Sport Sci Health
DOI 10.1007/s11332-016-0292-y

ORIGINAL ARTICLE

Eight weeks of *Capoeira* progressive training program increases flexibility of beginners

Sérgio Rodrigues Moreira[1,2] · **Ferdinando Oliveira Carvalho**[1,2] · **José Fernando Vila Nova de Moraes**[1,2] · **Rodrigo Gustavo da Silva Carvalho**[1] · **Rodrigo Cappato de Araújo**[3] · **Alfredo Anderson Teixeira-Araújo**[2] · **Alexandre Hideki Okano**[4]

Received: 23 April 2016 / Accepted: 17 June 2016

Abstract
Background No study has investigated the alterations in the flexibility of beginners using an experimental protocol with basic techniques of *Capoeira*.
Purpose To analyze the effects of 8 weeks of *Capoeira* progressive training program on the flexibility of beginners.
Methods Twenty-one individuals divided in two groups (*Capoeira*: $n = 13$; 26.1 ± 7.2 years; 22.7 ± 2.7 kg $m^{2(-1)}$ and control: $n = 08$; 27.1 ± 0.5 years; 24.3 ± 3.3 kg $m^{2(-1)}$) participated in the study. The *Capoeira* group performed 8 weeks of *Capoeira* progressive training program (two sessions per week lasting 60 min each). The experimental protocol used was exclusively based on the basic techniques of a programmed *Capoeira* training system. Before and after the intervention, measurements were performed aiming to analyze (1) trunk flexion flexibility through a sit-and-reach test using a Wells' Bench (WB_{tf}), (2) passive tension (PT_{hf}), and (3) maximum amplitude of hip flexion (MA_{hf}) through goniometry.
Results A two-way ANOVA revealed a main effect of group by time interaction to PT_{hf} ($F = 11.797$; $P = 0.003$; $\eta_p^2 = 0.383$) and MA_{hf} ($F = 9.650$; $P = 0.006$; $\eta_p^2 = 0.337$). No significant main effect of group by time interaction occurred to WB_{tf} ($F = 3.320$; $P = 0.084$; $\eta_p^2 = 0.149$). The relative changes (Δ %) before and after the intervention in both groups showed that the *Capoeira* group significantly differed to the control group in the PT_{hf} (*Capoeira*: 46.2 ± 29.9 % vs. control: 5.7 ± 27.6 %; $P = 0.003$) and MA_{hf} (*Capoeira*: 22.4 ± 24.5 % vs. control: −6.1 ± 13.1 %; $P = 0.006$).
Conclusion Eight weeks of *Capoeira* progressive training program resulted in a significant improvement in angular flexibility for beginners.

Keywords Brazilian fight · Chronic effects · Range of motion · Health

Introduction

Flexibility can be defined as the physical ability associated with voluntarily performing a joint movement through its maximum range of motion (ROM), without producing excessive muscle stress and pain [1, 2]. Flexibility is an important component for sport sciences and also for maintaining an independent lifestyle when it comes to performing daily activities [3–6]. Improvements in flexibility can reduce the risk of injuries and increase performance by decreasing the stiffness and increasing the mobility of soft tissues surrounding the joint, thereby enabling greater mechanical efficiency of movement [5, 7, 8].

Several studies have analyzed different techniques and strategies that aim at increasing flexibility [4, 8–11]. Usually, these studies compare the effectiveness of different stretching techniques and its influence on flexibility, analyzing parameters, such as intensity, frequency, and duration of stretching and training program [4, 8–11]. However,

✉ Sérgio Rodrigues Moreira
sergio.moreira@univasf.edu.br

1 Colegiado de Educação Física (CEFIS), Universidade Federal do Vale do São Francisco-UNIVASF, Av. José de Sá Maniçoba, S/N-Centro, Petrolina, PE CEP: 56304-917, Brazil

2 Graduate Program on Physical Education, Federal University of Vale do São Francisco-UNIVASF, Petrolina, PE, Brazil

3 Graduate Program on Physical Education, University of Pernambuco-UPE, Petrolina, PE, Brazil

4 Graduate Program on Physical Education, Federal University of Rio Grande do Norte-UFRN, Natal, RN, Brazil

Published online: 28 June 2016

isolated stretching exercises programs can be considered repetitious and tedious, affecting the adherence of participants in such programs. In this scenario, the practice of sports emerges as a viable alternative to maintain or improve flexibility.

A commonly used sport that helps enhancing physical fitness components is the *Capoeira* [12]. Such modality is defined as an athletic sport composed by attack and defense systems originally created in colonial Brazil [13, 14]. Currently, the *Capoeira* is inserted in more than 150 countries over the five continents [15], and its practice has been carried out by different social groups [16]. *Capoeira* is characterized by its main movement, called "ginga," and by several others, such as dodge, unbalance, impact, and acrobatic movements [12]. The *Capoeira* can be performed at different paces, marked by *Angola* and *Benguela* styles, as well as by *São Bento* style. These styles differ in the specificity of the technique and speed of execution of movements [17]. The physical demand for the practitioners reflects an important and gradual aerobic work, which over time may result, at least for the healthy beginners, in cardiovascular adaptations [18].

Oh the other hand, to the best of our knowledge, there are no studies investigating the chronic neuromuscular adaptations as a result of participation in an exercise training program composed exclusively by *Capoeira* techniques. The information about the impact of *Capoeira* on ROM may contribute to the body of the scientific literature, and exercise prescription aiming for the improvement of the neuromuscular function. Therefore, the aim of this study was to evaluate the effects of 8 weeks of *Capoeira* progressive training program on the flexibility of beginners. This way, the hypothesis of this study was that 8 weeks of *Capoeira* progressive training program would increase flexibility in beginners.

Materials and methods

To verify the effects of 8 weeks of *Capoeira* progressive training program on the levels of flexibility of the volunteers, a sample of healthy young adults of both sexes was selected. The training method used was based on Basic Programmed Lesson (Table 1). This method allows the initiation of novices without any kind of experience in

Table 1 Basic Programmed Lesson of *Capoeira* divided by stages

Stage	Movements
1st	1. "*Ginga*—M1abc" one time (start with right leg behind)
	2. "*Esquiva lateral*—M2" ("G*inga*—M1abc" one time), "*Esquiva lateral*—M2"
	3. "*Deslocamento em diagonal*—M3" on both sides
	4. "*Esquiva básica*—M4", change to "*Negative*—M5", "*Role*—M6" (ending with right leg behind)
2nd	5. "*Ginga*—M1abc" two times
	6. "*Meia-lua de frente*—M7ab" ("*Ginga*—M1abc" one time), "*Meia-lua de frente*—M7ab", "*Armada*—M8ab" (adjusts the left leg in position "*Paralela*—M19"), "*Aú*—M10"
	7. "*Ginga*—M1abc" two times (start with right leg behind)
	8. "*Queixada*—M11ab" on both sides, "*Negativa invertida*—M12", adjusting the position entering to "*Esquiva básica*—M4", change to "*Negative*—M5", "*Passada pelas costas*—M13", returning to the position "*Paralela*—M9"
	9. "*Ginga*—M1abc" two times (start with right leg behind)
	10. "*Martelo*—M14" ("*Ginga*—M1abc" one time), "*Martelo*—M14" and "*Esquiva alta*—M15"
3rd	11. "*Ginga*—M1abc" three times (start with left leg behind)
	12. "*Meia-lua de compasso*—M16" ("*Ginga*—M1abc" one time), "*Meia-lua de compasso*—M16"
	13. "*Ginga*—M1abc" three times (start with left leg behind)
	14. "*Finta de corpo*—M17" on single side, "*Rasteira*—M18" to another side (done for both sides)
	15. "*Ginga*—M1abc" three times (start with right leg behind)
	16. "*Martelo de chão*—M19" done for the left side (ending with left leg behind)
4th	17. "*Ginga*—M1abc" three times
	18. "*Rasteira de costas*—M20" ending the movement in the "*Paralela*—M9" position, "*Esquiva básica*—M4", "*Confronto*—M21", step forward, "*Ponteira*—M22";
	19. "*Ginga*—M1abc" three times (start with right leg behind)
	20. "*Esquiva em diagonal*—M23" to the left side, "*Aú-rolê*—M10 + M5 + M6" to the right side
	21. "*Ginga*—M1abc" one time (ending with left leg behind)

The descriptions of the names in "quotes" are original names of *Capoeira.* The acronyms (M1–M23) in "quotes" concerning the movements shown in Fig. 2

Capoeira, and can be adapted to individuals in an intermediate and advanced level.

Before and after the intervention, the participants (*Capoeira* and control groups) underwent flexibility evaluations involving linear and angular flexibility tests. In addition, besides having a control group, the experimental protocol used in this study was exclusively based on the basic techniques of a programmed *Capoeira* training system, without the influence of commonly used traditional stretching exercises.

Subjects

Initially, 32 apparently healthy sedentary volunteers from both genders were assessed for trial commencement. The volunteers were assigned into one of the two groups: *Capoeira* ($n = 22$) or control ($n = 8$; 6 men and 2 women). The allocation of the participants was based on the university's enrollment records for participation in the basic course of *Capoeira* and other courses that did not require performing any physical activity over time. The inclusion criteria of the study were the following: (1) participate in at least 80 % of the experimental sessions (*Capoeira* group); (2) not having any kind of bone, muscle or joint impairment that would preclude participating in the study and performing the flexibility evaluations before and after the intervention; (3) not participating in another physical activity program during the intervention and; (4) not having any kind of heart disease. Throughout the training protocol, and according to the requirements for satisfaction of study's participation (inclusion criteria), nine participants were removed from the *Capoeira* Group. As a result, this group was finally composed by 13 volunteers (8 men and 5 women) (Fig. 1). All participants had at least a 24-month period without practicing *Capoeira* and were oriented not to participate in other physical activity programs throughout the duration of the study. The main characteristics of the control and *Capoeira* groups were to age: 27.1 ± 10.5 vs. 26.1 ± 7.2 years, respectively ($P = 0.79$); body mass: 76.0 ± 17.1 vs. 67.3 ± 12.4 kg, respectively ($P = 0.21$); height: 175.7 ± 11.0 vs. 171.7 ± 7.5 cm, respectively ($P = 0.32$); and body mass index: 24.3 ± 3.3 vs. 22.7 ± 2.7 kg $m^{2(-1)}$, respectively ($P = 0.25$).

This study was conducted in accordance with the requirements stipulated in the Declaration of Helsinki and

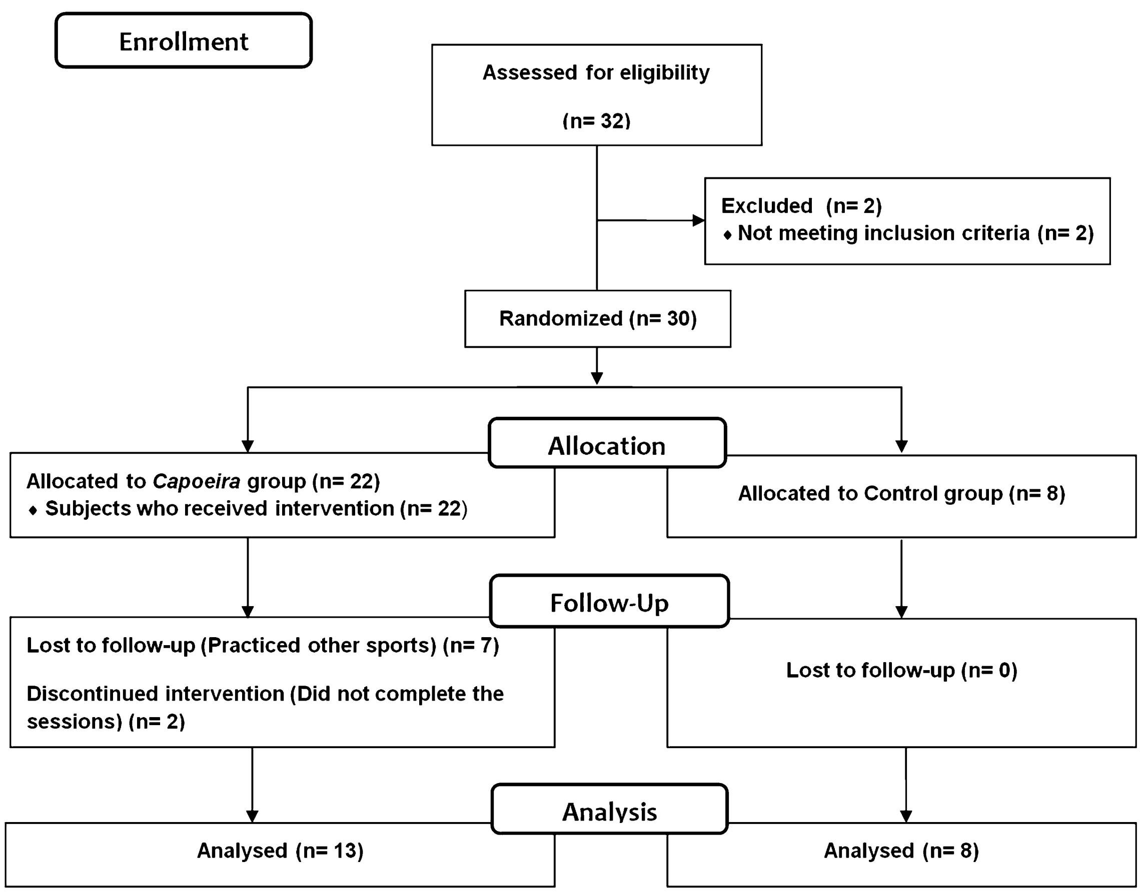

Fig. 1 Flow diagram of sample and allocation of volunteers

was approved by the Research and Ethics Committee of the Federal University of Vale do São Francisco (*protocol 0031/270511 CEDEP*) and after signing an informed consent term. In addition, the authors confirm that all ongoing and related trials for this intervention were registered (*Number Clinical Trials*: *02180360*).

Capoeira progressive training program protocol

The *Capoeira* progressive training program protocol, based on the modern styles of *Capoeira* [14], was applied by an instructor with 17 years of experience in teaching *Capoeira*, followed the directions of the Basic Programmed Lesson, created by Geraldo Pereira d'Santana (*Master Santana*) in a *Capoeira* group called *IUNA* from the city of São Paulo, Brazil, as described in Table 1 and showed in Fig. 2 adaptated of Moreira et al. [18].

The *Capoeira* progressive training program protocol lasted 8 weeks and was performed twice a week with duration of 60 min each. Each session was divided into three parts, being: (1) initial part: consisting of a 10-min warm-up with recreational activities at low intensity or the "ginga" used in *Capoeira*; (2) main part: following the directions from the Basic Programmed Lesson (40 min) and; (3) final part: with a *Capoeira* presentation of approximately 10 min. In this moment, the participants remained in a circle and, in pairs, freely executed the movements practiced earlier in the sessions.

To perform the Basic Programmed Lesson during the *Capoeira* progressive training program, the activities were divided into four stages (Table 1). These stages were composed by main movement that characterizes the *Capoeira* (the "*ginga*") and by other movements, such as dodging, unbalancing, impact, and acrobatic movements (Fig. 2). The model of *Capoeira* progressive training program is described in Table 2. Usually, each sequence of movements during the program was repeated by 20–8 times, with 45–120 s apart, respectively. The technical improvement naturally occurred every week, resulting in a higher speed in movements execution and thus to a gradual increase in training intensity. However, the number of

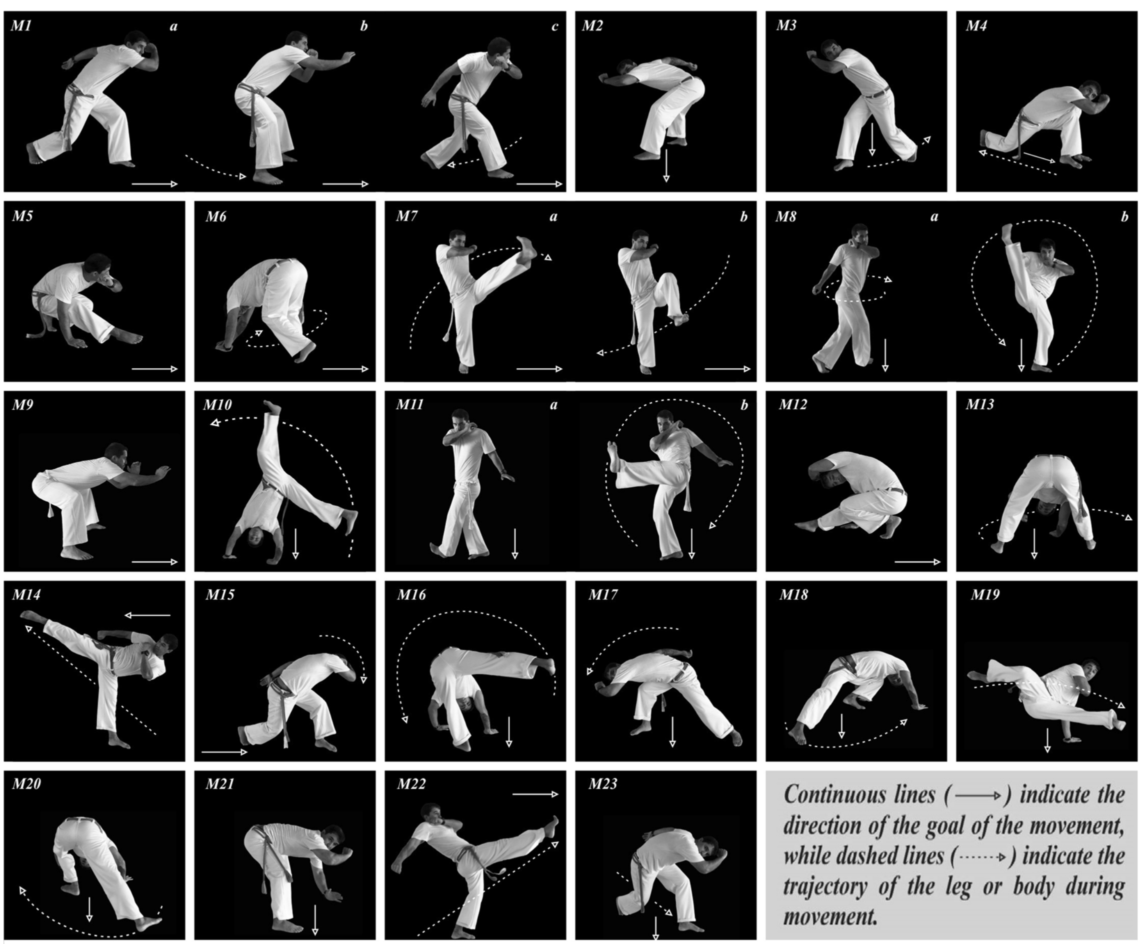

Fig. 2 The movements adopted in the Basic Programmed Lesson of *Capoeira*. Images from the instructor of *Capoeira* progressive training program ptotocol Adaptated of Moreira et al. [18]

Table 2 Progressive training program for Basic Programmed Lesson of *Capoeira*

Frequency	Intensity	Time	Type of training	Rep/Rec
1st week	Low	10′	Initial part: warm-up[a]	–
2×		40′	Main part: development of the “M1abc”, “M2”, “M3” and “M4”, displacement and beginning of the 1st stage of the Basic Programmed Lesson in accordance with Table 1	20/45″
		10′	Final part: technical development[b]	–
2nd week	Low	10′	Initial part: warm-up[a]	–
2×		40′	Main part: development of the 1st stage of the Basic Programmed Lesson (Table 1). Began development of other impact (“M7ab”, “M8ab”, “M11ab” and “M14”), and acrobatic movements (“M10”)	20/45″
		10′	Final part: technical Development[b]	–
3rd week	Low	10′	Initial part: warm-up[a]	–
2×		40′	Main part: beginning of the 2nd stage of the Basic Programmed Lesson (Table 1). Began development of other impact movements (“M16,” “M18,” and “M19”)	20/45″
		10′	Final part: technical development[b]	–
4th week	Low to Moderate	10′	Initial part: warm-up[a]	–
2×		40′	Main part: development of the 2nd stage of the Basic Programmed Lesson. Began of the 3rd stage of the Basic Programmed Lesson in accordance with Table 1	15/60″
		10′	Final part: technical development[b]	–
5th week	Low to Moderate	10′	Initial part: warm-up[a]	–
2×		40′	Main part: development of both the 1st and 2nd stages of the Basic Programmed Lesson and continuation of the 3rd stage of the Basic Programmed Lesson (Table 1)	15/60″
		10′	Final part: technical development[b]	–
6th week	Low to Moderate	10′	Initial part: warm-up[a]	–
2×		40′	Main part: development of the 1st, 2nd, and 3rd stages of the Basic Programmed Lesson in accordance with Table 1	12/90″
		10′	Final part: technical development[b]	–
7th week	Moderate	10′	Initial part: warm-up[a]	–
2×		40′	Main part: development of the 1st, 2nd, and 3rd stages of the Basic Programmed Lesson (Table 1). Begin the movements of the 4th stage (“M20” and “M22”), displacements (“M21” and step forward), dodging (“M4” and “M23”) and acrobatic movements (“M10”)	10/105″
		10′	Final part: technical development[b]	–
8th week	Moderate	10′	Initial part: warm-up[a]	–
2×		40′	Main part: development of the 1st, 2nd, 3rd, and 4th stages of the Basic Programmed Lesson in accordance with Table 1	8/120″
		10′	Final part: technical development[b]	–

Intensity: this variable was estimated by speed of movements and changed from slow to moderate speeds during the program; Type of training: The descriptions of movements in “quotes” are original names of *Capoeira*; Rep/Rec: number of repetition and recovery among repetitions

[a] The warm-up consists of specific recreational activities at low and moderate intensity and/or “*ginga*”

[b] The technical development in final part consists of participants in a circle and, in pairs, freely perform the movements practiced previously in the sessions

repetitions in each sequence was progressively decreased in parallel to the increase in training intensity.

An important thing to highlight in the experimental protocol is that the training performed in this study used only specific movements of *Capoeira* (Table 1; Fig. 2), without applying any other traditional stretching exercises.

Flexibility evaluation

The ROM was measured through linear and angular flexibility measures. Trunk flexion flexibility, through a sit-and-reach test using a Wells’ Bench (WB_{tf}), and passive tension (PT_{hf}) and maximum amplitude of hip flexion (MA_{hf}) were evaluated. Two previously trained evaluators performed the measurements. One was responsible for the measurements in the Wells’ Bench, while the other performed the measurements using goniometry. All measurements performed before and after the interventions, in both groups, were executed between 7:00 and 8:30 pm in a temperature controlled room (25 °C), and the volunteers were in a resting state.

To measure WB_{tf}, a sit-and-reach test using a Wells' Bench (WCS Cardiomed, Curitiba, Brazil) was used. The protocol adopted followed the procedures described by Heyward [19]. Each volunteer performed the test three times and the highest measure of trunk flexion was registered.

The angular flexibility measurements of passive tension (PT_{hf}) and maximum amplitude of hip flexion (MA_{hf}) were performed using a goniometer (Carci, São Paulo, Brazil). The measurement protocol followed the procedures described by Melegario et al. [20]. Both measurements were performed in the right leg of the volunteers. PT_{hf} was executed until the volunteer signaled any kind of pain, while MA_{hf} was performed until the maximum amplitude supported by the volunteer.

Statistical analysis

Data are expressed as mean ± standard deviation (SD). Data normality was verified through an exploratory analysis using a Shapiro–Wilk test. Student's *t* test for independent samples was used to compare the main characteristics and the relative changes between *Capoeira* and control groups. Changes were examined by two-way repeated-measures ANOVA reporting "*F* ratio" and "*P* value" to verify the main effects for interaction of time by group (time × group), main effects of time (pre vs. post) and main effects from independent comparisons of intervention (*Capoeira* vs. control). Mauchly's test was analyzed to assessing the data sphericity. In the case of sphericity assumption violation, the degrees of freedom were adjusted using the Greenhouse–Geisser épsilon correction. Partial eta squared (η_p^2) was used to determine the effect size. When interaction was found, Bonferroni-corrected multiple pairwise comparisons and adjusted *P* values were reported. The effect sizes within the intervention were calculated and classified [21], as follows: <0.1 = trivial; 0.1–0.3 = trivial/small; 0.3–0.5 = small; 0.5–0.7 = small/moderate; 0.7–1.1 = moderate; 1.1–1.3 = moderate/large; 1.3–1.9 = large; 1.9–2.1 = large/very large; >2.1 = very large. The level of significance adopted was set at $P < 0.05$, and the software used for analysis was the SPSS 22.0 for Windows (SPSS, Inc., Chicago, IL).

Results

The 8 weeks of *Capoeira* progressive training program totalized 15 experimental sessions. The mean value of adherence of the *Capoeira* group during the period of study was 87.2 ± 5.1 %.

To the pre-intervention values, no significant differences were found when comparing flexibility of *Capoeira* and control group to WB_{tf} ($P = 0.409$), PT_{hf} ($P = 0.310$), and MA_{hf} ($P = 0.493$) (Table 3).

The results showed a significant main effect of group by time interaction to PT_{hf} ($P = 0.003$) and MA_{hf} ($P = 0.006$) (Table 3). Although no significant main effect of group by time interaction occurred to WB_{tf} ($P = 0.084$), the main effect of time condition was evidenced ($P < 0.001$) (Table 3).

When the changes that occurred within group (Δ %) were compared between groups, significant differences were observed for the PT_{hf} ($P = 0.006$) and MA_{hf} ($P = 0.011$). On the other hand, the change in the WB_{tf} did not reach statistical significance ($P = 0.288$) (Fig. 3).

Table 3 Mean (± SD) and effect size within the intervention for linear (WB_{tf}) and angular (PT_{hf} and MA_{hf}) results of flexibility obtained before (pre) and after (post) the intervention in *Capoeira* and control groups

Variable	Time	CONTROL	*CAPOEIRA*	Main effect	
				Time × group	Time
WB_{tf} (cm)	Pre	26.5 ± 7.8	30.0 ± 10.0	$F = 3.320$	$F = 20.254$
	Post	28.8 ± 5.9	35.3 ± 8.2*	$P = 0.084$	$P < 0.001$
	Effect size	0.7	1.7	$\eta_p^2 = 0.149$	$\eta\eta_p^2 = 0.516$
PT_{hf} (°)	Pre	67.7 ± 18.9	58.5 ± 19.9	$F = 11.797$	$F = 11.535$
	Post	67.6 ± 10.4	80.8 ± 12.6*,†	$P = 0.003$	$P = 0.003$
	Effect size	0.0	1.9	$\eta_p^2 = 0.383$	$\eta_p^2 = 0.378$
MA_{hf} (°)	Pre	82.5 ± 15.8	77.0 ± 18.4	$F = 9.650$	$F = 1.442$
	Post	76.4 ± 10.5	90.8 ± 11.8*,‡	$P = 0.006$	$P = 0.245$
	Effect size	0.5	1.0	$\eta_p^2 = 0.337$	$\eta_p^2 = 0.071$

WB_{tf} trunk flexion using Wells' Bench, *PT_{hf}* passive tension during hip flexion using goniometry, *MA_{hf}* maximum amplitude of hip flexion using goniometry

* $P < 0.01$ to pre in the CAPOEIRA group; ANOVA showed main effect of intervention (control vs. *Capoeira*), where it was possible to verify difference to post in the CONTROL group with $^{\dagger}F = 6.205$, $P = 0.022$, $\eta_p^2 = 0.246$ and $^{\ddagger}F = 8.021$, $P = 0.011$, $\eta_p^2 = 0.297$ (adjusted *P* values by Bonferroni-corrected multiple pairwise comparisons)

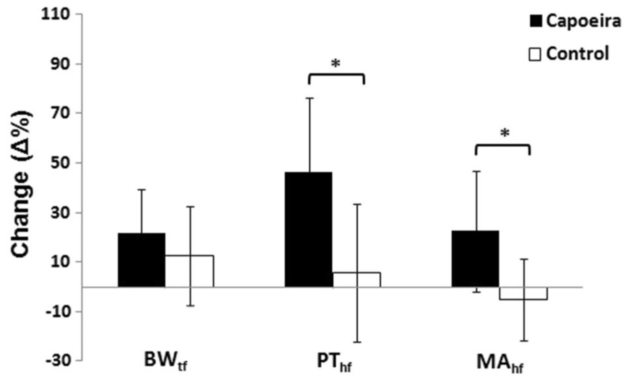

Fig. 3 Mean (±SD) of change (Δ %) between pre- and post-interventions of *Capoeira* or control groups to linear flexibility through trunk flexion using Wells' Bench (WB_{tf}) and angular flexibility through passive tension during hip flexion (PT_{hf}) and maximum amplitude during hip flexion (MA_{hf}). $*P \leq 0.01$ between groups

Discussion

The main findings of this study showed that 8 weeks of *Capoeira* progressive training program, using the Basic Programmed Lesson method (Tables 1, 2; Fig. 2), significantly increased the flexibility in beginners (Table 3). Moreover, when compared with the control group, practicing *Capoeira* resulted in significant increases in the relative change of angular flexibility when comparing before and after intervention values (Fig. 3).

To the best of our knowledge, this is the first controlled study that investigates flexibility in volunteers beginning *Capoeira*. Moreover, this study used an experimental protocol exclusively based on the basic *Capoeira* techniques of a programmed methodology (Fig. 2). The effect size classified [21] in the study showed that *Capoeira* progressive training program was effective in the improvement of flexibility (Table 3). The *Capoeira* group values for this measure were to $WB_{tf} = 1.7$ (large), $PT_{hf} = 1.9$ (large), and $MA_{hf} = 1.0$ (moderate).

Several studies have investigated the effect of different interventions in the flexibility of various groups of individuals. Among these interventions, the following can be highlighted: 12 weeks of Pilates training in women [22], 5 weeks of resistance training in healthy adults [23], 24 months of a physical activity program, including aerobic, resistance, and stretching in elderly women [24], 11 weeks of Tae Kwon Do training in elderly subjects [25], the effects of Tai Chi exercise in older adults [26], and 4 weeks of active eccentric stretching in healthy women [27]. However, none of those are related to *Capoeira* and variables of flexibility, which make the results of this study important and not applicable for comparisons with the aforementioned studies, due to the unique and novel methodology applied.

In addition, an improvement in flexibility can promote important functional benefits to an individual's quality of life, especially when considering the direct association between flexibility and performing daily life activities [28], or the inverse relation between passive muscular stiffness and hamstrings flexibility in youth [29]. This study used flexibility measurements that represent the hamstrings' movements after *Capoeira* progressive training program (WB_{tf}) and showed significant improvements (Table 3). Even though the association of flexibility and muscular stiffness is controversial [6], it is supposed that modifications in these variables can occur as a result of practicing *Capoeira* progressive training program. It is speculated that the improved flexibility occurs due to an acute effect of physical exercise performed in stress relaxation in the muscle (stress-relaxation ratio) that in long term (chronic effect) can be reflected in increased ROM [30]. However, the relationship between the mechanical adjustments in muscle and exercise regarding *Capoeira* progressive training program is still very complex and hypothetical, and still needs to be better investigated.

It is speculated that some isolated movements of the Basic Programmed Lesson, due to their biomechanics, could have influenced the results found in the *Capoeira* progressive training program group. These movements can be represented by the "*Esquiva básica*—M4," "*Meia-lua de frente*—M7a," "*Armada*—M8b," "*Queixada*—M11b," "*Martelo*—M14," "*Meia-lua de compasso*—M16," "*Rasteira*—M18," "*Rasteira de costas*—M20," and "*Ponteira*—M22" (Fig. 2). To do so, the potential effects on flexibility, caused by these movements, still need to be established. Therefore, new studies investigating the isolated effects of the different *Capoeira* moves on flexibility need to be performed. In addition, studies involving the evaluation of other joints and muscle structures and *Capoeira* progressive training program are also made necessary.

On the other hand, an additional challenge to flexibility researchers is the investigation of the mechanistic pathways that explain how *Capoeira* progressive training program, or its specific movements, influence in the increase of ROM. *Capoeira* is a sport that requires dynamic movements, and the literature partially suggests that the viscoelastic modulation of the joint and muscle structures involved in the movements, could enhance the relaxing and crepitation stress [31]. Nevertheless, it is believed that the repetition of dynamic movements during a *Capoeira* practice, independently of maintaining the position for a determined period, can contribute to the increase in flexibility, as occurred on the present study's experimental group (Table 3).

Some limitations of this study can be presented, as follows: (1) not using a specific movement of *Capoeira* (the "*martelo,*" for example) to investigate the changes in flexibility and thus explain it from a specific muscle group, since the protocol of Basic Programmed Lesson covers the sport as a whole. On the other hand, it is worth to highlight that in most training centers, *Capoeira* is taught using the global method of movements; (2) the trainability can be an important feature in the observed adaptation process and the investigated sample consisted of apparently healthy sedentary volunteers, suggesting that regardless of the type of training, improvements in physical fitness are more likely to occur in this group. Melo et al. [32] did not show a significant relationship between the level of physical activity and flexibility of teenagers. These authors pointed out that the changes in the flexibility of an individual can be determined by standard physical exercise, and it is possible that specific movements produce increases or even maintain a high ROM in a specific joint, but not the whole body; (3) another point to be considered is the absolute flexibility between different genders, since the study sample comprised men and women. Although Dias et al. [33] did not show significant differences between genders in the sit-and-reach test, other authors [2, 34] showed that women have greater flexibility when compared with men. This evidence limits the interpretation of our results from a gender-specific point of view; and (4) the anthropometric characteristics of the sample should be viewed with caution. Despite no statistical difference between groups was found ($P > 0.05$), the control group was about 13 % heavier and presented a body mass index 7 % higher than the *Capoeira* group (24.3 ± 3.3 vs. 22.7 ± 2.7 kg $m^{2(-1)}$, respectively). Bim and Nardo [35] showed that body mass index, being within the recommended values for health (<24.9 kg $m^{2(-1)}$), is not related to flexibility. However, the absolute weight values presented between groups are highlighted as a limitation of the study.

In summary, these results showed that 8 weeks of *Capoeira* progressive training program using the Basic Programmed Lesson method, when performed by beginners, promote a significant increase in flexibility measured by the amplitude of movements of trunk flexion (linear flexibility) and passive tension and maximum amplitude of hip flexion (angular flexibility). Further studies with similar methodologies are encouraged to investigate the variations in flexibility and mechanistic pathways in other populations, such as the elderly and individuals affected with joint diseases.

Acknowledgments CAPES (Research Support Foundation of the Brazil) to fund scholarships to Alfredo Anderson Teixeira de Araújo, and *Iraíma Lago* and *Karoline Andrade* by photo design.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

Ethical approval The present study was conducted in accordance to the requirements stipulated in the Declaration of Helsinki and was approved by the Research and Ethics Committee of the Federal University of Vale do São Francisco (*protocol 0031/270511 CEDEP*).

Informed consent The participants provided written informed consent before participating in the study.

References

1. Carregaro RL, Silva LCCB, Gil Coury HJC (2007) Comparison between two clinical tests for evaluating the flexibility of the posterior muscles of the thigh. Braz J Phys 11:139–145. doi:10.1590/S1413-35552007000200009
2. Alter MJ (2004) Science of flexibility, 3rd edn. Human Kinetics, Champaign
3. Funk DC, Swank AM, Mikla BM, Fagan TA, Farr BK (2003) Impact of prior exercise on hamstring flexibility: a comparison of proprioceptive neuromuscular facilitation and static stretching. J Strength Cond Res 17:489–492. doi:10.1519/1533-4287(2003)017<0489:IOPEOH>2.0.CO;2
4. Gonzalez-Rave JM, Sanchez-Gomez A, Santos-Garcia DJ (2012) Efficacy of two different stretch training programs (passive vs. Proprioceptive neuromuscular facilitation) on shoulder and hip range of motion in older people. J Strength Cond Res 26:1045–1051. doi:10.1519/JSC.0b013e31822dd4dd
5. Shrier I (2004) Does stretching improve performance? A systematic and critical review of the literature. Clin J Sport Med 14:267–273. doi:10.1097/00042752-200409000-00004
6. Gleim GW, McHugh MP (1997) Flexibility and its effects on sports injury and performance. Sports Med 24:289–299. doi:10.2165/00007256-199724050-00001
7. Wicke J, Gainey KMF (2013) A comparison of self-administered proprioceptive neuromuscular facilitation to static stretching on range of motion and flexibility. J Strength Cond Res 28:168–172. doi:10.1519/JSC.0b013e3182956432
8. Czaprowski D, Leszczewska J, Kolwicz A, Pawlowska P, Kedra A, Janusz P, Kotwicki T (2013) The comparison of the effects of three physiotherapy techniques on hamstring flexibility in children: a prospective, randomized, single-Blind study. PLoS One 8:e72026. doi:10.1371/journal.pone.0072026
9. Davis DS, Ashby PE, McCale KL, McQuain JA, Wine JM (2005) The effectiveness of 3 stretching techniques on hamstring flexibility using consistent stretching parameters. J Strength Cond Res 19:27–32. doi:10.1519/14273.1
10. O'Hora J, Cartwright A, Wade CD, Hough AD, Shum GL (2011) Efficacy of static stretching and proprioceptive neuromuscular facilitation stretch on hamstrings length after a single session. J Strength Cond Res 25:1586–1591. doi:10.1519/JSC.0b013e3181df7f98
11. O'Sullivan K, Murray E, Sainsbury D (2009) The effect of warm-up, static stretching and dynamic stretching on hamstring flexibility in previously injured subjects. BMC Musculoskelet Disord 10:37. doi:10.1186/1471-2474-10-37
12. Santos AO (2001) Capoeira Arte-Luta Brasileira [Brazilian Capoeira Arts Fight]. Editora Assoeste, Cascavel
13. Assunção MR (2005) Capoeira: the history of an Afro-Brazilian martial art. Taylor & Francis e-Library, London, New York
14. Assunção MR (2014) Capoeira circle or sports academy? The emergence of modern styles of capoeira and their global context. Hist Cienc Saude-Manguinhos 21:135–149. doi:10.1590/S0104-59702014005000002

15. Cunha IMCF, Vieira LR, Tavares LCV, Sampaio TMV (2014) Capoeira: a memória social construída por meio do corpo. Movimento 20:735–755
16. Vieira LP, Assunção MR (2009) Os desafios contemporâneos da capoeira. Ministério das Relações Exteriores—Textos do Brasil, 14: Capoeira, Brasília
17. Silva FF, Souza RA, Carvalho WRG, Costa RP, Jerônimo DP, Silveira Júnior L (2012) Analysis of acute cardiovascular responses in experienced practitioners of Capoeira: a Brazilian art form. JEPonline 15:112–119
18. Moreira SR, Teixeira-Araujo AA, Oliveira dos Santos A, Simões HG (2016) Ten weeks of Capoeira progressive training improved cardiovascular parameters in male practitioners. J Sports Med Phys Fitness **(Epub ahead of print)**
19. Heyward VH (2010) Assessing flexibility. In: Heyward VH, Gibson AL (eds) Advanced fitness assessment, 7th edn. Human Kinetics, Champaign **(chapter 10)**
20. Melegario SM, Simão R, Vale RGS, Batista LA, Novaes JS (2006) The influence of the menstrual cycle on the flexibility in practitioners of gymnastics at fitness centers. Rev Bras Med Esporte 12:125–128. doi:10.1590/S1517-86922006000300003
21. Batterham AM, Hopkins WG (2006) Making meaningful inferences about magnitudes. Int J Sports Phys Perform 1:50–57. http://journals.humankinetics.com/ijspp-backissues/IJSPPVolume1Issue1March/MakingMeaningfulInferencesAboutMagnitudes
22. Kao YH, Liou TH, Huang YC, Tsai YW, Wang KM (2014) Effects of a 12-week pilates course on lower limb muscle strength and trunk flexibility in women living in the community. Health Care Women 10:1–17. doi:10.1080/07399332.2014.900062
23. Morton SK, Whitehead JR, Brinkert RH, Caine DJ (2011) Resistance training vs. static stretching: effects on flexibility and strength. J Strength Cond Res 25:3391–3398. doi:10.1519/JSC.0b013e31821624aa
24. Rebelatto JR, Calvo JI, Orejuela JR, Portillo JC (2006) Influência de um programa de atividade física de longa duração sobre a força muscular manual e a flexibilidade corporal de mulheres idosas. Braz J Phys 10:127–132. doi:10.1590/S1413-35552006000100017
25. Cromwell RL, Meyers PM, Meyers PE, Newton RA (2007) Tae Kwon Do: an effective exercise for improving balance and walking ability in older adults. J Gerontol A Biol Sci Med Sci 62:641–646. doi:10.1093/gerona/62.6.641
26. Taylor-Piliae RE, Newell KA, Cherin R, Lee MJ, King AC, Haskell WL (2010) Effects of Tai Chi and Western exercise on physical and cognitive functioning in healthy community-dwelling older adults. J Aging Phys Act 18:261–279
27. Batista LH, Camargo PR, Oishi J, Salvini TF (2008) Effects of an active eccentric stretching program for the knee flexor muscles on range of motion and torque. Braz J Phys 12:176–182. doi:10.1590/S1413-35552008000300004
28. Coelho CW, Araújo CGS (2000) Relationship between increase in flexibility and improvement in the execution of daily actions by adults participating in supervised exercise program. Rev Bras Cineantrop Desempenho Hum 2:31–41
29. Sobolewski EJ, Ryan ED, Thompson BJ (2013) Influence of maximum range of motion and stiffness on the viscoelastic stretch response. Muscle Nerve 48:571–577. doi:10.1002/mus.23791
30. Knudson D (2006) The biomechanics of stretching. J Exerc Sci Physiother 2:3–12
31. Taylor DC, Dalton JD, Seaber AV, Garrett WE Jr (1990) Viscoelastic properties of muscle-tendon units: the biomechanical effects of stretching. Am J Sports Med 13:263–268. doi:10.1177/036354659001800314
32. Melo FA, Oliveira FMF, Almeida MB (2009) Nível de atividade física não identifica o nível de flexibilidade de adolescentes. Rev Bras Ativ Fís Saúde 14:48–54. doi:10.12820/rbafs.v.14n1p48-54
33. Dias DF, Reis ICB, Reis DA, Cyrino ESOD, Carvalho FO, Casonatto J, Loch MR (2008) Comparação da aptidão física relacionada à saúde de adultos de diferentes faixas etárias. Rev Bras Cineantropom Desempenho Hum 10:123–128
34. Pedrero-Chamizo R, Gómez-Cabello A, Delgado S, Rodríguez-Llarena S, Rodríguez-Marroyo JA, Cabanillas E et al (2012) Physical fitness levels among independent non-institutionalized Spanish elderly: the elderly EXERNET multi-center study. Arch Gerontol Geriatr 55:406–416. doi:10.1016/j.archger.2012.02.004
35. Bim RH, Nardo N Jr (2005) Aptidão física relacionada à saúde de adolescentes estagiários da universidade Estadual de Maringá. Acta Sci Health Sci 27:77–85. doi:10.4025/actascihealthsci.v27i1.1448