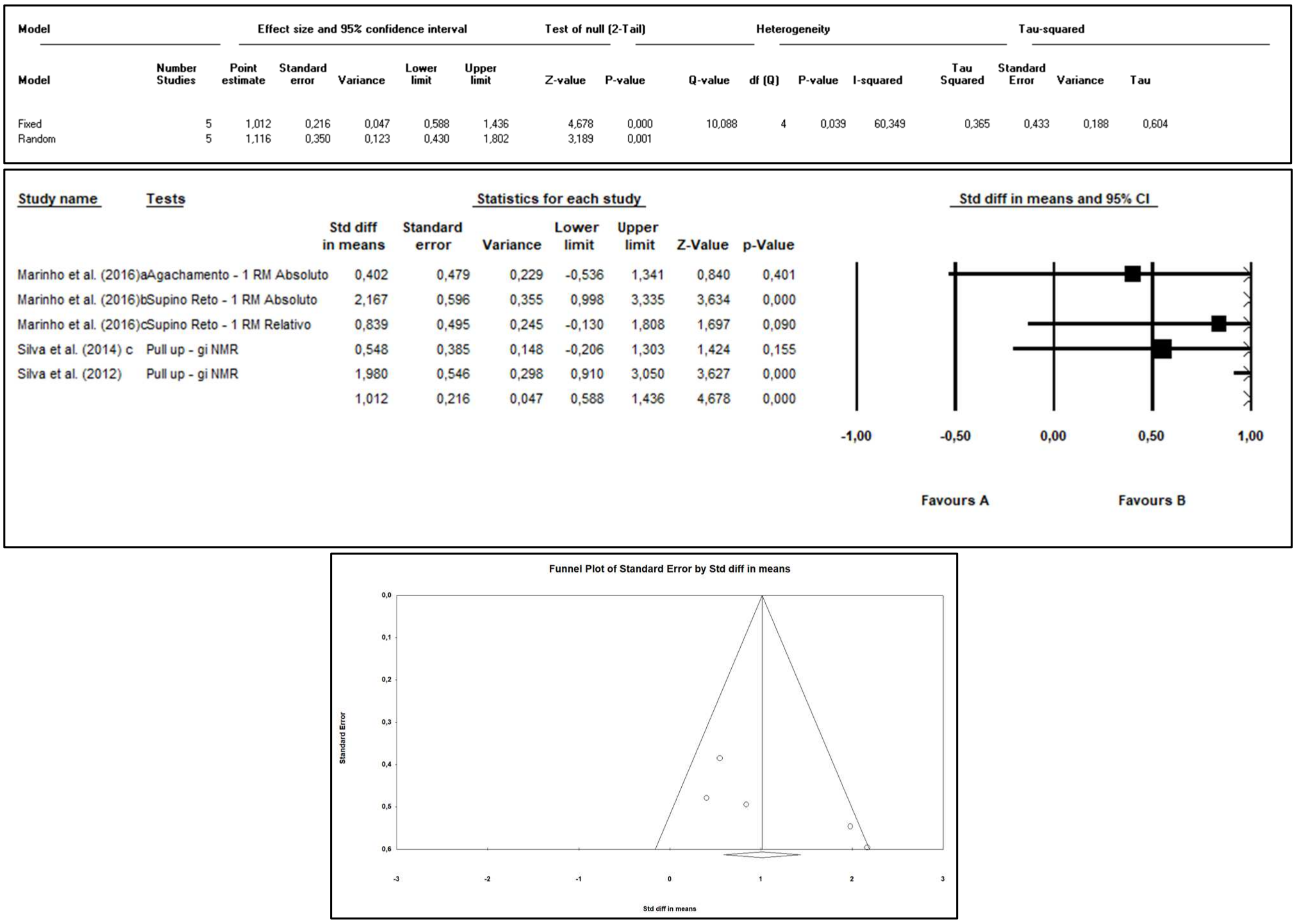

Figure 2. Meta-analysis and Funnel Plot of Standard Error results for the measures of dynamic strength in BJJ studies.

Table 5.
Results of the meta-analysis on muscle power in BJJ athletes.

		Non-elite			Elite									
Study	Test	n	Mean	SD	n	Mean	SD	DOE	SMD	SE	Hedge's g	SE	MD	SE
Diaz-Lara et al. (2014)	CMJ (cm)	24	29.7	5	32	34.2	5.1	Positive	0.89	0.28	0.88	0.28	4.5	1.37
Coswig et al. (2011)	HJ (cm)	7	225	25	7	226	12	Positive	0.05	0.53	0.05	0.5	1	10.5
Kons et al. (2017)	CMJ (cm)	12	43.25	7	8	48.44	4.76	Positive	0.83	0.48	0.8	0.46	5.19	2.84
Kons et al. (2017)	Maximun force (N/kg)	12	22.9	7	8	24.09	2.97	Positive	0.21	0.46	0.2	0.44	1.19	2.64
Kons et al. (2017)	Average power (W/kg)	12	27.32	3.8	8	28.62	2.3	Positive	0.39	0.46	0.38	0.44	1.3	1.51
Kons et al. (2017)	Peak power (W/kg)	12	49.32	5.7	8	51.87	3.54	Positive	0.51	0.46	0.49	0.44	2.55	2.27
Kons et al. (2017)	Peak velocity (m/s)	12	2.56	0.27	8	2.76	0.13	Positive	0.88	0.48	0.85	0.46	0.2	0.1

Note. CMJ - countermovement jump; HJ - horizontal jump; SD - standard deviation; SDM - standard difference in the means; SE - Standard error; MD - mean difference.

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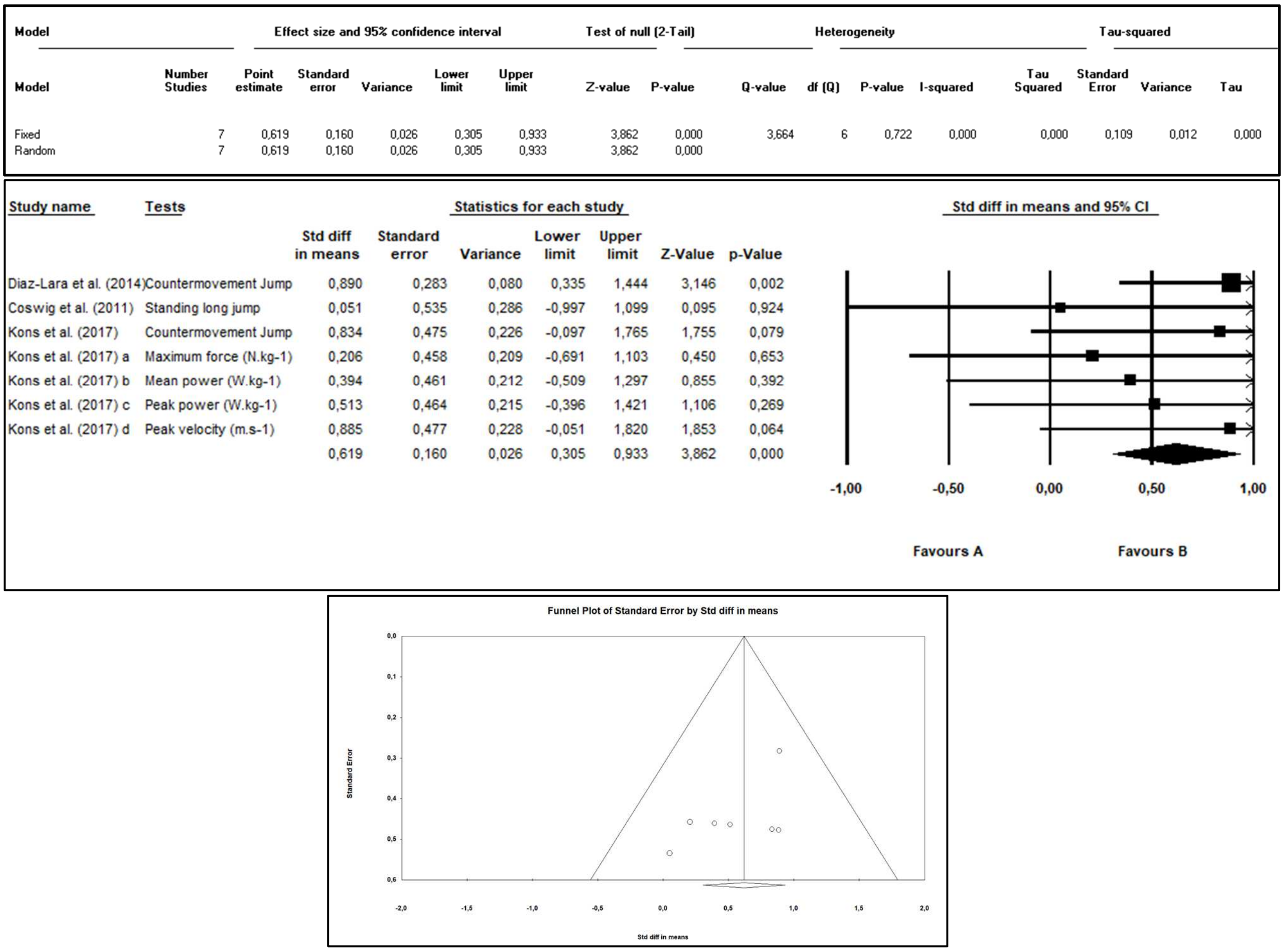
The meta-analysis evaluated the tests of countermovement, horizontal jump, and the data regarding jumping tests using a force platform, comparing the results between elite and non-elite groups of the studies. The data exposed a significant difference in the performance of elite athletes, suggesting that the competitive level influences athletes' performance regarding muscle power.



Model	Number Studies	Point estimate	Standard error	Variance	Lower limit	Upper limit	Z-value	P-value	Q-value	df (Q)	P-value	I-squared	Tau Squared	Standard Error	Variance	Tau
	Effect size and 95% confidence interval						Test of null (2-Tail)		Heterogeneity				Tau-squared			
Fixed	7	0,619	0,160	0,026	0,305	0,933	3,862	0,000	3,664	6	0,722	0,000	0,000	0,109	0,012	0,000
Random	7	0,619	0,160	0,026	0,305	0,933	3,862	0,000								

Study name	Tests	Std diff in means	Standard error	Variance	Lower limit	Upper limit	Z-Value	p-Value
Diaz-Lara et al. (2014)	Countermovement Jump	0,890	0,283	0,080	0,335	1,444	3,146	0,002
Coswig et al. (2011)	Standing long jump	0,051	0,535	0,286	-0,997	1,099	0,095	0,924
Kons et al. (2017)	Countermovement Jump	0,834	0,475	0,226	-0,097	1,765	1,755	0,079
Kons et al. (2017) a	Maximum force (N.kg-1)	0,206	0,458	0,209	-0,691	1,103	0,450	0,653
Kons et al. (2017) b	Mean power (W.kg-1)	0,394	0,461	0,212	-0,509	1,297	0,855	0,392
Kons et al. (2017) c	Peak power (W.kg-1)	0,513	0,464	0,215	-0,396	1,421	1,106	0,269
Kons et al. (2017) d	Peak velocity (m.s-1)	0,885	0,477	0,228	-0,051	1,820	1,853	0,064
		0,619	0,160	0,026	0,305	0,933	3,862	0,000

Figure 3. Meta-analysis and funnel plot of standard errors for the measures of muscular power in BJJ studies.

Discussion

This study aimed to systematically review and perform a meta-analysis on the differences in validated strength and power tests between elite and non-elite BJJ athletes. The main findings indicated a significant effect size, with 0.706 for power tests and 0.882 for strength tests, highlighting notable disparities between the two groups. Despite the GRADE tool assessing the quality of evidence as low, with only 5% high certainty, the meta-analysis still revealed meaningful differences in these physical attributes, accompanied by a moderate inconsistency (i^2) for both strength and power assessments. This suggests a strong association between physical fitness, specifically strength and power, and competitive levels in BJJ. The importance of strength, as measured by 1RM (one-repetition maximum) and absolute 1RM tests, is particularly emphasized as these metrics are closely associated with combat performance. They provide a direct measure of an athlete's maximum strength capacity, which is a critical determinant in BJJ where forceful (i.e., gripping, side control, mounting, submissions, locks and chokes) and powerful movements (i.e. Projections, transitions, rapid movements) are essential for success (Santos et al., 2023). In conclusion, the study's findings highlight the crucial role of strength and power in distinguishing between different competitive levels in BJJ, offering valuable insights for training and athlete development.

In our systematic review, we observed that studies evaluating strength in BJJ employed various protocols, with the flat bench press being the most frequently utilized measure (Silva et al., 2015; Øvretveit, 2020; Øvretveit & Tøien, 2018). Less commonly, dynamic strength assessments such as leg press 45°, squat, and biceps curl were employed (Del Vecchio et al., 2007). Additionally, previous investigations evaluated dynamic strength through the application of 1RM and absolute 1RM tests, which are closely linked to combat performance (Campos et al., 2022; da Silva Junior et al., 2022; Lima et al., 2017). In contrast, common measurement protocols for power included countermovement jump, standing long jump, medicine ball throw, and vertical jump (Coswig et al., 2018; Detanico et al., 2021). Nevertheless, while these studies emphasize the significance of absolute strength and power, future research should consider the sesx dimension (Brandt et al., 2021; Santos et al., 2022) and the athlete's body mass since performance is intrinsically linked to an athlete's body mass, particularly within the context of the eight official weight divisions stipulated by the IBJJF (2015).

In our current investigation, the mean effect sizes for muscle power and strength tests exhibited a substantial effect size for strength and a moderate effect size for power. This underscores the importance of incorporating strength-focused training into BJJ athlete regimens, especially as they progress through their ranks. For comparison, previous research on Judo athletes employed tests such as vertical jump, horizontal jump, and medicine ball throw (Andreato et al., 2016; Drid et al., 2015; Franchini et al., 2011). Elite Judo athletes demonstrated superior performance in vertical and horizontal jumps compared to BJJ athletes, indicating the sport-specific demands for power generation (Coswig et al., 2015; Drid et al., 2015; Stachoń et al., 2015).

Concerning power tests, elite Judo athletes also exhibited impressive performance in the 5 kg medicine ball throw, highlighting the significance of upper limb power in grappling sports, which is crucial for executing high-intensity actions in Jiu-jitsu (Coswig et al., 2018). Thus, enhancing power becomes indispensable for scoring points and achieving high-performance levels in BJJ.

When it comes to strength assessment, studies like the one by Franchini et al. (2011) proposed dynamic and isometric strength tests, specifically in suspension on a fixed bar while holding the kimono. This innovative approach enabled differentiation between regional athletes and those in the Brazilian national team, emphasizing the utility of strength assessment methods in gauging an athlete's capacity to generate dynamic force. These test outcomes could provide valuable insights for guiding individualized training plans and tracking each athlete's progress within their respective competitive levels (Coswig et al., 2018). Furthermore, normative tables developed by Branco et al. (2017) for judokas classified results in dynamic and isometric tests, offering specific benchmarks for excellence in these strength assessments.

Nonetheless, it is essential to note that the present study encountered challenges due to the limited number of published BJJ studies addressing strength and power. As a result, the sampled studies in this review covered a range of athlete characterizations, including state-level, high-level, novice, expert, beginner, and experienced athletes (Andreato et al., 2017). Such diversity in classifications, along with variations in inclusion and exclusion criteria across studies, contributed to the overall low quality of evidence, as indicated by the GRADE protocol. Importantly, no selected study exhibited a high risk of bias, though the reliability classification remained low. In terms of evidence reliability, GRADE emphasizes the need for randomized clinical trials to attain high reliability scores. Implementing GRADE in BJJ studies is pivotal for enhancing the overall quality of research in the field (Atkins et al., 2004).

Regarding methods, the decision to focus on general terms like "muscle power" and "strength" in the study, rather than including specific metrics such as "peak torque", "torque", "rate of force/torque development", "maximal strength", and "rapid strength", likely stems from several considerations. Firstly, the study's objectives had centered on broader concepts of muscle power and strength due to their direct relevance to BJJ performance. These terms are often more uniformly defined and measured, facilitating comparative analysis in a systematic review. Additionally, the choice reflected the availability of data in existing literature; terms like "peak torque" had less consistent data across BJJ studies, complicating data synthesis. The study's scope is also a factor; focusing on a narrower set of variables enables a more in-depth and manageable analysis.

Significant information such as belt, tests used, sample size, and the results of each study's evaluations in the systematic review can be observed in Tables 2 and 3. The current research classified elite athletes as those with more experience, described in the article as holding purple, brown, and black belts, while less experienced athletes were considered non-elite. Some studies do not include this information in their classification, which is a limitation. Concerning the exclusion of studies with female athletes from the analysis in research on muscle strength and power in BJJ stem from several considerations. Primarily, physiological differences between males and females, particularly in muscle mass and strength, could introduce significant variability that might confound the results. Focusing on a more homogeneous group, in this case, male athletes, helps in reducing data variability for more precise conclusions. Additionally, the decision was influenced by the limited availability of studies focusing on female BJJ athletes in this context. In addition to these challenges, a significant limitation observed in the present study relates to discrepancies in participant recruitment and selection criteria. Variability in terminology and groupings was evident. For instance, some studies included specific training volume requirements, such as three months of uninterrupted training with a frequency of three times a week (Coswig et al., 2018), while others required a minimum weekly frequency of 2-3 times a week (Detanico et al., 2021). Interestingly, the inclusion of competition participation as a criterion varied across studies, with some studies not specifying the federation (Coswig et al., 2018; Detanico et al., 2021), whereas others explicitly mentioned participation in the European Open Jiu-Jitsu Championship organized by the IBJJF (Diaz-Lara et al., 2014). Clarification on the type of federation an athlete belongs to, along with other relevant information about recruitment and selection criteria, could have influenced sample quality. Establishing standardized criteria for sample inclusion based on professional levels, akin to Judo studies, could potentially alleviate these issues and enhance the robustness of BJJ research (Barreto et al., 2022).

In this study focusing on muscle strength and power in

Brazilian Jiu-Jitsu (BJJ), the analysis of dynamic strength assessment studies between elite and non-elite athletes using a funnel plot revealed asymmetric dispersion of effect estimates. This asymmetry, potentially due to qualitative GRADE assessment's lack of precision and indicated by small sample sizes on the vertical axis, highlights the necessity for more epidemiological studies or larger participant cohorts. Such studies are essential to control internal validity more effectively and distinguish levels or other factors impacting dynamic strength and power in BJJ athletes.

Simultaneously, meta-analysis provides a comprehensive overview of how strength and power correlate with competitive levels in BJJ. Despite challenges like limited studies and variations in participant selection criteria, the findings accentuate the significance of incorporating strength-focused training, especially as athletes advance through the ranks. Future research should strive for greater standardization in recruitment criteria and larger sample sizes, enhancing the overall quality and reliability of the findings (Silva Batista et al., 2022). This approach will not only address the current limitations but also contribute to a deeper understanding of the physical attributes crucial for success in BJJ. The outcomes of this research are particularly beneficial for athletes and coaches, offering insights that can inform training strategies and aid in the development of athletes at different competitive levels in BJJ and other grappling combat sports (Torres Luque et al., 2010. Vargas-Molina et al., 2023).

Conclusion

This study's systematic review and meta-analysis, focusing on muscle strength and power in BJJ and comparing elite with non-elite athletes, yielded significant findings despite the limitations of BJJ studies, like small sample sizes in the included studies. Moreover, the study underscores the necessity for standardized sample qualification criteria in future research. The implementation of such criteria would lead to more reliable and comprehensive meta-analyses, enriching our understanding of how strength and power contribute to success in BJJ. This would not only benefit scientific inquiry but also inform practical applications in training and performance optimization in the sport.

The meta-analysis showed substantial effect sizes for strength, highlighting a distinct correlation between an athlete's competitive level and their physical capabilities. This discovery is pivotal for sports science researchers and coaches, as it emphasizes the critical role of strength and power in differentiating performance levels in BJJ. The larger muscle strength and power observed in elite athletes compared to their non-elite counterparts underscores the importance of these attributes in competitive BJJ. This information is invaluable for coaches and trainers, offering a concrete basis for tailoring training programs to enhance these specific physical traits. It also provides a framework for developing targeted strategies to elevate non-elite athletes' performance, bringing them closer to elite standards.

These findings are crucial for both the academic study of BJJ and its practical application. They offer sports science researchers and coaches in BJJ valuable insights into the physical attributes that are essential for high-level performance, guiding the development of more effective training methods and strategies to enhance athlete performance in this demanding combat sport.

Conflict of Interest

There are no conflicts of interest on the part of the authors.

Author Contributions

All authors contributed equivalently to the study.

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