SPORMETRE
The Journal of Physical Education and Sport Sciences
Beden Eğitimi ve Spor Bilimleri Dergisi

DOI: 10.33689/spormetre.1093293

Geliş Tarihi (Received): 25.03.2022 Kabul Tarihi (Accepted): 25.08.2022 Online Yayın Tarihi (Published): 30.09.2022

ASSOCIATION OF BODY COMPOSITION WITH LEG STRENGTH, BALANCE CAPACITY AND DROP JUMP ABILITY IN CAPOEIRA ATHLETES: A PILOT STUDY

Muhammed M. Atakan[1], Evrim Ünver[2], Yasemin Güzel[1], Selin Aktitiz[1], H. Hüsrev Turnagöl[1*]
[1]Division of Exercise Nutrition and Metabolism, Faculty of Sport Sciences, Hacettepe University, Ankara, Turkey
[2]Division of Movement and Training Sciences, Faculty of Sports Sciences, Hacettepe University, Ankara, Turkey

Abstract: This study aimed to determine the association of body composition (BC) with leg strength, balance capacity, and drop jump ability in capoeira athletes. A total of 10 male (age: 26.5±2.6 years) and 5 female (age: 25.0±2.9 years) capoeira athletes participated in this study. BC measurement of the participants was performed using dual-energy X-ray absorptiometry. Performance measurements consisted of 30º, 60º, 90º leg strength measurement, anterior-posterior balance, medial-lateral balance capacity measurement, and drop jumps from heights of 20 (DJ20), 40 (DJ40), and 50 cm (DJ50). Reactive strength index (RSI) was calculated as jump height/contact time ($mm \cdot ms^{-1}$). Statistical results showed that there was no significant association between BC with balance ($p > 0.05$). Fat-free mass (FFM) was found to be correlated with RSI for DJ20 ($r = 0.52$; $p = 0.049$) and DJ40 ($r = 0.66$; $p = 0.01$), while there was a negative association between fat mass (FM) with DJ40 ($r = -0.65$; $p = 0.01$) and DJ50 ($r = -0.59$; $p = 0.02$). In addition, FM was negatively associated with 90º right leg strength ($r = -0.59$; $p = 0.02$), 90º left leg strength ($r = -0.62$; $p = 0.01$), and 60º left leg strength ($r = -0.57$; $p = 0.03$), while there was a positive association between FFM and 90º right leg strength ($r = 0.59$; $p = 0.02$). As a result, FM and lean mass (LM) exert profound effects on leg strength and drop jump ability, while BC doesn't seem to affect balance capacity in capoeira athletes, showing that possessing low FM and high LM likely leads to better athletic performance in capoeira athletes.

Key Words: Capoeira, body composition, balance, jumping, strength

CAPOEIRA SPORCULARINDA VÜCUT KOMPOZISYONUNUN BACAK KUVVETİ, SIÇRAMA VE DENGE YETENEĞİ İLE İLİŞKİSİ: PİLOT ÇALIŞMA

Öz: Bu çalışma, Capoeira sporcularında vücut kompozisyonu (VK) ile bacak kuvveti, sıçrama ve denge becerisi arasındaki ilişkiyi belirlemeyi amaçlamıştır. Toplam 10 erkek (yaş: 26,5±2,6 yıl) ve 5 kadın (yaş: 25,0±2,9 yıl) Capoeira sporcusu bu çalışmaya gönüllü olarak katılmıştır. Katılımcıların VK ölçümü, çift enerjili X-ışını absorpsiyometrisi kullanılarak gerçekleştirilmiştir. Katılımcıların 30º, 60º, 90º bacak kuvveti ölçümleri, ön-arka denge, medial-yan denge ölçümleri ve 20 cm, (DJ20), 40 cm (DJ40) ve 50 cm (DJ50) düşme yüksekliklerinden atlama ölçümleri belirlenmiştir. Reaktif kuvvet indeksi (RKİ), sıçrama yüksekliğinin (mm), zemin temas süresine (ms) bölünmesiyle hesaplanmıştır. İstatistiksel sonuçlar, VK değişkenleri ile denge becerisi arasında anlamlı bir ilişkisi olmadığını göstermiştir ($p > 0.05$). Yağsız kas kütlesi ile DJ20 ($r = 0.52$; $p = 0.049$) ve DJ40 ($r = 0.66$; $p = 0.01$) RKİ arasında pozitif yönlü anlamlı ilişkili bulunmuştur. Ayrıca yağ kütlesi ile DJ40 ($r = -0.65$; $p = 0.01$) ve DJ50 ($r = -0.59$; $p = 0.02$) düşme yükseklikleri arasında negatif yönlü ilişki bulunmuştur. Yağ kütlesi ile 90º sağ bacak kuvveti ($r = -0.59$; $p = 0.02$), 90º sol bacak kuvveti ($r = -0.62$; $p = 0.01$) ve 60º sol bacak kuvveti ($r = -0.57$; $p = 0.03$) ile negatif yönlü anlamlı ilişki belirlenmiştir. Yağsız kas kütlesi ile 90º sağ bacak kuvveti arasında pozitif yönlü ilişki vardır ($r = 0.59$; $p = 0.02$). Sonuç olarak, Capoeira sporcularında yağ kütlesi ve yağsız kas kütlesi bacak kuvveti ve sıçrama performansını önemli düzeyde etkilerken, VK'nın denge becerisi üzerine etkisi sınırılıdır. Bu sonuçlar, düşük yağ kütlesi ve yüksek kas kütlesine sahip olmanın Capoeira sporcularında daha iyi atletik performans sağlayabileceğini göstermektedir.

Anahtar Kelimeler: Capoeira, vücut kompozisyonu, denge, sıçrama, kuvvet

**Sorumlu Yazar: H. Hüsrev Turnagöl, Doçent, E-mail: deniz@hacettepe.edu.tr*

INTRODUCTION

Capoeira was originally created by African slaves to preserve their fighting skills. In the following years, it was considered a Brazilian martial art widely performed to percussion and chanting by various social groups in more than 150 countries across five continents, particularly in Brazil (Radicchi, Papertalk, & Thompson, 2019). In 2014, the United Nations Educational, Scientific and Cultural Organization recognized capoeira as an intangible cultural heritage of humanity (UNESCO, 2014). Capoeira is a combined form of various simultaneous elements such as dance, fighting, games, and body rhythm as well as including a broad range of continuous movements with medium to high impact, applied at varying speeds and directions in order to increase heart rate and to load a variety of muscle groups and skeletal regions in the upper and the lower body. Due to the important physical strength and flexibility required by various elements involved in its practice, capoeira is an effective exercise intervention and involves immense acrobatic beauty capable of improving physical and social skills (de Paula Lima et al., 2017).

Given that capoeira includes various movements leading to lack of balance due to possible changes in muscle strength, flexibility, postural balance, and motor coordination, capoeira practitioners may have increased risk of injury (Nogueira, Weeks, & Beck, 2017). This indicates the need for capoeira athletes to be evaluated for various factors likely to affect balance, which refers to an athlete's ability to stay in control of their body position and plays an essential role in sports performance (Moreira et al., 2016). Moreover, the risk of injuries in capoeira athletes might be markedly reduced with optimal muscle strength and body composition (BC) that are also known to improve athletic performance (de Paula Lima et al., 2017; Nogueira, Weeks, & Beck, 2014).

Furthermore, considering that BC is an important component of physical performance (Santos et al., 2014) and various muscle groups are actively involved in capoeira practice, including the upper and lower extremities (de Paula Lima et al., 2017), it is of significant importance to ascertain the relationship between BC with muscle strength, jump ability, and balance capacity in capoeira athletes. Additionally, there are limited studies that determined the BC components of Capoeira athletes using waist circumference (Nogueira et al., 2017) or skinfold (Almeida, Filho, Santos, Cardoso, & Moreira, 2021; Marinho, Follmer, Del Conti Esteves, & Andreato, 2016), which limits the findings of these studies. Dual-energy X-ray absorptiometry (DXA) is accepted as the gold standard in assessing BC. DXA uses tissue density to assess the whole body and regional fat mass (FM), lean mass (LM), and bone mineral density (BMD). Furthermore, assessment of BC using DXA allows for the quantification of segmental measurements, such as arms and legs, important components for the characterization of athletes looking to improve strength in specific muscle groups. To the best of our knowledge, however, no study to date has used DXA to assess the BC of capoeira athletes. Therefore, this study aimed to investigate the associations of BC measured via DXA with leg strength, jump and balance parameters in active capoeira athletes.

METHODS

Research Group

A total of 10 male and 5 female capoeira athletes aged 25.7 ± 2.8 years, who had at least 3 years of capoeira training, volunteered to participate in this study. The participants did not have any previous low extremity injuries and disabilities. They were all members of the capoeira community of Hacettepe University. All athletes were over the age of 18 and signed informed consent forms in accordance with the Declaration of Helsinki. This study was approved by the Non-Interventional Clinical Research Ethics Board of Hacettepe University (Approval no: 2021/12-20).

Data Collection Tools

The experimental protocol included the measurements of BC, leg strength, balance capacity, and drop jump which were performed on the same day following overnight fasting (Figure 1). Upon arrival to the laboratory, weight and height were measured using a validated scale (Holtain Ltd. UK) and stadiometer (Tanita TBF 401 A, Japan) without shoes and wearing light clothing. DXA was used to determine BC components, including FM, body fat percent, LM, visceral adipose tissue, visceral adipose tissue volume, and BMD. Following the DXA scan, the participants consumed a 10 kcal/kg standard meal composed of 55% CHO, 30% fat, and 15% protein as recommended by the Institute of Medicine of National Academies (Trumbo, Schlicker, Yates, & Poos, 2002) before the postural stability test (PST) that included 3 sets x 30 seconds, with 10 s rest periods between each set. Prior to the PST, a standard warm-up protocol consisting of cycling at self-selected low-intensity for 5 minutes and a dynamic warm-up protocol including five low extremity exercises were performed. Afterwards, drop jumps (DJs) from heights of 20, 40, and 50 cm (in sequence), with hands-on the hips and elbows bowed outward were performed twice, separated by 1 min of rest. After the DJs, the isometric force at three leg angles (30º, 60º and 90º) was tested by using a dynamometer. Each repeat consisted of 3 sets x 5 seconds with 15 s recovery between each set.

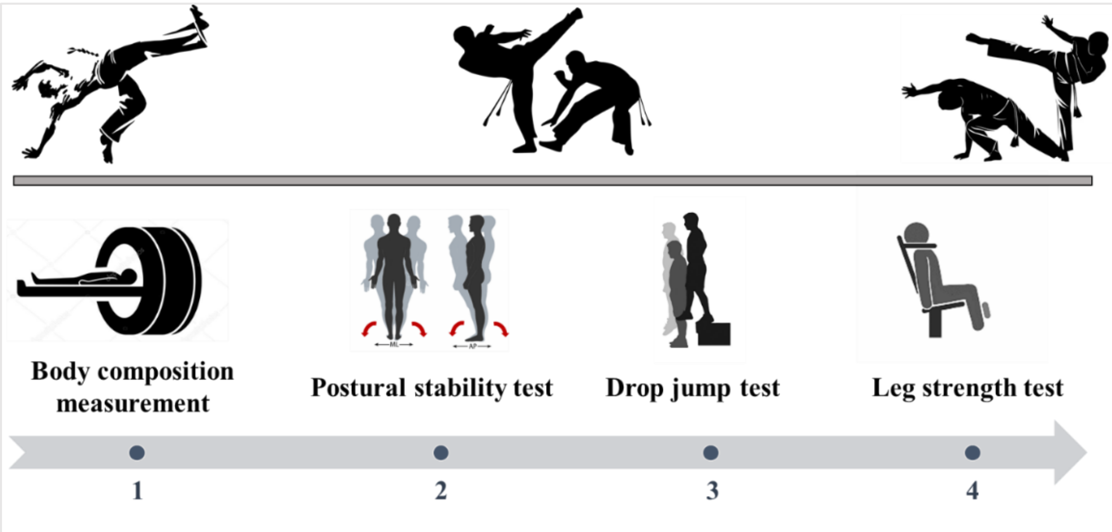

Figure 1. Study design.

Body Composition Measurement

BC and BMD were assessed using a narrow fan beam (4.5°) DXA scanner (Lunar Prodigy Pro; GE Healthcare, Madison, WI, USA) and the obtained data were analyzed with GE Encore v14.1 software. The participants reported to the laboratory following 12 hours of fasting and were instructed to refrain from heavy physical activity, alcohol and caffeine consumption for 24 hours before the DXA measurement. All electronic and metal-containing devices or jewelry were removed from participants before measurement. The measurement was started after the appropriate position for the measurement was checked. The test-retest reliability of DXA measurement from the laboratory calculated for 30 young males who were not participants of the present study were 0.18, 2.09, 0.75 and 0.4% for body mass, FM, LM and BMD, respectively. All the DXA measurements were performed by the same experienced staff.

Postural Stability Test

PSTs were performed by using a portable balance system (Biodex Biosway 950-461, USA). The device had a platform coupled with a monitor and foam used to create an unstable surface. The device is easy to use, yields reliable, repeatable, and objective data about neuromuscular control, as well as allowing for assessment of stability on both a stable and an unstable surface (Biodex Medical Systems, 2009). During the PST the participants stood in the upright position on a stable surface to maintain the center of balance for 3 x 30s separated by 10 s rest intervals. During the test, the stability index, which was the average position from the center, was determined for each athlete. The stability index was not considered the score for body sway, instead, the body sway index was accepted as the standard deviation of the stability index. The stability index included the overall stability index, anterior/posterior (A/P) in the sagittal plane and medial/lateral (M/L) in the frontal plane.

Drop Jump Test

DJs were used to determine the reactive strength by using the reactive strength index (RSI) in this study. The RSI calculated by the division of jump height (mm) and the ground contact time (ms) were determined by using three DJs from 3 drop heights, including 20 cm drop-height (DJ20), 40 cm drop-height (DJ40) and 50 cm drop-height (DJ50) as suggested by Markwick et al. who reported 20, 40, and 50 cm drop-heights had high coefficients of variation (3.1%, 3.0%, and 2.1% for 20 cm, 40 cm, and 50 cm, respectively) (Markwick, Bird, Tufano, Seitz, & Haff, 2014). During DJs, the participants were asked to jump as high as possible after dropping from the platform with minimum ground contact time, with hands-on the hips and elbows bowed outward. We also standardized take-off and landing to the same spot and the participants were required to perform full leg and ankle extensions during the flight phase. All jumps were performed twice, separated by 1-min resting period. A Smartjump device (Smart Jump; Fusion Sport, Coopers Plains, Australia) with a connectable mobile application was used to measure the drop jumping ability of the participants.

Leg Strength Test

Before the test, the participants performed a standardized warm up for five minutes on a cycle ergometer (Monark Ergodemic 894 E a; Pike Bike, Varberg, Sweden) at 60 rpm with no resistance. The isometric strengths of legs were determined by using a dynamometer (CSMI Humac Cybex Norm, USA). Maximal isometric leg extension torque was measured at an angle of 30, 60 and 90 degrees from the fully extended leg towards flexion. Before the test, stabilization straps were secured across the hips and over the shoulders and the participants were positioned in the chair and given a verbal description of the test, which was followed by the testing protocol involving the tested leg being moved passively through the desired range of motion by the investigator. The participants were allowed to make up to three practice attempts, followed by three submaximal contractions for 5 seconds. The submaximal contractions were performed at intensity corresponding to 50% - 60% of personal maximal effort. After a rest period for 15 seconds, the test was started and the participants performed maximal isometric contraction for 3 x 5 seconds, with a rest interval of 15 seconds.

Data Analysis

Descriptive statistical methods were used for the calculation of means and standard deviations. The data normality was verified by the Shapiro-Wilk test. The non-parametric Spearman correlation test was used to determine the correlations between BC and other performance parameters evaluated. Mann-Whitney U test was used to examine gender differences across the BC components since the variables of interest were skewed. Considering the small sample size of this study did not allow for definitive analysis, the statistical analysis of the collected data was exploratory only. All statistical analyses were computed using SPSS Statistics for

Windows, Version 21.0 (IBM Corp., Armonk, NY, USA) and the level of significance was set at $p < 0.05$.

RESULTS

The characteristics of the participants are presented in Table 1. There were significant differences in the BC components presented in Table 1 between male and female capoeira athletes ($p < 0.05$), except for BMI ($p = 0.730$), FM ($p = 0.156$), BMD z-score ($p = 0.102$), and BMD t-score ($p = 0.804$) (Table 1).

Table 1. Body composition and bone mineral density variables of capoeira athletes

	Males (n=10)	**Females (n=5)**
Height (cm)	177.1 ± 8.6	160.6 ± 6.3*
Weight (kg)	72.1 ± 7.9	60.7 ± 7.2*
BMI (kg/m^2)	23.0 ± 2.3	23.5 ± 2.3
DXA body mass (kg)	72.8 ± 7.8	61.5 ± 7.3*
FM (kg)	14.4 ± 3.2	19.4 ± 4.7
VAT mass (gr)	188.9 ± 211.6	195.5 ± 148.3*
VAT volume (cm^3)	200.2 ± 224.1	207.0 ±157.4*
BMD T scores (g/cm^2)	0.84 ± 0.42	0.95 ± 0.98
BMD Z scores (g/cm^2)	0.69 ± 0.554	1.32 ± 0.83

BMI; Body mass index, **BMD;** Bone mineral density, **FM;** Fat mass, **VAT;** Visceral adipose tissue. Values are presented as mean ± SD. *Significant difference between males and females.

The association of jumping performance with fat-free mass (FFM) and FM is presented in Figure 2. Accordingly, FFM was positively correlated with RSI for DJ20 (r = 0.52; p =0.049; Figure 2A) and DJ40 (r = 0.66; p = 0.01; Figure 2B). There were negative associations between FM with DJ40 (r = -0.65; p = 0.01; Figure 2C) and DJ50 (r = -0.59; p = 0.02; Figure 2D).

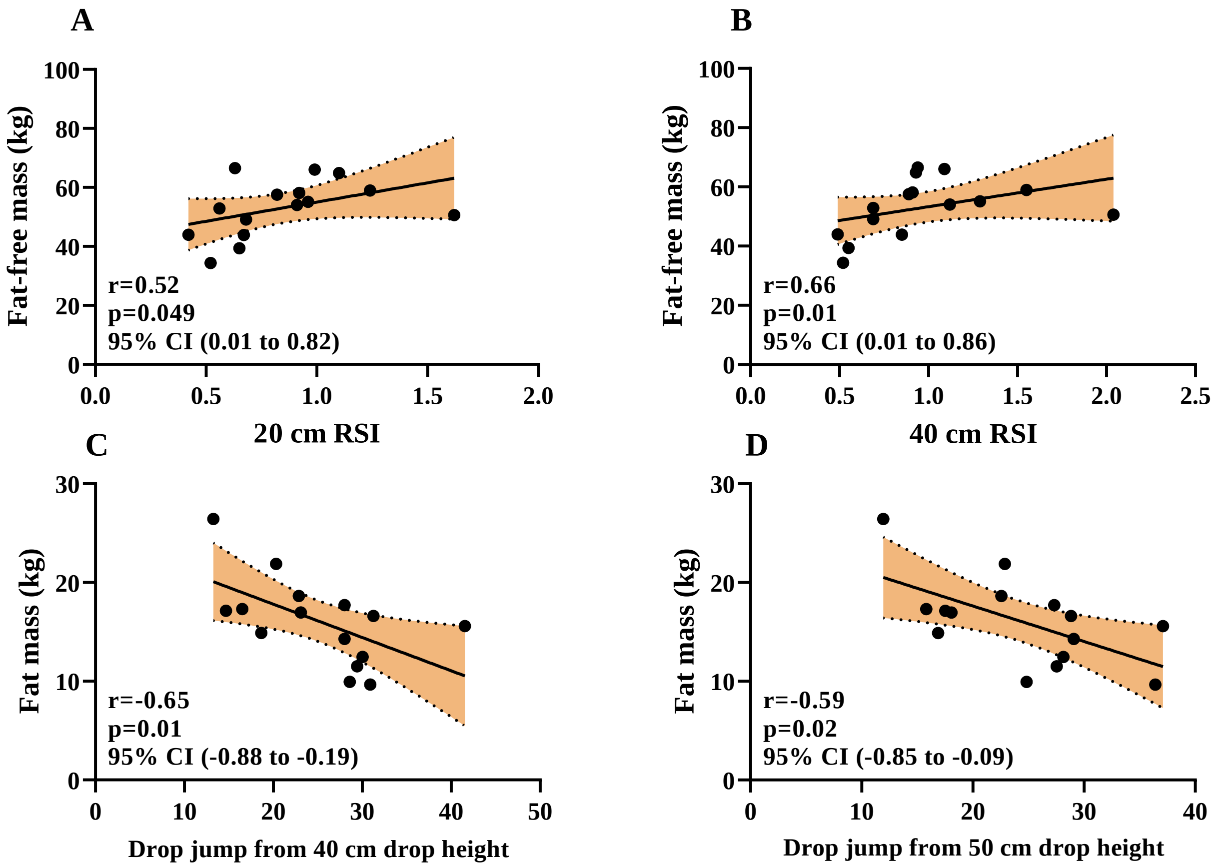

Figure 2. Association of drop jumping ability with fat-free mass (A - B) and fat mass (C - D). RSI; Reactive strength index. CI; Confidence interval.

There was a positive association between FFM and 90º right leg strength (r = 0.59; p = 0.02; Figure 3A). FM was found to be negatively associated with 90º right leg strength (r = -0.59; p =0.02; Figure 3B), 90º left leg strength (r = -0.62; p = 0.01; Figure 3C), and 60º left leg strength (r = -0.57; p = 0.03; Figure 3D). There was no statistically significant association between BC components with balance capacity (data not reported).

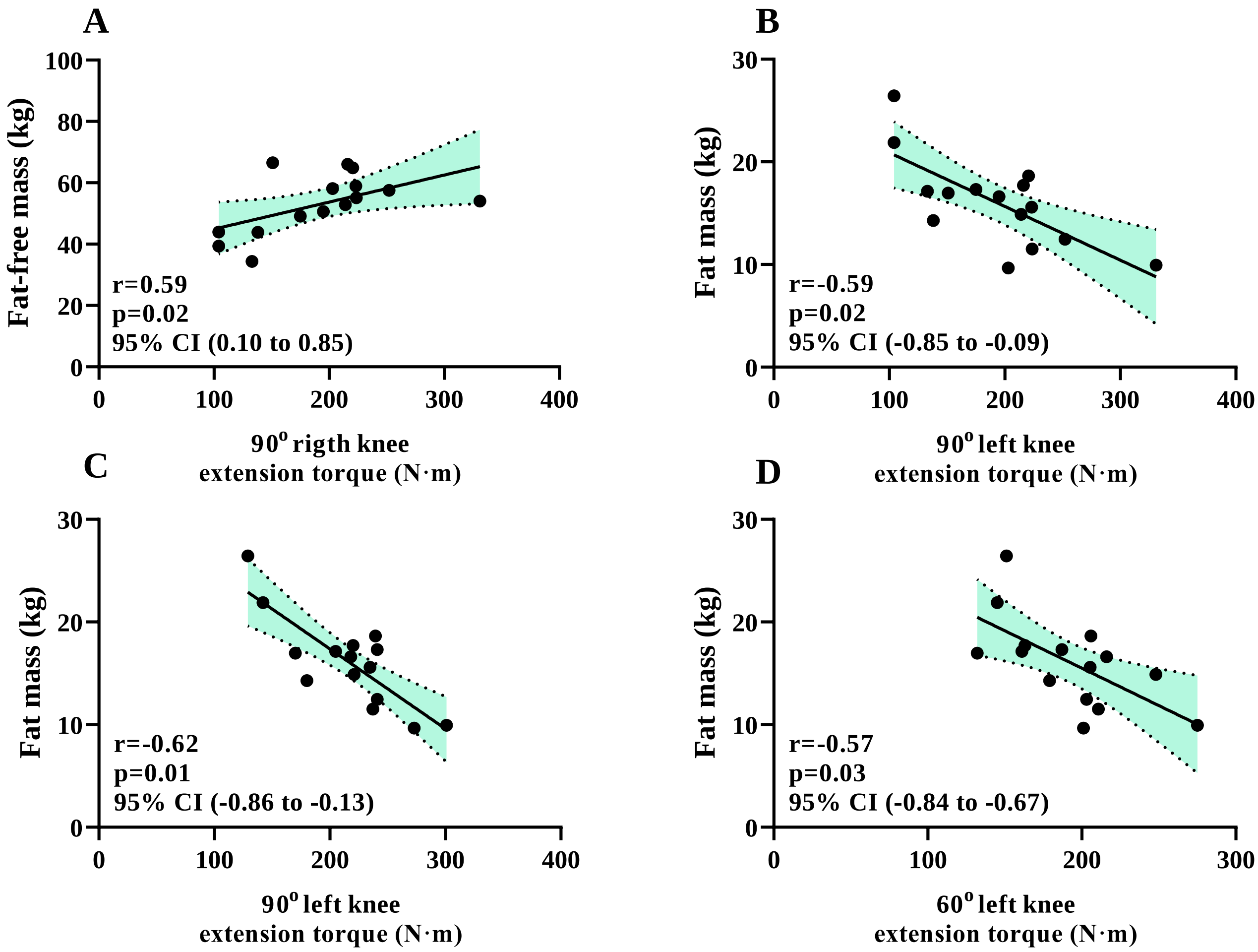

Figure 3. Association of strength parameters with fat-free mass (A) and fat mass (B - C - D). CI; Confidence interval.

DISCUSSION

This study aimed to investigate whether there was a significant association of BC components with leg strength, jumping ability, and balance capacity in active capoeira athletes. The main findings of the present study showed that BC, specifically FM and LM, is an important factor affecting leg strength and jumping ability in active capoeira athletes, while balance capacity is not affected by the BC components.

It is well known that additional weight, especially in the form of nonessential fat, leads to greater resistance to athletic motion that in turn forces athletes to increase the muscle force of contraction per given workload. Furthermore, additional FM is an important factor limiting endurance, balance, coordination, and movement capacity as well as negatively affecting joint range of motion and being a physical barrier to joint movement in a complete range of motion. The findings of the present study do not appreciably support the previous findings indicating a significant association of FM with balance capacity. Also, similar to our findings, Erkılıç and Şener reported that there was no significant association between balance capacity and LM or FM in young male wrestlers (Erkılıç & Şenel, 2019). On the other hand, McGraw et al. documented instability caused by excess weight in adolescent boys (McGraw, McClenaghan, Williams, Dickerson, & Ward, 2000). Also, there was a positive correlation between BMI and increased postural instability, suggesting greater shifts required for postural balance (Greve, Alonso, Bordini, & Camanho, 2007). These findings were supported by a recent study highlighting the relationship of balance capacity with BMI and percent FM in soccer players (Zerf, 2017). It is worth noting that the findings of the present study should be interpreted with caution due to the low sample size in the present study, showing the need for further studies of capoeira athletes with larger sample sizes.

We also reported that RSI was associated with LM and there was a significant negative correlation between drop jump and FM, indicating that excess FM is a significant factor affecting jumping ability in capoeira athletes. It is well documented that RSI is an important indicator of the stretch-shortening cycle (SSC) efficiency, defined as muscle action when active muscle lengthening is immediately followed by active muscle shortening (Louder, Thompson, & Bressel, 2021; Seiberl, Hahn, Power, Fletcher, & Siebert, 2021). For example, Flynn (Flynn, 2016) reported that RSI was negatively associated with percent FM and body weight, which is in line with the findings of the current study, indicating the role of excess body weight in jumping ability. Similarly, Horn et al. (Horn et al., 2018) showed negative and positive associations of RSI with body weight and LM, respectively. Also, Copic et al. (Copic, Dopsaj, Ivanovic, NešiC, & JariC, 2014) showed that BC is a strong predictor of jumping performance in physically active individuals. Despite the convincing findings of the published studies and the current study that support the association of BC components with jumping ability, some studies reported there was no association of jumping performance with FM and LM in elite athletes (Ugarkovic, Matavulj, Kukolj, & Jaric, 2002). This might be attributed to the different study populations included and testing procedures applied.

We found that FM was negatively associated with 90º and 60º peak leg extension torque. There was also a positive correlation observed between 90º peak leg extension torque and LM. These findings are in agreement with previous research that reported a significant correlation ($r = 0.61$ to 0.95) between maximal strength measurements and LM in different populations (Chalhoub et al., 2018; Ferland, St-Jean Miron, Laurier, & Comtois, 2020; Frontera, Hughes, Lutz, & Evans, 1991; Zhang, Pan, Deng, & Fu, 2020). For example, Zhang et al. showed percent FM was negatively associated with the relative peak leg extension and flexion torque and LM was positively associated with the relative peak leg extension torque (Zhang et al., 2020). Similar to the findings of the current study, Miyatake et al. (Miyatake et al., 2012) reported significant negative ($r = -0.48$) and positive ($r = 0.71$) associations of leg strength with percent FM and LM, respectively. Chen et al. also documented that appendicular LM was positively correlated with isokinetic quadriceps strength ($r = 0.37$), showing LM to be a predictor of muscle strength (Chen, Nelson, Zhao, Cui, & Johnston, 2013).

This study has some shortcomings that merit consideration. First, a limitation of the study is the lack of a control group that would have allowed comparison of the variables in capoeira athletes with the non-athletic population. Second, the small sample size limits the generalization of the findings and likely limits the detection of statistical significance; thus our study should be considered as a pilot study. Also, given that capoeira is a new sport and is not as popular as other sports in the general population, we believe the current study provides preliminary data about the potential association of BC with LM, balance capacity, and jump ability in capoeira athletes. Third, we did not consider dietary habits, injury histories, detailed menstrual histories, genetic information, or hormonal status that should be taken into account in further studies.

CONCLUSION

In summary, this study is the first to report the association of BC components with leg strength, jump ability, and balance capacity in active capoeira athletes. The findings of this indicate that LM and FM seem to exert profound effects on jumping ability and leg strength, showing the importance of monitoring BC components in this athletic group. Thus, considering that capoeira sport requires high levels of flexibility and strength, capoeira athletes should consider benefiting from low levels of FM and high levels of LM.

REFERENCES

Almeida, L. G., Filho, E. S. N., Santos, G. A., Cardoso, J. T. C., Moreira, S. R. (2021). Anthropometric Profile and Functional Performance of Capoeira Competitors in the World Games. *International Journal of Morphology, 39*(4), 969-976.

Chalhoub, D., Boudreau, R., Greenspan, S., Newman, A. B., Zmuda, J., Frank-Wilson, A. W., Nagaraj, N., Hoffman, A.R., Lane, N.E., Stefanick, M.L., Barrett-Connor, E., Dam, T., Cawthon, P.M., Orwoll, E.S., Cauley, J.A., Osteoporotic Fractures in Men Study Research Group (2018). Associations between lean mass, muscle strength and power, and skeletal size, density and strength in older men. *J Bone Miner Res, 33*(9), 1612-1621. doi:10.1002/jbmr.3458

Chen, L., Nelson, D. R., Zhao, Y., Cui, Z., Johnston, J. A. (2013). Relationship between muscle mass and muscle strength, and the impact of comorbidities: a population-based, cross-sectional study of older adults in the United States. *BMC Geriatrics, 13*(1), 74. doi:10.1186/1471-2318-13-74

Copic, N., Dopsaj, M., Ivanovic, J., Nešic, G., Jaric, S. (2014). Body composition and muscle strength predictors of jumping performance: differences between elite female volleyball competitors and nontrained individuals. *The Journal of Strength & Conditioning Research, 28*(10), 2709-2716. doi:10.1519/jsc.0000000000000468

de Paula Lima, P. O., Camelo, P. R. P., Ferreira, V., do Nascimento, P. J. S., Bezerra, M. A., Almeida, G. P. L., de Oliveira, R. R. (2017). Evaluation of the isokinetic muscle function, postural control and plantar pressure distribution in capoeira players: a cross-sectional study. *Muscles Ligaments Tendons J, 7*(3), 498-503. doi:10.11138/mltj/2017.7.3.498

Erkılıç, Ş., Şenel, Ö. (2019). Determination of relationships between body composition, anaerobic performance and balance in wrestlers. *International Journal of Sport Culture and Science, 7*(4), 1-10. doi:10.14486/ IntJSCS.2019.581

Ferland, P. M., St-Jean Miron, F., Laurier, A., Comtois, A. S. (2020). The relationship between body composition measured by dual-energy X-ray absorptiometry and maximal strength in classic powerlifting. *J Sports Med Phys Fitness, 60*(3), 407-416. doi:10.23736/s0022-4707.19.09996-1

Flynn, A. (2016). An analysis of ground reaction forces due to body weight during drop jumps: *University of Central Arkansas.*

Frontera, W. R., Hughes, V. A., Lutz, K. J., Evans, W. J. (1991). A cross-sectional study of muscle strength and mass in 45- to 78-yr-old men and women. *Journal of Applied Physiology, 71*(2), 644-650. doi:10.1152/jappl.1991.71.2.644

Greve, J., Alonso, A., Bordini, A. C., Camanho, G. L. (2007). Correlation between body mass index and postural balance. *Clinics (Sao Paulo), 62*(6), 717-720. doi:10.1590/s1807-59322007000600010

Horn, C., Klahr, D., Mokha, M., Antonio, J., Peacock, C., Bommarito, P. (2018). Relationship of reactive strength and body composition in elite american football players. *ISBS Proceedings Archive, 36*(1).

Louder, T., Thompson, B. J., Bressel, E. (2021). Association and agreement between reactive strength index and reactive strength index-modified scores. *Sports, 9*(7), 97. doi: 10.3390/sports9070097

Marinho, B. F., Follmer, B., Del Conti Esteves, J. V., Andreato, L. V. (2016). Body composition, somatotype, and physical fitness of mixed martial arts athletes. *Sport Sciences for Health, 12*(2), 157-165. doi:10.1007/s11332-016-0270-4

Markwick WJ, Bird SP, Tufano JJ, Seitz LB, Haff GG. The intraday reliability of the reactive strength index calculated from a drop jump in professional men's basketball. Int J Sports Physiol Perform. 2015 May;10(4):482-8. doi: 10.1123/ijspp.2014-0265

McGraw, B., McClenaghan, B. A., Williams, H. G., Dickerson, J., Ward, D. S. (2000). Gait and postural stability in obese and nonobese prepubertal boys. *Arch Phys Med Rehabil, 81*(4), 484-489. doi:10.1053/mr.2000.3782

Miyatake, N., Miyachi, M., Tabata, I., Sakano, N., Hirao, T., Numata, T. (2012). Relationship between muscle strength and anthropometric, body composition parameters in Japanese adolescents. *Health, 04*(01), 1-5. doi:10.4236/health.2012.41001

Moreira, S. R., Carvalho, F. O., de Moraes, J. F. V. N., da Silva Carvalho, R. G., de Araújo, R. C., Teixeira-Araújo, A. A., Okano, A. H. (2016). Eight weeks of Capoeira progressive training program increases flexibility of beginners. *Sport Sciences for Health, 12*(3), 329-337. doi:10.1007/s11332-016-0292-y

Nogueira, R. C., Weeks, B. K., Beck, B. (2017). One-year follow-up of the capo kids trial: are physical benefits maintained? *Pediatr Exerc Sci, 29*(4), 486-495. doi:10.1123/pes.2017-0044

Nogueira, R. C., Weeks, B. K., Beck, B. R. (2014). An in-school exercise intervention to enhance bone and reduce fat in girls: the CAPO Kids trial. *Bone, 68*, 92-99. doi:10.1016/j.bone.2014.08.006

Radicchi, M. R., Papertalk, L., Thompson, S. (2019). "It made me feel Brazilian!": Addressing prejudice through Capoeira classes in a school in Western Australia. *Health Promot J Austr, 30*(3), 299-302. doi:10.1002/hpja.219

Santos, D. A., Dawson, J. A., Matias, C. N., Rocha, P. M., Minderico, C. S., Allison, D. B., Silva, A. M. (2014). Reference values for body composition and anthropometric measurements in athletes. *PLoS One, 9*(5), e97846. doi:10.1371/journal.pone.0097846

Seiberl, W., Hahn, D., Power, G. A., Fletcher, J. R., Siebert, T. (2021). Editorial: The stretch-shortening cycle of active muscle and muscle-tendon complex: what, why and how it increases muscle performance? *Front Physiol, 12*, 693141. doi:10.3389/fphys.2021.693141

Trumbo, P., Schlicker, S., Yates, A. A., Poos, M. (2002). Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. *J Am Diet Assoc, 102*(11), 1621-1630. doi:10.1016/s0002-8223(02)90346-9

Ugarkovic, D., Matavulj, D., Kukolj, M., Jaric, S. (2002). Standard anthropometric, body composition, and strength variables as predictors of jumping performance in elite junior athletes. *J Strength Cond Res, 16*(2), 227-230.

UNESCO. (2014). United Nations Educational, Scientific and Cultural Organization (UNESCO): Capoeira circle. Retrieved from https://ich.unesco.org/en/RL/capoeira-circle-00892

Zerf, M. (2017). Body composition versus body fat percentage as predictors of posture/balance control mobility and stability among football players under 21 years. *Physical education of students, 21*(2). doi:10.15561/20755279.2017.0208

Zhang, X., Pan, X., Deng, L., Fu, W. (2020). Relationship between knee muscle strength and fat/muscle mass in elderly women with knee osteoarthritis based on dual-energy x-ray absorptiometry. *Int J Environ Res Public Health, 17*(2). doi:10.3390/ijerph17020573