Evaluation of the isokinetic muscle function, postural control and plantar pressure distribution in capoeira players: a cross-sectional study

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Summary

***Background*: Capoeira is a cultural practice with Brazilian roots that combines several elements including dance, fighting and body rhythm. Because of the diverse elements involved in its practice, capoeira is excellent at developing the physical and social abilities of its players. The aim of this study was to compare the biomechanical profile of muscle strength, plantar pressure distribution, and postural balance between players and non-players of capoeira.**
***Methods*: We evaluated 51 subjects who were allocated into two groups: capoeira group and control group. Subjects were evaluated using a baropodometer (Diasu®) and an isokinetic dynamometer (Biodex®).**
***Results*: When comparing plantar pressure distribution between groups and limbs, there were significant differences in mean load of forefoot (*p*=0.008) and total load (*p*=0.001). There were no significant differences between groups and limbs in balance and muscle strength; however, a significant difference was found in quadriceps torque peak (*p*=0.001) and agonist/antagonist ratio (*p*=0.001) when comparing these variables between the groups.**
***Conclusion*: Capoeira players displayed a tendency to have an asymmetric profile in plantar pressure distribution. No difference was found in balance between groups. Despite the fact that capoeira players showed increased strength of the quadriceps muscle, their agonist/antagonist ratio was more asymmetrical than the control group.**
Level of evidence: IV.

KEY WORDS: isokinetic, martial arts, muscular strength, muscular imbalance, postural balance.

Introduction

Capoeira is a cultural practice with Brazilian roots that combines several elements including dance, fighting, playing, and body rhythm[1,2] and has been widely practiced in Brazil and other countries[3]. Because of the diverse elements involved in its practice, capoeira is excellent at developing the physical and social abilities of its players[4-6].
Balance is one of the most important physical abilities in capoeira. Thus, the evaluation of deficits in postural balance is a very relevant tool for detecting asymmetries and preventing injuries in the lower limbs, as differences between limbs often result in an increased risk of injury for those who practice capoeira[7,8].
Changes in plantar pressure distribution is also related to factors that may significantly interfere with physical training and, consequently sports performance. Authors suggest that the normality pattern for plantar distribution is 60% load in the rearfoot, 30% load in the forefoot and 10% in the middle part of the foot. The electronic baropodometer has been used extensively in the evaluation of plantar pressure distribution and postural balance as well as in the analysis of static and stabilometric measurements[9,10].
Muscle strength is another important element in athletic performance in several sports modalities. As such, bilateral differences in muscle strength and the agonist/antagonist ratio have been considered as requirements in each sport, which may create a motor pattern that is capable of modifying the functional profile of an athlete.
Capoeira requires certain movements that may lead to a lack of balance in the body due to possible alterations in muscle strength, flexibility, postural balance, and/or motor coordination, subjecting capoeira practitioners to postural adaptations that may increase

their risk of injuries[2]. Thus, considering this fact and that capoeira still lacks research regarding biomechanical aspects[11], this study aims to compare the biomechanical profile of muscle performance, plantar pressure distribution, and postural balance between players and non- players of capoeira.

Materials and methods

Participants

We conducted a transversal study with 51 adult male subjects. They were allocated into two groups: capoeira group (CPG; n=28) and control group (COG; n=23). The subjects in the CPG group were required to have at least 6 consecutive months of capoeira practice, while the COG required participants to be physically active. Subjects with any of the following were excluded from the study: pain prior to or after the tests, neurological injuries, cardiovascular dysfunctions, recent musculoskeletal injuries, limitation of range of motion in the evaluated joints, and athletes who underwent surgery less than 6 months prior to the tests. CPG subjects were randomly recruited from groups of capoeira players in the city of Fortaleza and presented an average of 7 years of practice, while COG subjects were recruited for convenience, consisting of physically active university students. This study was approved by the Ethics Committee of Federal University of Ceara - Protocol COMEPE n. 230/1. All methods used in this study meet the ethical standards of Muscles, Ligaments and Tendons Journal (MLTJ)[12].

Procedures

Before beginning the tests, participants answered a questionnaire with personal data including age, dominant limb, injury history, duration of training, weekly load of training, etc. All tests were performed by the same evaluator.

Each subject underwent two tests on the electronic baropodometer in the following order: 1) static analysis and 2) stabilometric analysis. Both tests were conducted on the same equipment (Diagnostic Support, Diasu Health Technologies, Rome, Italy) and processed using Milletrix® software. Subjects were asked to be barefoot and to wear comfortable clothes during the procedure, as well as to concentrate and take each test calmly. Both tests have high reproducibility attested by the literature[13-15]. Temperature (average of 23°C) and noises in the room were controlled in order to avoid any possible external interference.

Starting with the static test, participants were asked to step up on the platform and adjust their feet in a comfortable position, keep their arms aligned with their body and stare directly into the horizon while keeping their mouth slightly open. This test takes 60 seconds to finish and assesses the condition of plantar pressure in a standing position by quantifying loads in rearfoot and forefoot, as well as total load in both feet. Stabilometry was assessed from a monopodalic position, where the individuals were first supported by their left foot, keeping the right foot elevated with the knee flexed and then changed the foot of support, holding each position for 5 seconds to avoid the influence of fatigue on the test[16]. Readings for the center of pressure sway of the antero-posterior (x, axis), medial-lateral (y, axis) position, and total oscillation (mm²) were collected. The sample rate for a stabilometric device was 50Hz[17] according the MLTJ guideline[12].

An assessment of muscle performance was conducted using the isokinetic dynamometer (Biodex System 4, Biodex Medical Systems, Inc, New York, USA*)* and surface electromyography (Miotool, Miotec Equipamentos Biomédicos, Porto Alegre, Brasil)[16].

The isokinetic dynamometer is the gold standard to assess muscle strength[18] and the isokinetic knee extensor and flexor strength variables are reliable[19]. It provides quantification of certain parameters such as ability to produce torque. The established protocol included five maximal knee concentric flexion/extension repetitions at ratio 1.05 rad· s^{-1} with 90 seconds of recovery in-between[20,21]. The tongue position during the test was standardized (lying on the lower arch of the mouth) for all participants to avoid any influence on performance. Subjects were positioned in the dynamometer chair and stabilized with two belts around the trunk, one around the pelvis, and another one in the non-involved leg in order to avoid compensatory movements[22]. The chair was inclined at 85° and the axis of the knee joint was aligned at 90° flexion in order to maintain the popliteal fossa 5 centimeters away from the seat. Prior to the tests, the subjects received a proper explanation regarding the procedure and then performed three submaximal repetitions to get acquainted with the equipment. The order of which limb would be evaluated first was randomized by a draw. During the procedures, every subject was told to perform at his maximum strength in both flexion and extension movements while receiving verbal stimulation from the evaluators.

Before the electromyography analyses and positioning of the electrodes, the detection surfaces were properly cleaned, exfoliated and, if necessary, subjects were trichotomized according to the recommendations from SENIAM (*Surface Electromyography for Non Invasive Assessment of Muscles*) in order to create less impedance between the skin and electrodes[16]. The bipolar surface electrodes (Al/AgCl - Meditrace®) were positioned on the vastus medialis obliquus muscle, while a reference electrode was put on the lateral epicondyle of the right umerus. Initially, 60 seconds of no muscle activity was recorded with the purpose of detecting the electromyography silence (basal tonus). Right after this recording, each subject underwent the maximum voluntary isometric contractions (MVIC) according to the SENIAM protocol: three five-second contractions with three-second intervals between each, with 3 repetitions (for a total of nine contractions). Subjects had 1 minute of rest between each repetition. After this round, we conducted simultaneous data acquisition along with the strength test on the isokinetic dynamometer (five maximal concentric knee flexion/extension at ratio 1.05 rad· s^{-1}). Electrical muscle activity data were collected and transmitted to a monitor connected to the electromyography equipment and the isokinetic dynamometer. Electromyography data had a sampling rate of 2000 Hz and all signals were filtered between 20-450 Hz (band-pass filter) and the isokinetic dynamometer had a sampling rate up to 2000 Hz. Analyses were conducted on the RMS (root means square) electromyography domain and all data were normalized considering the MVIC. Neuromuscular efficiency (NME) was calculated using the EMG/torque peak ratio[23].

Statistical analysis

Sample data were displayed with descriptive measures such as central tendency measurements (mean) and dispersion (standard deviation). Initially, we used the Kolmogorov-Smirnov test to verify the normality of the data distribution. The t-test was used for anthropometric variables. The ANOVA two-way test was used to verify the differences between groups (capoeira and control) and between limbs (dominant and non-dominant) in the plantar pressure, postural balance, and muscle performance variables. All data were analyzed in the SPSS (Statistical Package for Social Sciences) version 20.0 software, using a 5% level of significance.

Results

Table I shows the descriptive sample data. No significant difference was found.

Table II shows the comparison between groups and limbs in relation to plantar pressure distribution, for which we found significant differences in mean load on the forefoot and total load.

Table III shows the comparison between groups and limbs in relation to stabilometry, for which we did not find any significant differences.

Table IV shows the results of the comparison between groups and limbs for muscle performance, for which we also did not find any significant difference. However, when we observed only the between-groups analysis, we found a higher peak torque for the capoeira group ($p<0.01$) and a worse agonist/antagonist ratio ($p<0.01$).

Table I. Descriptive sample data.

	CPG (n=28)	**COG** (n=23)	***p***
Age	26.6 ± 5.5 years	24.4 ± 5.8 years	0.18
Weight	78.2 ± 8.5 kg	75.4 ± 10.0 kg	0.24
Height	1.7 ± 0.06 m	1.7 ± 0.07 m	0.52
BMI	26.0 ± 2.8 kg/cm²	23.7 ± 5.7 kg/cm²	0.09

CPG= Capoeira Group. COG= Control Group.

Table II. Comparison of plantar pressure distribution.

Variables	**CPG**		**COG**		***p***
	DL	NDL	DL	NDL	
Forefoot Load (%)	16.56 ± 6.30%	10.82 ± 6.41%	14.64 ± 5.72%	15.42 ± 5.52%	0.008*
Rearfoot Load (%)	38.10 ± 7.64%	34.51 ± 6.61%	34.73 ± 7.44%	35.02 ± 8.97%	0.209
Total Load (%)	54.66 ± 7.11%	45.34 ± 7.12%	49.37 ± 8.14%	50.60 ± 8.33%	0.001*

DL= Dominant Limb; NDL= Non-dominant limb; *(p<0.05).

Table III. Comparison of the stabilometric variables.

Variables	CPG		COG		*p*
	DL	NDL	DL	NDL	
OE Sway (mm²)	632.04 ± 1681.62	286.83 ± 229.64	422.68 ± 788.72	550.00 ± 2105.65	0.167
CE Sway (mm²)	2331.20 ± 2959.24	2079.95 ± 1603.36	1579.88 ± 1438.90	1562.10 ± 1392.72	0.086
MLS OE (mm)	0.40 ± 0.49	0.32 ± 0.17	0.46 ± 0.73	0.45 ± 0.46	0.139
MLS OE (mm)	0.79 ± 0.53	0.86 ± 0.42	0.83 ± 0.43	0.75 ± 0.43	0.718
APS CE (mm)	0.47 ± 0.40	0.42 ± 0.20	0.36 ± 0.16	0.37 ± 0.23	0.309
APS CE (mm)	1.02 ± 0.62	1.07 ± 0.58	0.92 ± 0.67	0.89 ± 0.45	0.107

DL= Dominant Limb; NDL= Non-dominant Limb; OE= Open Eyes. CE= Closed Eyes. MLS= Medial-lateral Sway. APS= Anteroposterior Sway.

Table IV. Comparison of muscle performance variables.

Variables	CPG		COG		*p*
	DL	NDL	DL	NDL	
KETP (%)	276.54 ± 39.20	271.56 ± 43.97	245.80 ± 53.31	226.59 ± 61.98	0.255
KFTP (%)	123.28 ± 22.43	118.21 ± 23.74	123.15 ± 36.72	115.80 ± 27.46	0.288
Agonist/Antagonist Ratio (%)	45.22 ± 6.50	43.09 ± 6.28	48.87 ± 7.07	53.26 ± 15.90	0.584
EMG (μV)	166.56 ± 26.16	165.72 ± 32.37	157.42 ± 37.27	158.69 ± 33.99	0.975
NME (μV/N)	0.78 ± 0.17	0.77 ± 0.20	0.81 ± 0.24	0.90 ± 0.02	0.399

DL= Dominant Limb; NDL= Non-dominant Limb; KETP = Knee Extension Torque Peak normalized by body weight; KFTP= Knee Flexion Torque Peak normalized by body weight; EMG = Surface Electromyography; NME= Neuromuscular Efficiency.

Discussion

The purpose of this study was to compare the biomechanical profile of muscular performance, plantar pressure distribution, and balance between players and non-players of capoeira. The literature regarding analyses of capoeira with an emphasis on biomechanical aspects is very limited, which makes this research relevant[11].

Capoeira is a sport of impact, which means that it significantly increases the chance of injuries by overload. Using the results of this study, we can identify associated factors and gain a more reliable understanding of the injury mechanism, thereby determining specific prevention strategies for the players[24].

In a study by Neto et al.[24], the most affected areas in capoeira were knees and ankles, followed by the shoulders. Knee injuries occur mainly in sports practices that involve rotation and jumps. The anterior cruciate ligament injury could occur in capoeira due to rapid shifts (swing, strokes, and rotary), as well as the presence of muscle imbalances in the relationship between the quadriceps and the hamstring.

Mariconda et al.[25] conducted a study on a group of capoeira players to assess the prevalence of femoroacetabular impact. The results showed that, in capoeira players, the prevalence of impact in this joint is not related to the symptoms.

Besides the injuries themselves, the specific athletic moves of capoeira which require body agility, defense movements, sudden attacks, jumps, and landings lead to an overload of the musculoskeletal system, generating impacts in joints and consequently postural changes. Such imbalances can be exacerbated by excessive repetition of movements and the regular positions and movements of capoeira, thereby increasing the chances of injury in athletes who are poorly conditioned (and perform strokes improperly)[2].

In the evaluation of plantar pressure distribution, a difference between groups and limbs was observed in which members of the CPG were found to have an asymmetry that involved higher plantar pressure in the forefoot and the total charge of the dominant limb, while in the COG there was a more symmetrical distribution. In this case, the evaluation indicated that there is a tendency towards unilateral practice in capoeira, since despite training that encourages players to perform the moves on both sides, athletes usually prefer to perform the movements on their dominant side[2].

This preference was also identified in classic ballet practitioners who perform athletic moves with their dominant side in search of better results in technique and execution of movements, resulting in a unilateral practice. We believe that the training of sports such as capoeira can promote disharmonious development of muscles.

Another fact that may explain this asymmetry in the plantar distribution in capoeira players is that capoeira is usually performed without the use of footwear. In sports activities that usually not require the use of tennis, such as capoeira, beach volleyball, and barefoot runners, there is constant adaptation of the locomotor system to absorb the direct and constant collision with the surface. These athletes cushion ground reaction forces and absorb shock with the engagement of the sural triceps muscle and not with the heel, as they get used to the practice[26].

Regarding stabilometric variables, we found no significant differences with eyes open or eyes closed, which is consistent with other Authors who evaluated gymnastics and soccer athletes under these same conditions[16,27]. These results can be explained by the fact that capoeira players need of dynamic postural balance, since the position adopted for the test is not part of routine training sport. Our results are consistent with a study that assessed balance in blind individuals, half who practiced capoeira and have who did not. That study's results, according to the Berg Balance Scale (BBS), showed no significant difference between groups[28].

Regarding the variables of muscle performance, there were no differences between groups and members; however, the CPG was found to have significantly superior quadriceps peak torque, while the COG had a better outcome regarding the agonist/antagonist relationship. These results show a greater development of bilateral quadriceps strength in capoeira players; however, this development is not accompanied by increased strength in the hamstrings, resulting more distant from the reference values (agonist/antagonist ratio at 60°/s equal to 60%)[29].

Due to the study design, it is not possible to verify the cause and effect relationship between the practice of capoeira and biomechanical adaptations. In the CPG, there is wide variety in the amount of time group members spend practicing, which may likewise make this difficult to compare. Another point worth mentioning is the use of the isokinetic dynamometer for the measurement of force, which, although relevant to assessing the dynamic (gold standard) muscle work, is not specific enough to assess functional movements of the sport.

The variables that showed no significant differences indicate that the capoeira players behave biomechanically similar to the COG. The results obtained in this study allow a better assessment of the capoeira player, enabling the identification of possible factors that could guide injury prevention in this population.

Conclusions

There is a tendency towards asymmetry in the distribution of plantar pressure in capoeira players. Regarding balance, there is no difference between groups. Although capoeira players have shown greater strength in the quadriceps muscle than the control group, they have an agonist/antagonist relationship that is worse than that of the control group.

Conflict of interest

The Author has no financial or personal relationships with other people or organizations that could inappropriately influence their work.

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