The role of static stretching on performance variables and induced effects of exhaustion exercises in Brazilian jiu-jitsu athletes

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A Study Design
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D Manuscript Preparation
E Funds Collection

Received: 31 March 2016; **Accepted:** 23 June 2016; **Published online:** 12 August 2016

AoBID: 11056

Abstract

Background & Study Aim: Static stretching (SS) is often used before physical exercises and sports in order to improve performance and prevent injuries and delayed-onset muscle soreness, although there is no consensus in the scientific literature about these effects. In addition, a growing body of evidence has shown an acute stretch-induced strength loss in some muscles and sports but not in others. The effects of SS on handgrip strength in Brazilian jiu-jitsu (BJJ) athletes remain unknown. The aim of this study was the effect of SS on dynamic and isometric strength performance, on the range of motion (ROM) and on the recovery time of these indicators in BJJ athletes.

Material & Methods: Fifteen male BJJ athletes were randomly allocated to an SS group (n = 8) or a control group (CG, n = 7). The ROM, passive torque (PT), handgrip strength (HG) and isometric (ISO) and dynamic strength (DYN) were tested before, immediately after, 24 h after and 48 h after in both groups.

Results: There was a significant interaction between group and time for ROM, which showed an improvement immediately after SS. There was also a decrease in the CG after 48 h compared to the before measure. There was also an SS-induced strength loss in HG immediately after, 24 h after and 48 h after SS compared to before stretching. The CG showed a significant improvement in HG after 48 h compared to immediately after. None of the other variables tested showed a significant difference.

Conclusions: Stretching exercises of the wrist flexor and finger muscles should be avoided previous to practicing fighting sports for which grip strength is necessary.

Key words: hand strength• martial arts• muscle strength• muscle stretching exercises• recovery of function

Conflict of interest: All authors declared did not have financial support of any institution

Ethical approval: This study was approved by the local Ethics Committee (UNIPAC/Brazil, process n. 802.06/2013)

Provenance & peer review: Not commissioned; externally peer reviewed

Source of support: Departmental sources

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Brazilian jiu-jitsu (BJJ) – the combat sport version developed in Brazil and derived from the Japanese martial art ju-jutsu that focuses on projecting or taking your opponent down and, once on the ground, seeking to control your adversary by grappling with his kimono using different techniques (immobilizations, chokes and joints locks).

Combat sport – *noun* a sport in which one person fights another, e.g. wrestling, boxing and the martial arts [43].

Martial arts – *plural noun* any of various systems of combat and self-defence, e.g. judo or karate, developed especially in Japan and Korea and now usually practised as a sport [43].

Main relationship between combat sport and martial arts – every combat sport is martial arts but not vice versa [44].

Dynamic stretching – *noun* stretching that involves some movement but does not force the muscle past its range of motion [43].

Static stretching – *noun* stretching in which a position that stretches a muscle is assumed and then held [43].

Static strength – *noun* force exerted by a muscle while it is neither extending nor contracting [43].

Muscle strength – essential and basic physical capacity in combat sports by which the body moving status is modified [40] .

Eccentric strength – *noun* the force exerted by a muscle while it is extending [43].

Judogi – is the formal Japanese name for the traditional uniform used for judo practice and competition [Wikipedia, see also 39].

Position – *noun* **1.**the place where a player is standing or playing **2.** the way in which a person's body is arranged [43].

Dynamic Kimono Grip Strength Test – a test in which the subject is instructed to make the maximum number of pull-ups holding the kimono (judogi).

Isometric Kimono Grip Strength Test – a test in which the subject is instructed to hold the kimono (judogi) and hang on to it as long as possible.

Introduction

Jiu-jitsu is a martial art (and combat sport) that is widespread throughout the world and consists of the use of falls, immobilizations and joint locks to limit a person's range of motion (ROM), which overloads the static (osteo-articular structures) and dynamic stabilizers (muscles that cross joints) [1]. One of the most important physical components developed for this sport is muscle strength, especially in the upper limbs, through static and dynamic actions [2]. This claim is corroborated by Sánchez et al. [3], who mention numerous pieces of scientific evidence about the importance of grip strength for some sports, such as rock climbing, sailing, motocross and jiu-jitsu.

The combination of technique, endurance and muscle strength is required for the effectiveness of handgrip movement in these kinds of sports [4]. According to Oliveira et al. [1], grip strength and endurance are the most important physical capacities for controlling an opponent and performing new attacks during a jiu-jitsu fight. During the match, the athlete is in continuous contact with the opponent, performing successive handgrip movements with his kimono (judogi), which requires high levels of strength and endurance in these specific movements.

It is typical to use static stretching as part of a warm-up routine in sports [5]. The more common aim is to increase the mobility of the soft tissues and the length of the structures that suffer adaptive shortening, besides increasing the muscle-tendon extensibility and periarticular tissue and thereby increasing ROM [6]. Furthermore, there is controversial evidence of the prophylactic role of SS on delayed-onset muscle soreness (DOMS) symptoms and injury incidence when performed prior to sports activities, which has fueled the debate about the real importance of SS before sports practice [5, 7, 8].

Several [9, 10], but not all, studies [11, 12] have pointed to an acute deleterious effect of SS on dynamic, isometric and endurance strength. This discrepancy reveals a possible influence of some variables, such as the time spent stretching (dose-response effect), the type of muscle contraction used (dynamic or isometric) and the particular characteristics of the stretched muscle. Some authors suggest that stretching can relieve the DOMS that usually occurs 8 h after the end of the exercise, reaching maximum intensity between 24 and 72 h and disappearing after five to seven days [13]. Reisman et al. [14] found a reduced sensation of DOMS when SS was done previous to eccentric exercise and determined that a reduction in muscle stiffness was responsible for this outcome. In the same way, McHugh et al. [15] showed the role of muscle stiffness in the symptoms of DOMS and muscle damage and reported that the subjects with greater muscle-tendon stiffness are more susceptible to the negative symptoms related to muscle damage, such as pain and loss of strength. This fact leads to the assumption that SS can reduce the symptoms of DOMS through its ability to reduce muscle-tendon stiffness [9]. However, Bonfim et al. [13] found no reduction in DOMS from 24 h to 72 h after performing active SS, and the ineffectiveness of this type of stretching in preventing DOMS has often been discussed elsewhere [16].

We should note that, despite numerous investigations of the effect of SS on strength and the prevention of the symptoms of DOMS, no study, as far as we know, has investigated the effect of SS in minor and peculiar muscles, such as the flexors of the fingers and wrists. Therefore, due to the controversies mentioned above, this study aim was the effect of SS on dynamic and isometric strength performance, on the range of motion (ROM) and on the recovery time of these indicators in BJJ athletes.

Material and methods

Subjects

This study was approved by the local Ethics Committee (UNIPAC/Brazil, process no. 802.06/2013) and was performed in accordance with international ethical standards. Before the research began, the volunteers signed an informed consent form. The sample size was calculated using the equation proposed by Hopkins [17] for experimental designs with repeated measures in order to achieve a statistical power ($1 - \beta$) of 0.80.

Accordingly, 15 male BJJ practitioners (age: 31.33 ± 13.9 yr.; weight: 73.6 ± 15.0 kg; height: 1.73 ± 0.05 m) took part voluntarily in this study. The subjects were allocated randomly to a static stretching (SS; n = 8) group or a control group (CG; n = 7). The criteria to participate in this study were: a) practicing BJJ for at least one year, b) being male, c) having no history of injury of the fingers, wrists and shoulders in the last

6 months and d) not using steroids or ergogenic resources.

General procedures

The subjects visited the laboratory over six days for the data collection. The first visit was dedicated to the familiarization of the volunteers to the experimental procedures of unilateral handgrip strength (HG), dynamic (DYN) and isometric kimono grip strength (ISO), ROM and passive torque (PT) tests. In the following two visits, the subjects were submitted to ROM, PT, HG, DYN and ISO tests. All tests were properly described and clarified such that there were no questions from the volunteers about the procedures. The results were used to calculate the reliability of the measures.

The fourth visit was devoted to experimental or control conditions. In the SS group, the subjects remained seated at rest for 5 min before the start of the tests. ROM, PT and HG strength were measured before the SS routine (pre). Immediately after, the subjects underwent a 3 x 30 s passive SS of the fingers and wrists on both sides and, sequentially, they were submitted to ROM, PT and HG tests (post). After that, the subjects performed DYN and ISO tests with 5 min intervals between them. Then, the participants were given 10 min of rest before the exhaustion exercise routine. The CG performed the same battery of tests and exercises but without completing the SS routine prior.

The two last visits (5 and 6) were made within 24 and 48 h after visit 4, respectively, when subjects were given all tests again. Figure 1 illustrates the general procedures performed.

Range of Movement Test

ROM was measured by wrist hyperextension using a wooden apparatus with hinges and a digital goniometer attached (EMG Systems, São José do Rio Preto, SP, Brazil) with an interface and an acquisition system with 2000 kHz of maximum sampling frequency (EMG 800 EMG Systems, São José do Rio Preto, SP, Brazil). During passive mobilization, the tester secured a load cell (EMG Systems, São José do Rio Preto, SP, Brazil) fixed on the apparatus to measure the torque generated during hyperextension of the wrist. The subject remained standing beside the apparatus with the right shoulder abducted and the elbow flexed to 90°. The forearm rested on the table where the apparatus was set, and a non-elastic tape was used to secure the forearm, hand and fingers of the subject during the test (Figure 2a and 2b).

Three passive mobilizations were conducted with 1 min intervals between them and only to the right side to calculate the ROM and PT average.

Static stretching routine

The subject remained seated with the arm close to the body, elbow flexed to 90° and the forearm in a prone position resting on a table. Then, the researcher conducted the hyperextension of the wrist and fingers slowly and gradually until the greatest discomfort was reported by the subject. The position was held for 30 s, alternating left and right sides without rest between them. The procedure was repeated tree times by the same investigator in all individuals.

Handgrip test

The handgrip strength of the right limb was measured using a stainless steel dynamometer (EMG Systems São José do Rio Preto, SP, Brazil) with 100 kgf of capacity. The subject sat in a chair with the elbow flexed at 90°, the arms relaxed along the trunk and the forearm in a neutral position leaning on a table. The grip position on the dynamometer was performed following the previously established mark for the accommodation of the fingers. The subject was asked to exert their maximum handgrip strength for 5 s. Three measurements with 1 min rest intervals between each were performed, and the average was calculated.

Passive torque – the resistance to stretching (in kgf) offered by the wrist and finger muscle groups during passive wrist hyperextension that is measured using a load cell.

Body balance disturbation tolerance skills – the ability to maintain the vertical posture in circumstances of the fall hazard [42].

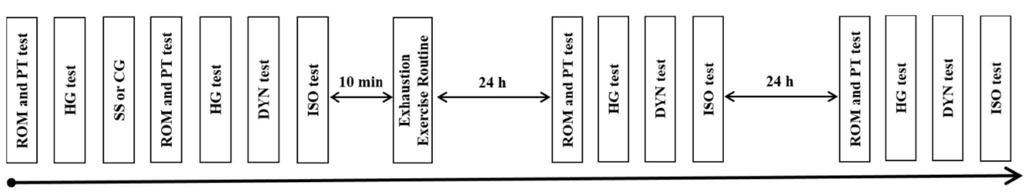

Figure 1. Experimental design.

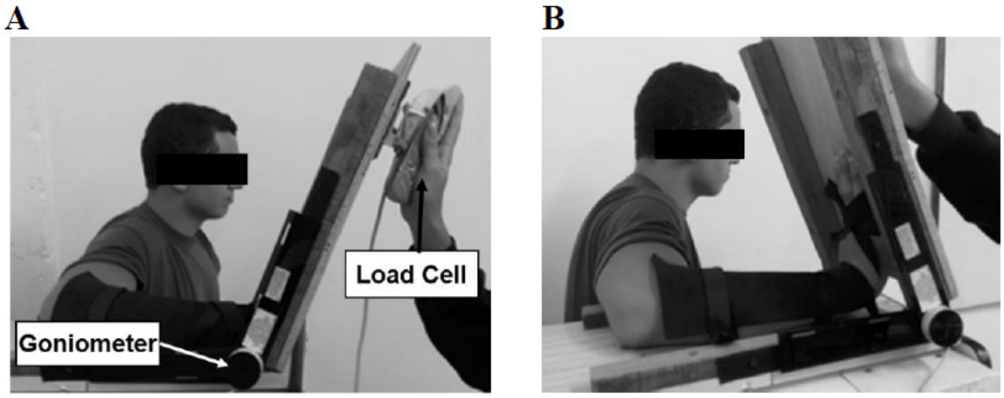

Figure 2A. Passive carpal hyperextension mobilization with load cell (initial position); **2B**. Passive carpal hyperextension mobilization with load cell (final position).

Dynamic Kimono Grip Strength Test

To perform the DYN test, a kimono (Atama Store) was placed on a beam (2.38 m and 10 cm wide apart) with demarcations on the collar indicating the place where the grip should be held. Then, the subject was instructed to hold the marks and leave the starting position with fully extended elbows and without any support on the floor. From that position, he was instructed to pull, flexing the elbows and extending the shoulders, until his head touched the pad attached in the beam, returning to the starting position as many times as possible.

The test was discontinued if the subject did not extend the elbows in the eccentric phase, did not reach the height specified in the concentric phase twice in succession or if the error persisted after the first incorrect repetition even with a verbal alert.

Isometric Kimono Grip Strength Test

With the same procedures used in the DYN test, the subject performed the hold at the marks on the collar of the kimono (judogi) and hung themselves with the elbows fully extended as long as possible. A chronometer (kk-2802 Kenko) was used to compute the time the subject remained suspended. The test was interrupted when the subject dropped the kimono (judogi) or touched the ground with his feet.

Exhaustion Exercise Routine

After performing all tests, the subjects sat at rest for 10 min. Subsequently, they performed an exercise routine intended to cause exhaustion of handgrip strength. The exercises consisted of three sets of maximum repetitions of pull-ups on the kimono (judogi) with 1 min of rest between sets. After an interval of 5 min, the subjects performed three sets of maximum isometric strength, gripping the kimono (judogi) and hanging themselves as long as possible with 1 min of rest between sets. Both exercises followed the same adjustments used in the DYN and ISO tests. The exercise routine for exhaustion lasted about fifteen minutes.

Statistical Analysis

The normality of the data was tested by Shapiro-Wilk tests. Intra-class correlation coefficients (ICC, parallel method), typical error of measurement (TEM) [18], Bland and Altman plots and limits of agreement [19] were used to verify the reliability of ROM, PT, HG, DYN and ISO tests.

The effect of SS on performance on the variables tested was determined by a two-way ANOVA (group x time) with repeated measures as a time factor. The Bonferroni post-hoc test was used to determine differences in the specific main effects or interactions when significant differences were found.

Data were analyzed using SPSS 17.0 for Windows (IBM, USA), and $\alpha = 0.05$ was adopted as the threshold of statistical significance.

Results

The reliability values of all dependent variables in this study are presented in Table 1. With the exception of the measure of PT, all others showed a high degree of association and agreement and low error.

Table 1. The reliability values of all dependent variables of measures Brazilian jiu-jitsu athletes (n = 15).

Variable	ICC (R)	TEM	TEM (%)	BIAS
ROM (degree)	0.85	2.9	3.0	–1.1
HG (kgf)	0.95	3.0	5.0	–0.6
DYN (n.)	0.89	1.3	8.0	–0.06
ISO (s)	0.85	8.7	16.0	0.86
PT (kgf)	0.65	1.8	29.0	0.06

Legend: **ROM** range of motion; **HG** handgrip strength; **DYN** dynamic kimono grip strength; **ISO** isometric kimono grip strength; **PT** passive torque.

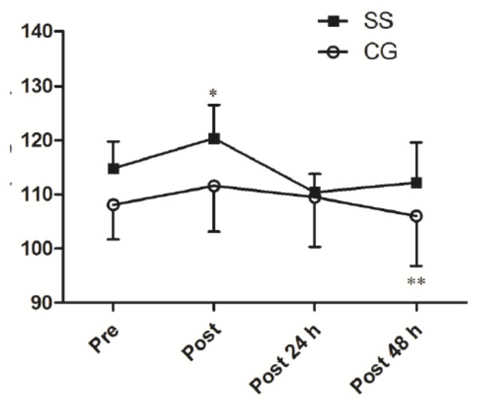

Figure 3. Changes in the time function indicator ROM. *significant difference in immediate post vs. pre measure ** significant difference in 48 h post vs. immediate post measure

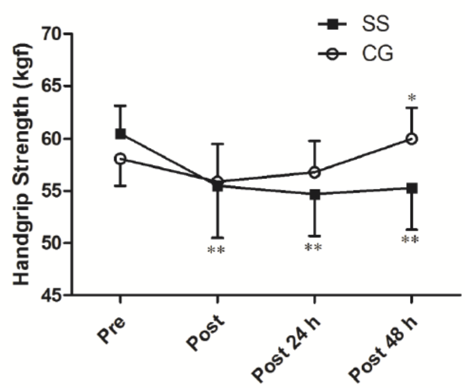

Figure 4. Changes in the time function indicator HG. * significant difference in 48 h post vs. immediate post. ** significant difference compared to pre.

The two-way ANOVA with repeated measures showed an interaction between group and time (p = 0.024) for ROM. The Bonferroni post-hoc identified a significant acute improvement in ROM (p = 0.035; 5%) in the SS group at the immediately post-test compared to the pre-test. There was a significant decrease (p = 0.037; 5%) in ROM for the CG 48 h post-test compared to immediately post-test (Figure 3).

The two-way ANOVA with repeated measures showed an interaction between group and time (p = 0.004) for unilateral HG strength. A significant decrease (p = 0.002) in HG for the SS group was identified as the main effect (time). The Bonferroni post-hoc identified a decrease in HG strength immediately post-test (p = 0.029; 8%), 24 h post-test (p = 0.004; 10%) and 48 h post-test (p = 0.037; –9%) for the SS group compared to the pre-test. There was an increase in HG strength (p = 0.032) for the CG at the 48 h post-test compared to immediately post-test (Figure 4).

There was no difference for the other comparisons in relation to all other variables measured in this study (Table 2).

Discussion

The main finding was that a 3 x 30 s SS routine increased ROM without causing changes in passive tension. Some authors have suggested the reduction in stiffness as one of the factors that causes the increase in ROM [20]. One of the most common mechanisms postulated to explain the reduction in passive stiffness and, consequently, the increase in ROM is autogenic inhibition. However, Mitchell et al. [21] were not able to verify this mechanism following a proprioceptive neuromuscular facilitation (PNF) technique and suggested that although the Golgi tendon

Table 2. Descriptive values of passive torque, number of repetitions and total time of isometric tests over 48 h in the control (CG, n = 7) and stretching groups (SS, n = 8) Brazilian jiu-jitsu athletes.

Variable	Post		Post 24 h		Post 48 h	
	CG	SS	CG	SS	CG	SS
Passive Torque (kgf)	6.7 ±1.8	5.7 ±2.0	6.8 ±2.7	6.3 ±3.1	6.4 ±2.9	5.1 ±2.3
DYN (n)	17.0 ±6.0	15.2 ±4.4	16.1 ±6.7	13.1 ±6.5	17.8 ±6.5	13.5 ±6.3
ISO (s)	47.5 ±18.4	53.4 ±19.0	44.4 ±20.5	48.4 ±20.2	47.3 ±20.1	44.7 ±26.5

Legend: **CG** control group; **SS** static stretching group; **DYN** dynamic kimono grip strength test; **ISO** isometric kimono grip strength test.

organ (GTO) is capable of inhibiting muscle tone, this effect is so fast that an acute improvement in ROM would be unlikely.

This mechanism was not likely the main mechanism responsible for the acute increase in ROM in this study because passive tension remained unchanged. However, there is evidence for the acute increase in ROM without changes in passive torque offered by the segment [22-24]. It is postulated that tolerance to pain and discomfort are the main mechanisms responsible for the increase. This study corroborated the body of evidence pointing to the increased tolerance to discomfort caused by stretching as one of the possible mechanisms that could explain the acute improvement in ROM.

Despite the fact that the acute increase in ROM is something desired and necessary in some sports, the inclusion of static stretching before sports events remains controversial and debated. Evidence points to impairment in strength and power, especially when high volumes are employed [10]. However, such deleterious effects are less frequent when shorter routines of SS that are closer to what is generally used before sports are performed [12, 25]. In the present study, 3 x 30 s of SS promoted a decrease of 8% in handgrip strength immediately after stretching, which lasted for 48 h. Considering the total volume of SS employed in this study (90 s), evidence shows that similar volumes were also able to further decrease strength in other muscle groups [26, 27].

It is still common to use SS during warm-up routines in order to reduce the symptoms of DOMS, which generally begin 8 h after the end of activity [28]. However, there is controversy about this effect, and some evidence does not support this claim. Bonfim et al. [13] reported that decrements in strength remain 72 hours after eccentric exercise, even with prior 3 x 30 s of SS, and attributed this result to the inefficiency of SS in reducing DOMS. Although no pain scale measure was used in the present study, it is largely postulated in the literature that strength loss (mainly maximum strength) is one of the strongest muscle damage indicators caused by exercise [29]. As in the present study, we observed a decrement in HG strength immediately after SS, which lasted for 48 h and may suggest that SS was unable to prevent the symptoms associated with DOMS, at least strength loss.

It should be noted that, in this study, SS did not promote decrements in dynamic and isometric strength in the DYN and ISO tests. It can be suggested that the HG test performed immediately after SS, but before these other two tests, may have been able to neutralize the possible deleterious effects. Similar to this finding, Little and Williams [30] found no decrease in vertical jump height when warm-up exercises were used immediately after stretching. Additionally, as these tests (DYN and ISO) were performed only approximately 10 min after SS, it is likely that this time was enough to suppress the deleterious effect of stretching. This belief is supported by Mizuno et al. [31] who showed the restoration of maximal isometric force levels 10 min after stretching exercises. Considering the protocol used in this study, stretch-induced strength loss likely would have dissipated when the DYN and ISO tests were performed. It should also be considered that because these tests involve other muscle groups that were not stretched (e.g., the arm, shoulder and back muscles), this factor may contribute to the absence of decline in performance on these tests.

It should be noted that, as far as we know, no studies have investigated the effect of SS on strength in small muscle groups, such as the flexors of the wrist and fingers. Most studies have investigate these effects on large muscle groups, such as the quadriceps, hamstrings and triceps sural [11, 32], making it difficult to extrapolate the findings in the literature for the muscles tested in this study. Thus, this study adds information about the acute effects of a SS routine preformed before exercise on ROM, passive torque and dynamic and isometric strength performance in smaller muscles that is very important for some sports, such as jiu-jitsu.

The importance of our observations raise the conclusions of a recent study published by the Iermakov et al. [33]. The authors concluded that grip strength is factor of martial arts sportsmen's successfulness specialising in throws and grips of immobilisation of opponent's body (judo, sambo, wrestling etc.). In the last three years published results of several studies in which authors applied different tests of grip strength both with reference to juveniles martial arts and combat sports athletes [34], as well as adults of both sexes [35, 36] and novices and experts, including Brazilian jiu jitsu [37].

The issue of gripping configurations during the execution of throwing techniques (particularly in judo) is being analysed in literature of science of martial arts in the wider context than from a perspective of results of hand grip, grip strength tests, muscle power etc. [38-40]. However possibilities of applying that kind of tests are going beyond the practice of sport. With good example of the possibility of the comprehensive application grip strength tests are firefighters studies [41]. Besides the body balance disturbation tolerance skills (BBDTS) important feature of firefighters are grip strength. Jagiełło et al. [41] formulating conditions for simulation of rescue task associated with the results of laboratory tests of BBDTS using "Rotational Test" [42] present drawing, in which firefighter transport the child to a safe place, where the only possible way of escape is narrow surface with a length of several meters located at a considerable height above the stable ground.

Conclusions

it was concluded that the use of static stretching routines similar to those used in the present study were able to increase ROM without promoting changes in the passive torque offered by the muscle-tendon unit, indicating a higher tolerance for discomfort as a main mechanism for this result.

Furthermore, because static stretching reduced handgrip strength and this impairment remained for 48 h, it is suggested that athletes avoid this practice before sports that require high levels of grip strength, as in jiu-jitsu.

Highlights

As far as we know, this is the first study to verify the effect of static stretching on ROM and strength in the muscles involved in the grab techniques often used in BJJ fighting. The results found highlight the importance of avoiding this practice before a BJJ fight.

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Cite this article as: Peixoto César E, da Silva TK, de Resende CS et al. The role of static stretching on performance variables and induced effects of exhaustion exercises in Brazilian jiu-jitsu athletes. Arch Budo 2016; 12: 211-218