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Maximal strength, sprint and jump performance in elite kumite karatekas

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Abstract

Background Both maximal muscle strength and muscle power are independently important for karatekas. However, the relationship between strength and power in elite male kumite karatekas is under researched. This study aimed to determine the relationship between back-leg-chest (BLC) isometric muscle strength with sprint and jump variables in elite male karatekas.

Methods Male elite/international level (tier 4) kumite karatekas ($n=14$; age, 20.79 ± 1.67 year; height, 1.77 ± 0.06 m; weight, 72.21 ± 5.20 kg) were recruited. BLC strength, sprint and jump values were measured with a dynamometer, a photocell, and an application, respectively. Pearson correlation (trivial $r<0.1$; small $r<0.3$; moderate $r<0.5$; large $r<0.7$; very large $r<0.9$; nearly perfect/perfect $r\geq0.9$) and linear regression analyses were performed to determine the relationship and shared variance between BLC strength, sprint, and jump performance.

Results There were large to very large correlations between BLC strength and sprint time ($r=-0.930$, $p<0.01$), velocity ($r=0.918$; $p<0.01$), acceleration ($r=0.913$; $p<0.01$) and running momentum ($r=0.721$; $p<0.01$). Additionally, BLC strength correlated with jump height (moderate, $r=0.550$, $p<0.05$), peak anaerobic power (moderate, $r=0.672$, $p<0.01$) and power to body mass ratio (moderate, $r=0.545$, $p<0.05$). BLC strength and sprint variables showed an $r^2=0.52–0.86$ ($p<0.01$), while BLC strength and jump variables showed an $r^2=0.29–0.45$ ($p<0.05$).

Conclusions BLC strength is related to jump and sprint performance in male elite karate athletes. This relationship underscores the importance of including strength training that targets BLC muscle strength in training programs for coaches and athletes.

Keywords Plyometric exercise, Muscle strength, Resistance training, Karate, Martial arts

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Introduction

Performance in karate is related to the muscular strength and dynamic power developed in a short period of time [1]. Movement speed and power can differentiate karate competitive level [2], particularly in *kumite* karatekas [3]. Kumite is known as a style in which competing athletes use each other's fighting techniques, emphasizing speed, agility and strength. This style involves dynamic movements in competition as well as fast attack and defense techniques and requires a high level of physical performance to achieve superiority in karate competitions. Kumite karatekas demonstrated superior acceleration (10 m sprint; $p = 0.03$) and power (standing triple jump; $p = 0.03$) compared to *kata* karatekas [4]. Improved muscle strength and movement velocity may offer an advantage for *kumite* karate competition [5]. Kumite athletes at international level had significantly higher ($p < 0.05$; Cohen's d: 1.27, 95% CI 0.31–2.13) squat jump heights compared to kumite athletes at national level [2]. A two-time world champion in kumite karate generated ~ 7% more thrust during the jump squat than his teammates [6]. Moreover, kumite athletes' performance in offensive and defensive actions depend on their ability to quickly execute horizontal changes in body position [7]. Indeed, Krkeljas and Kovac found a significant moderate correlation ($r = 0.46$, $p < 0.05$) between the 20 m linear running times of male karatekas and gedan barai/jaku zuki, one of the basic combinations of karate [8]. Moreover, the lower limbs maximum relative strength and punch speed were correlated in kumite karatekas ($r = 0.66$–0.80; $p = 0.005$–0.037) [9].

Furthermore, greater muscle strength can improve jump and sprint performance [10–12], particularly in martial artists [13, 14]. Striking power in martial arts is largely dependent on the supporting strength qualities of the lower and upper body and shows a significant correlation ($R = 0.68$) with movements such as the isometric mid-thigh pull [15]. Some variables such as strength, stroke hardness and increased speed can provide increased force production [16]. Although the kicking speed in karate is different from the kicking performance in football, it is known that the BLC force almost completely explains the kicking speed in football [17]. The strength performance of the BLC can therefore have a positive effect on requirements such as the speed required in karate. Additionally, for kumite athletes competing in body weight categories [18], power to body mass ratio is an important performance determinant [19, 20]. Body weight correlated ($r^2 = 0.56$) with peak power (Wingate test) in internationally ranked male kumite athletes [21], and was the only predictor ($r = 0.68$; variance explained = 46%) of gedan barai/jaku zuki performance [8]. Further, body mass × velocity (e.g., sprint momentum) may distinguish individual differences much better than other sprint variables such as acceleration and maximum speed [22].

Although the relationships between muscle strength and athletic performance in karate have been examined in the literature, studies usually did not recruit elite/international level athletes [8], with kumite athletes under researched [4]. Our study makes a particular contribution to explaining the relationship between muscle strength and the athletic performance of athletes practicing kumite at elite level.

Therefore, the aim of this study was to investigate the relationship between maximal strength, sprint, and jump variables in elite male kumite karate athletes. Based on key studies [8, 11, 23], it was hypothesized that there would be a significant correlation between maximal strength, sprint, and jump variables.

Methods

Study design and participants

The study was approved by the ethics committee of the University (2024/1802). We declare that the measurements reported in the manuscript were performed in accordance with the ethical standards of the Helsinki Declaration and that the participants signed an informed consent form.

Using a sample size calculator (G-Power 3.1.9.3; Heinrich Heine University Düsseldorf, Germany), and based on the relationship between squat strength/power and punch speed in elite male karatekas ($r^2 = 0.40$–0.45) [24], with a 95% (1-β) statistical power, a minimum of 12 athletes were deemed necessary, although 14 participants were recruited due to potential drop outs. Therefore, elite/international level (tier 4) [25] male kumite karatekas ($n = 14$; age, 20.79 ± 1.67 year; height, 1.77 ± 0.06 m; weight, 72.21 ± 5.20 kg) were included.

The measurements were taken on rest days that coincided with competition times so as not to interfere with the athletes' circadian rhythm. The karate athletes were informed 48 h before the measurements that they should not train and should maintain their usual eating habits until the time of measurement. Anthropometric measurements were taken on the first day. Additionally, the participants were informed about the tests to be used in the study, and the karate players were given moderate-intensity training to familiarize themselves with them. In the second session, strength and other field tests were performed. The sports performance tests were carried out in the presence of the national karate coach. None of the test subjects had any health restrictions in the past that could impair their ability to perform field and strength tests. Inclusion criteria included being between 18 and 25 years old, having been an active competitive athlete for at least 5 years and being able to meet the strength requirements of the test. Exclusion criteria included chronic disability and loss of joint range of motion that limited movement.

Anthropometric measurement

The height of the participants was measured with a portable stadiometer (Seca Ltd., Bonn, Germany) with an accuracy of 0.1 cm, with the head in the Frankfort plane, while the body was standing upright, and the weight was evenly distributed on both legs. Body mass was measured with a bioelectrical impedance with a capacity of 270 kg and a sensitivity of 100 g (Tanita SC -330 S, Amsterdam, The Netherlands).

Muscle strength measurement

The back-leg-chest (BLC) dynamometer (Baseline, USA) was used to determine isometric muscle strength. For the test, the length of the chain was adjusted to the height of the participants by asking the subject to stand on the base of the BLC dynamometer with knees extended. The handle was then positioned at the level of the intra-articular space of the knee joint. Participants were required to stand on the base, knees and hips slightly flexed, while the lower back maintained a proper lordotic curve. While holding the arm, the athlete was asked to lift it vertically by performing continuous isometric contractions of the knee, hip, and waist extensors [23]. The duration of the isometric contraction was 3 s and a total of 3 repetitions were performed 30 s apart. The highest value (kg) between repetitions was recorded as absolute strength.

Sprint measurement

The value of the participants' linear acceleration was determined by sprinting over 10 m using an electronic dual-beam device (Fusion Sport Smart Speed; Fusion Sport, Australia). The 10 m sprint test is generally regarded as a reliable and valid measure of a person's acceleration [26]. The participants began each sprint 30 cm behind the starting line to trigger the first sprint. There was a 2-minute break between the sprints. The time was measured to the nearest 0.01 s, with the best result from three attempts being used for analyses [27]. The sprint velocity, acceleration and momentum were determined using the following formulas: (i) Velocity ($m \cdot s^{-1}$) = distance ÷ sprint time; (ii) Acceleration ($m \cdot s^{-2}$) = velocity ÷ sprint time; (iii) Momentum ($kg \cdot m \cdot s^{-1}$) = body mass × velocity.

Jump measurement

The squat jump test was used to determine the performance values of the participants in the vertical jump (cm). The application called My Jump2 was used to determine the squat jump test. This application was found to be highly valid, reliable, and useful in determining squat jump performance [28]. The starting position for SJ was a 90° squat angle, trunk straight, hands on hips and feet shoulder-width apart. This position was maintained for 2 s before the jump. The push-off phase was performed avoiding any counter movement [29]. The peak anaerobic power (PAP) and power to body mass ratio (P:BM) were also determined using the following formulas: (i) PAP (W) = 60.7 × jump height + 45.3 × body mass ÷ 2055; (ii) P:BM ($W \cdot kg^{-1}$) = PAP ÷ body mass.

Table 1 Descriptive statistics for the participants ($n = 14$)

Variables	Mean ± standard deviation	95% confidence interval
Age (years)	20.79 ± 1.67	19.82–21.75
Height (m)	1.77 ± 0.06	1.74–1.81
Weight (kg)	72.21 ± 5.20	69.21–75.22
Body mass index (kg/m^{-2})	22.88 ± 1.93	21.76–23.99
Competitive experience (years)	6.92 ± 1.20	6.23–7.62

Table 2 Descriptive statistics for the sprint and jump variables in karate athletes ($n = 14$)

Variables	Mean ± standard deviation	95% confidence interval
Back-leg-chest strength (kg)	135.0 ± 13.30	127.3 ± 142.7
Sprint time (s)	1.97 ± 0.06	1.93 ± 2.01
Velocity ($m \cdot s^{-1}$)	5.06 ± 0.17	4.96 ± 5.17
Acceleration ($m \cdot s^{-2}$)	2.57 ± 0.17	2.46 ± 2.67
Momentum ($kg \cdot m \cdot s^{-1}$)	366.2 ± 31.8	347.8 ± 384.5
Jump height (cm)	39.89 ± 5.43	36.75 ± 43.03
Peak anaerobic power (W)	3638 ± 429.7	3390 ± 3886
Power to body mass ratio ($W \cdot kg^{-1}$)	50.35 ± 4.61	47.65 ± 53.05

Statistical analysis

Statistical analyses were performed using the Statistical Package for Social Sciences (version 24; IBM Corporation, Armonk, NY, USA). Data homogeneity was determined with the Shapiro–Wilks test. The correlations between the strengths and all sprint and jump variables were calculated using Pearson correlation coefficients, considered as: trivial $r < 0.1$, small $0.1 < r < 0.3$, moderate $0.3 < r < 0.5$, large $0.5 < r < 0.7$, very large $0.7 < r < 0.9$, nearly perfect $r \geq 0.9$, and perfect $r = 1.0$. Simple linear regression analyses were used to determine whether muscle strength was able to predict physical performance in sprinting and jumping. The variables were expressed as mean values ± standard deviation (SD) with 95% confidence intervals (CI), with alpha level at $p < 0.05$.

Results

Demographic values and training status are expressed in Table 1, and performance outcomes for sprint and jump variables in Table 2.

BLC strength correlated with sprint variables (all $p < 0.01$, Fig. 1) and jump variables (all $p < 0.05$, Fig. 2).

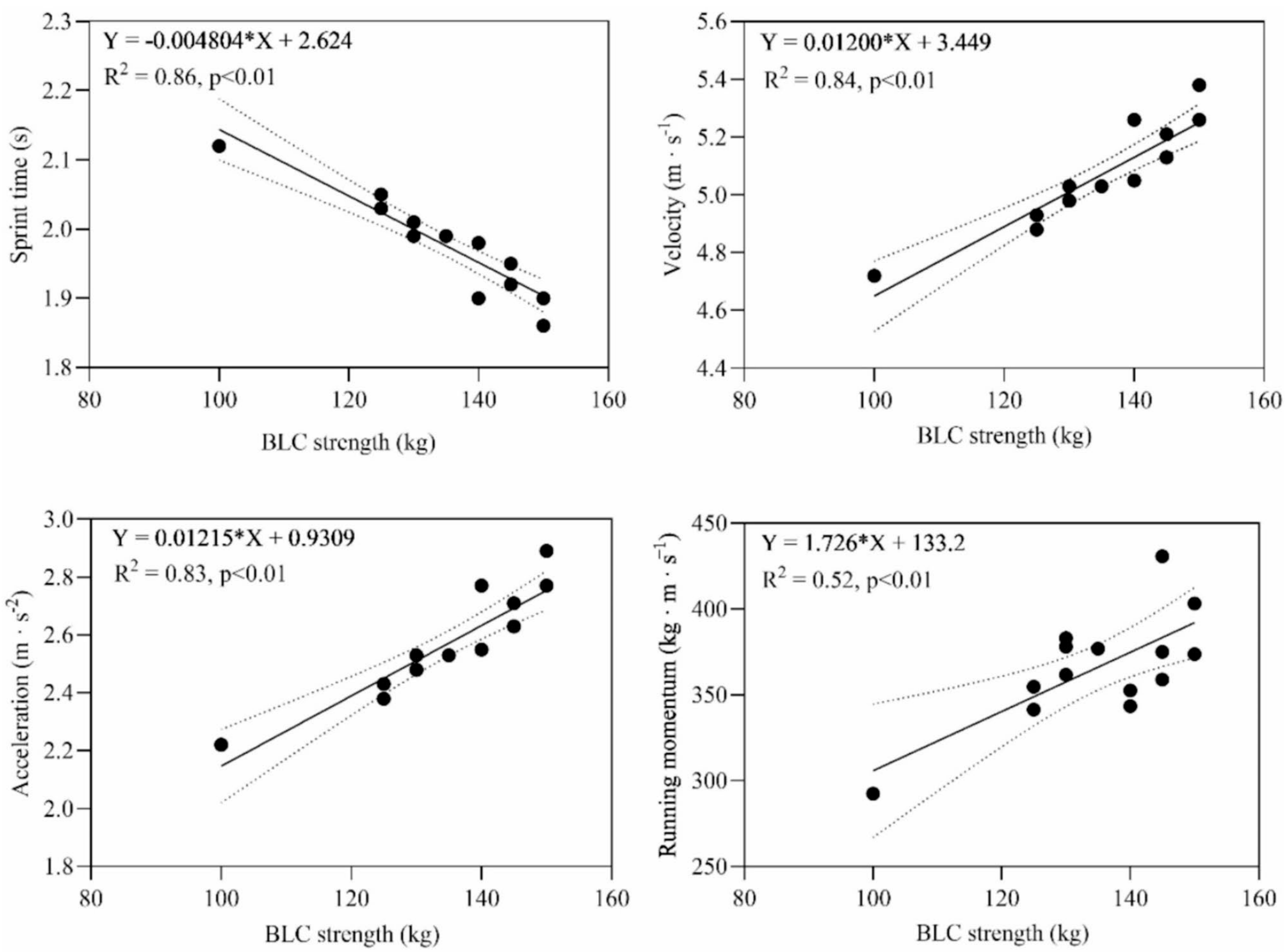

Fig. 1 Simple linear regression analysis between maximal strength and sprint performance. *BLC* back-leg-chest maximal strength

There is a large and very large correlation between BLC strength and sprint time ($r = -0.930$; $p < 0.01$, 95% CI = 0.78 to 0.978), velocity ($r = 0.918$; $p < 0.01$, 95% CI = 0.755 to 0.974), acceleration ($r = 0.913$; $p < 0.01$, 95% CI = 0.742 to 0.972) and running momentum ($r = 0.721$; $p < 0.01$, 95% CI = 0.308 to 0.905), and a moderate correlation between BLC strength and jump height ($r = 0.550$; $p < 0.05$, 95% CI = 0.026 to 0.836), peak anaerobic power ($r = 0.672$; $p < 0.01$, 95% CI = 0.219 to 0.886) and power to body mass ratio ($r = 0.545$; $p < 0.05$, 95% CI = 0.020 to 0.834).

Discussion

The aim of this study was to investigate the relationships between BLC strength and linear sprint and vertical jump performance. There were significant relationships between BLC strength and the variables of horizontal and vertical explosive performance. Further regression analyses showed that the sprint and jump variables can be related to BLC strength.

Karate performance is closely related to strength, with parameters such as vertical jump, maximum strength, and maximum speed in both the lower and upper extremities differing significantly between national and international level karate athletes [18, 30]. When karatekas were divided into winners and losers, winners were more powerful in bench press and squat (30% 1RM) [1], suggesting that muscle strength in karate can also influence the outcome of the fight [21].

Since the BLC was found to explain about 87% of the strength of the handgrip, knee extensor and knee flexor, it can be said that this test provides important conclusions about overall muscle strength [23]. Although it has not been examined whether BLC strength affects kicking speed in karate, it has been found to explain about 98% of kicking speed in football [17]. It can therefore be said that BLC strength influences the values for explosive power and is an important basic skill in karate. Explosive power is one of the main indicators of success in karate and is extremely important for the effectiveness of the technique used [31]. The highest performance in karate is possible by transferring very high kinetic energy to a segment in the shortest possible time [32]. Therefore, the ability to move the body in the vertical and horizontal

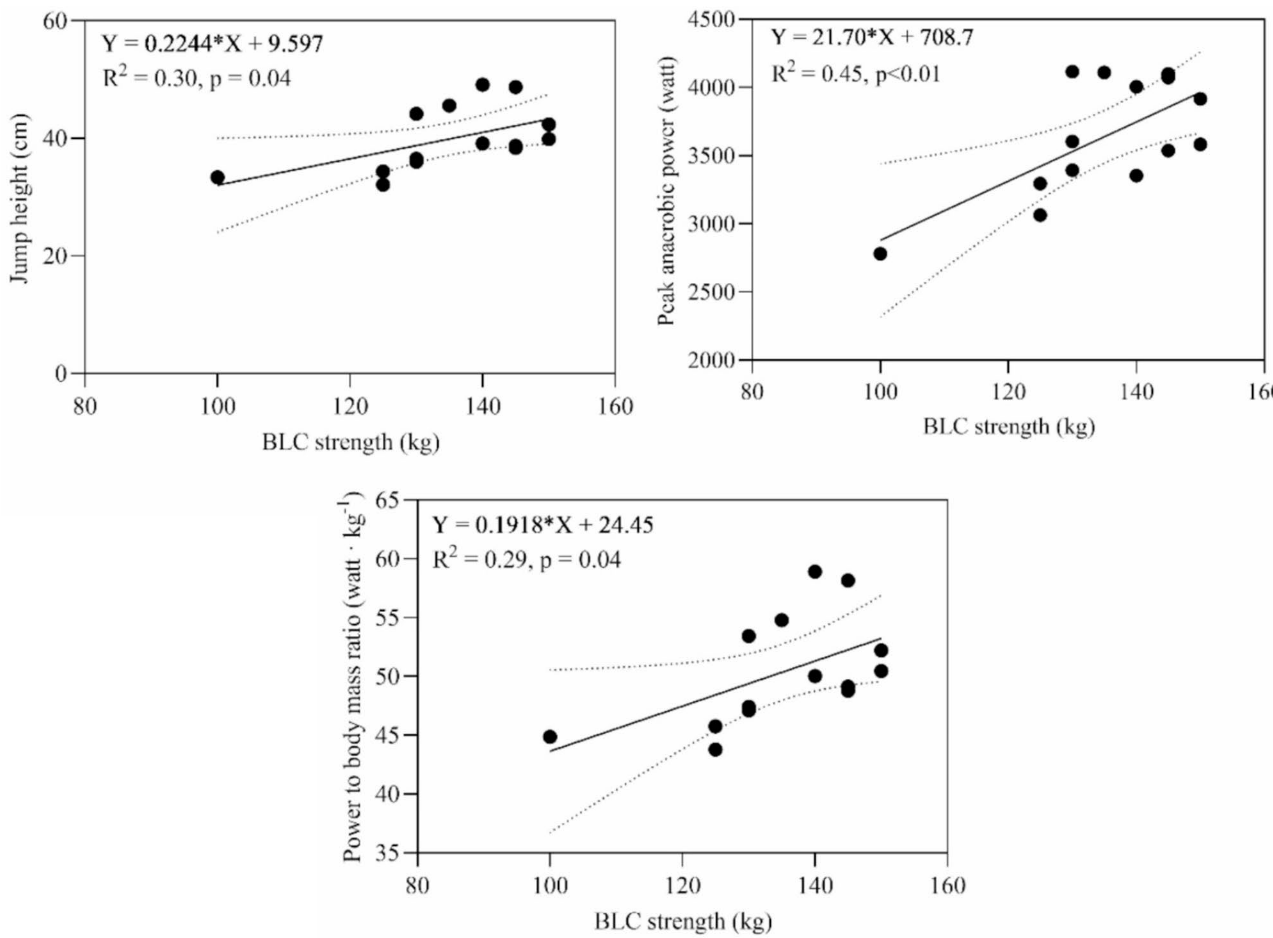

Fig. 2 Simple linear regression analysis between maximal strength and jump performance. *BLC* back-leg-chest maximal strength

axis in the shortest possible time is a significant advantage in kumite [33].

Although there was a significant relationship between BLC performance and the sprint and jump variables, the shared variance (r^2) between BLC and sprint reached up to 86% compared to 45% for jump variables. This could be because the posterior muscles (e.g., hamstrings and back extensors) contribute significantly to the strength of the BLC. In a previous study, it was found that hip thrust performance, which targets muscle groups such as the gluteus maximus, erector spinae, hamstrings, and quadriceps femoris, exhibited a stronger correlation with maximal acceleration (10-meter sprint; $r = 0.93$), whereas variations of the vertical jump were more effective at speeds over distances exceeding 40 m (r range: 0.88 to 0.96) [34]. It was found that the erector spinae and quadratus lumborum muscles contribute to sprint speed over short distances (r^2 range = 0.42–0.50) [35]. The strength of the posterior muscle chain, including the hamstrings, plays a significant role in horizontal movements, particularly during the pushing phase [36]. Another explanation could be the contribution of the arm mechanics during the horizontal movement [37]. The arm movement contributes significantly to maintaining the increase in velocity during the initial and acceleration phases [38]. It has been stated that the vertical component of arm movement at the beginning of a sprint can create a situation where leg movement increases in contact with the ground, thus indirectly helping to increase the forward velocity of the main movement [39].

Finally, the relationship levels of momentum and other linear sprint variables showed very striking differences. While it was observed that linear sprint variables other than momentum were > 80 explained by BLC strength, running momentum (body mass × velocity) was found to be explained by approximately 50%. To our knowledge, the sprint momentum has not been studied in karate athletes, although the importance of the momentum has been emphasized in many different athletes. Jalilvand et al. found that the magnitude of the relationship between vertical jump and sprint variables changed significantly when body weight was considered [40]. A recent study found that momentum is a much more meaningful indicator of performance than sprint speed [41]. It has also been found that velocity approaches peak performance in the 20 s, but momentum can be improved in later periods [42]. Therefore, it may be advisable to consider body mass when examining other performance outcomes of kata and kumite athletes in future studies. In this way, the development process of the athletes can be followed more objectively and a reasonable explanation for the interpretation of the differences can be provided.

This study specifically focuses on elite male kumite karatekas, a population that is often under-researched in the context of muscle strength and power relationships. By targeting a high-performance group, the findings are particularly relevant for elite athletic training and performance enhancement. The study found large to very large correlations between muscle strength and various sprint performance metrics, and moderate correlations with jump performance metrics. These significant findings highlight the importance of BLC strength in the performance of elite karatekas, providing actionable insights for coaches and athletes. Although BLC strength, sprint, and jump performance are critical metrics, other factors such as agility, endurance, and technique may also play significant roles in karate performance. Including a broader range of variables could provide a more comprehensive understanding of the determinants of performance in elite karatekas. The study exclusively includes male karatekas, which means the findings cannot be generalized to female athletes. Further research should include female participants to examine whether similar relationships exist across genders.

Conclusion

Maximal strength is significantly associated with jump and sprint performance in male elite kumite karate athletes, particularly in movements involving the horizontal axis rather than the vertical axis. These findings highlight the importance of maximal strength as a determinant of key performance metrics in kumite, such as acceleration and quickness in offensive and defensive maneuvers. Additionally, incorporating body mass considerations into strength assessments and performance analyses could provide a more nuanced understanding of how strength contributes to competitive success. This study underscores the necessity for further research to evaluate the longitudinal effects of training interventions aimed at enhancing maximal strength and to expand the participant pool to include both genders and diverse athletic populations, thereby broadening the generalizability of these findings.

Abbreviations

BLC Back-leg-chest
PAP Peak anaerobic power
P:BM Power to body mass ratio

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Author contributions
F.S.C., O.A., C.A., and R.R.C analysed and interpreted the data and were involved in writing the first draft of the manuscript. F.S.C., R.R.C, A.B., G.T., and A.K. made substantial contributions to the conception and design of the work, as well as writing and editing the manuscript's final version. F.S.C., R.R.C., Y.A., and N.Y. contributed to data interpretation, writing, and editing of the manuscript's final version. All authors read and approved the final manuscript.

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Data availability
The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical restrictions.

Declarations

Ethics approval and consent to participate
All the procedures implemented in this study were approved by the Ethics Committee of the Inonu University, (approval number: 2024/1802). Informed consent forms were signed after the participants were informed of the study.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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