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Effects of core strengthening on balance in university judo athletes

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ABSTRACT

Background: Core strengthening prepares the body in an integral, safe and efficient way, favoring balance and postural control; physical abilities constantly demanded in sports, especially in body contact modalities, such as Judo. **Objective:** This study investigated the effects of core strengthening on balance in university judo athletes.

Methods: Eighteen athletes from the University of Southern Santa Catarina (UNISUL) were randomly allocated into two groups: experimental ($n = 9$) and control ($n = 9$). Experimental group athletes were submitted to a core strengthening protocol (30-min sessions, twice a week for 5 consecutive weeks). Evaluations consisted of Stabilometric (center of pressure behavior parameters: total area in mm², laterolateral and anteroposterior width in mm) and baropodometric analysis [peak pressure: obtained during a 30-s acquisition period and expressed by foot area, i.e., (a) forefoot (metatarsal heads and toes); and (b) hindfoot (calcaneus region, distal third of the foot)]. Right/left foot ratios were calculated as relative percentages and used for the analysis. The analyzes were performed at baseline and after 5 weeks of core strengthening. The athletes were evaluated in two situations: eyes-open and eyes-closed. **Results:** Total right/left foot ratio pressure, right/left fore and hindfoot ratio pressure, as well as anteroposterior width measurements were statistically smaller in the experimental group.

Conclusion: Although the results obtained showed that core strengthening presents certain benefits, these data alone are not enough to confirm its effects upon postural oscillation in university judo athletes.

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1. Introduction

Postural control is a complex skill based on the interaction of dynamic sensorimotor processes, whose main functional objective involves postural orientation and postural balance. Postural orientation is related to trunk alignment in relation to gravity, and postural balance involves the coordination of movement strategies to stabilize the body mass center relative to its support base (Horak,

2006). It is known that in order to maintain balance, the postural system tends to maintain the body's center of pressure (CoP) within the limits of stability. This adjustment is performed by the integration of sensory receptors (somatosensory, visual and vestibular), musculoskeletal system and environmental conditions; together these factors maintain the orthostatic posture of the body. In this context, one of the principles of balance training is to prepare the body in an integral, safe and efficient way through core strengthening (Monteiro and Evangelista, 2015).

The term 'core' usually refers to the muscular control necessary to maintain functional stability, and involves the ability of the lumbopelvic-hip complex to prevent as well as re-establish balance after disruption (Joyce and Kotler, 2017). Although static elements (bones and soft tissues) contribute to some degree to core

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stabilization, it is predominantly maintained by the dynamic function of muscular elements. There is a clear relationship between trunk muscle activity and lower extremity movement, therefore, core stability is imperative for almost all global motor activities (Willson et al., 2005). A weak core triggers ineffective movement, and predisposes the individuals to injury; whereas a strong core provides a stable basis for the body to perform any movement in a balanced, coordinated and functioning manner (Richardson et al., 1999).

Postural imbalances in space can be observed through the position of the body's CoP in a stabilometric evaluation (Moreira, 2004). Posturographic analysis consists of graphical representations of CoP oscillations in anteroposterior and laterolateral directions (Oliveira 1993). This method has been applied both in research and as a clinical evaluation tool, to analyze postural balance (Chamlian, 1999). In addition to stabilometry, baropodometry is used to measure the distribution of static plantar pressure, by providing data on peak pressure on specific areas of the foot (forefoot and hindfoot); as well as the differences between these areas (de Oliveira et al., 2017).

Amongst sports modalities, judo can be defined as a “game” of constant balance and unbalance, action and reaction, in which two contestants struggle to gain points by either projecting and/or knocking the opponent to the ground; or to end a match altogether, by applying a hold or control technique (Detanico and Santos, 2012). In Judo, balance is of utmost importance, as the athletes need to maintain posture control and good balance to avoid losing points and ultimately the match (Alonso et al., 2008).

Even though judo is an Olympic modality, which attests to its global importance, few studies have been conducted on this sport (Detanico and Santos, 2012). While researchers have looked at the importance of orthostatic balance (Alonso et al., 2008; Sá and Pereira, 2003), and muscular strength (Gunsch and Silva, 2010) for Judo athletes; few studies investigated the effects of core strength on balance in Judo athletes.

In this context, the aim of the present study is to verify the effect of core strengthening on orthostatic balance in university judo athletes.

2. Methodology

This is a clinical trial with a non-probability sampling distributed in two groups (same category). Prior to conducting the study, approval was obtained with the Human Research Ethics Committee of the University of Southern Santa Catarina, following the guidelines proposed in Resolution 466/12 of the National Health Council (protocol number: 54422615.8.0000.5369).

2.1. Participants

All eighteen athletes from the university Judo Team were randomized by simple draw into control ($n = 9$) or experimental group ($n = 9$). Individuals in the control group did not receive intervention, whereas individuals in the experimental group were submitted to a core strengthening protocol.

The participants of the study had a green or a higher rank belt, at least three years of continuous training twice a week, and voluntarily agreed to participate in the study by signing an Informed Consent Form. Exclusion criteria were: having any problem or disabilities that would affect the continuity in the study; lower limb injuries in the previous 12 months; or presence of any neurological diseases or vestibular disorders of any etiology.

2.2. Core strengthening protocol

The core strengthening protocol consisted of 30-min sessions, twice a week for 5 weeks and was conducted after regular judo training sessions of the university judo team. The protocol used in the present study was adapted from Boyle (2015), and the exercises were conducted by the same researcher and performed in accordance to the sequence shown in Table 1.

Additionally, prior to each exercise, the athletes were instructed to perform core activation through specific verbal commands, such as: at the time of exhalation, perform a “ribcage contraction” together with a force “centering” movement, which consists of directing the navel posteriorly and at the same time contracting the pelvic floor. For each series performed, there were 10 s of interruption.

The exercises used in the protocol are described below (Fig. 1):

Abdominal butterfly: Lie in dorsal decubitus, upper extremities (UEs) elevated above the head line, maintaining contact with the ground while lower extremities (LEs) remain extended (panel A1). Initially, the limbs were flexed with a hip abduction, approaching the trunk until they reached the sitting position, while the UEs were directed forward, remaining always extended and parallel to the trunk (panel B1).

Climbing: In ventral decubitus with support on the palmar surfaces, maintain trunk alignment, with the LEs extended with tiptoe support (panel A2). The movement begins with the flexion of one of the LEs while the other one remains in extension (panel B2). Then the LEs position is alternately shifted in a coordinated fashion, always maintaining the same trunk position.

Trunk and LEs Extension: In ventral decubitus, shoulders and elbows maintained at 90°, hands aligned with ears, LEs extended and feet joined (panel A3). The movement begins with the extension of the trunk and the LEs simultaneously (panel B3).

Oblique Abdominal: In dorsal decubitus with extended LEs and UEs in abduction of 90° (panel A4), the movement begins with the elevation of the LEs toward the UEs and vice versa (panel B4). Movement is performed cross-shaped and alternating between the limbs.

Frontal plank with elastic band: In the supine position with support on the palmar surfaces, trunk aligned, LEs extended with tiptoe support and a mini elastic at the ankles (panel A5). The movement with outward jumps (abduction of the LEs) and inwards (LEs adduction) begins. In the execution of the exercises, the participants were asked to maintain the tension of the elastic band (panel B5).

2.3. Measurements

To evaluate postural control, a pressure platform (Medicapteurs, S-PLATE model; Balma, France) connected to a computer was used. Body oscillations were recorded in a frequency of 10 Hz. The platform has the following characteristics: 610 × 580 mm wide, 4 mm thick, and weighing 6.5 kg. The platform is equipped with 1600

Table 1
Core strengthening protocol.

EXERCISE	PROGRESSION	
	1st – 5th Day	6th – 10th Day
Abdominal butterfly	3 × 20 repetitions	3 × 25 repetitions
Climbing	3 × 30 s	3 × 35 s
Extension of trunk and lower limbs	3 × 15 repetitions	3 × 20 repetitions
Oblique Abdominal	3 × 20 repetitions	3 × 30 repetitions
Front plank with mini-elastic	3 × 30 s	3 × 35 s

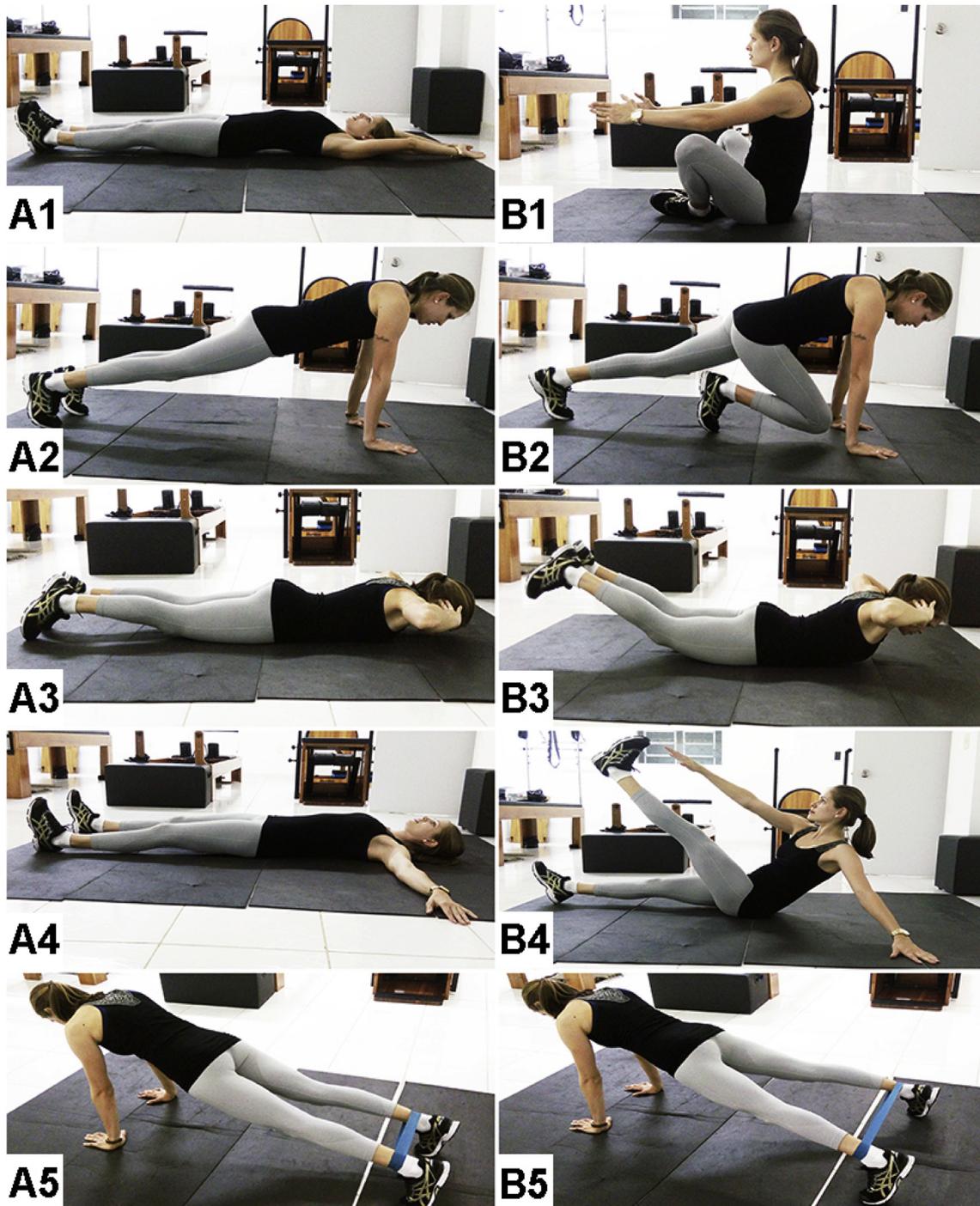


Fig. 1. Images of the core strengthening protocol. Starting (panels A1–A5) and ending positions (panels B1–B5).

pressure piezoelectric sensors (48×48) and acquires 100 images per second. Before each evaluation, the calibration of the platform was conducted using the individuals' weight. For the analyses, the participants were asked to remove their shoes and stand on the platform with the arms relaxed alongside the body for 30 s. The platform was calibrated with information on the individual body mass and each subject remained in orthostatic position on it, looking straight ahead (at a fixed point on the wall) and with arms dropped alongside the body. The subjects were instructed to keep the feet apart at a natural and comfortable position. The system recorded images for 30 s (300 frames) and the assessment was

performed with the subjects with eyes-open and then with eyes-closed. The means of three consecutive evaluations were used in the results.

In the baropodometry analysis the following parameters were measured: peak pressure (obtained during a 30-second acquisition period and expressed by foot area). The areas were defined according to the following: (a) forefoot (the metatarsal heads and the toes), and (b) hindfoot (the calcaneus region, the distal third of the foot). Right/left foot ratio was calculated as relative percentages and used for the analysis. In the stabilometric analysis, the following parameters of the center of pressure behavior were measured: area

(mm²), and laterolateral and anteroposterior (mm) widths, all captured by the platform and stored in the computer as indicators of postural balance.

2.4. Statistical Analysis

Statistical Analysis was performed with the GraphPad Prism 6.0 program; the Shapiro-Wilk test was applied, followed by paired or unpaired student *t*-test for parametric data and Wilcoxon or Mann-Whitney test for non-parametric data. Data was presented as mean \pm standard deviation (parametric) and median and interquartile range (non-parametric). Values of $p < 0.05$ were considered as statistically significant.

3. Results

Of the eighteen subjects in the sample, 8 were male and 10 were female, equally distributed among groups. In the control group, mean age was 23.4 ± 3.6 years and mean body mass index was 26.4 ± 4.5 kg/m². In the experimental group the mean age was 20.8 ± 3.2 years and the mean body mass index was 25.4 ± 4.1 kg/m².

3.1. Baropodometric parameters

Fig. 2 depicts right/left foot relative pressure ratio, pre and post intervention. In the open-eyes evaluation (Fig. 2A), a statistically significant difference was observed between the groups post intervention ($p < 0.05$). In Fig. 2B, in the closed-eyes evaluation, there was no difference between groups post intervention. However, there was an increase in foot pressure in the control group (57.3%), and a reduction in the experimental group (13.6%).

The results demonstrated in Fig. 3, shown right/left forefoot and hindfoot pressure ratio, pre and post intervention. There was no statistically significant difference between pressure peaks in the forefoot (Fig. 3A - $p > 0.05$). Hind foot pressure peaks significantly reduced, in both control (49.5%) and experimental (46.4%) groups post intervention, however, control and experimental groups did not statistically differ from each other (Fig. 3B). Fig. 3C and D shown that in the eyes-closed analysis there was no statistically significant difference between groups ($p > 0.05$).

3.2. Stabilometric parameters

The results illustrated in Fig. 4 demonstrate the body's CoP total

area. In the eyes-open analysis (Fig. 4A), there was no statistically significant difference between the groups ($p > 0.05$); however, in both groups an increase in the CoP total area was observed post-intervention (113.7% in the control, and 60.8% in the experimental group). In the eyes-closed evaluation (Fig. 4B), in both groups there was an increase in CoP total area (118.1%, $p < 0.05$ in the control, and 66.9%, $p < 0.05$ in the experimental group); however, control and experimental groups did not statistically differ from each other.

The results depicted in Fig. 5 demonstrate laterolateral and anteroposterior CoP oscillations in the eyes-open and -closed analysis, pre- and post-intervention. In the eyes-open evaluation, there was a statistically significant increase in laterolateral oscillation in the experimental group (width, $p < 0.05$) but not in the control group ($p > 0.05$). Furthermore, there were no statistically significant differences between groups post-intervention (Fig. 5A). In the eyes-closed analysis, there was no statistically significant difference between the groups ($p > 0.05$, Fig. 5B). In Fig. 5C, in the eyes-open evaluation, there was an increase on anteroposterior oscillation in the control group ($p < 0.05$) but not in the experimental group ($p > 0.05$). Furthermore, there was no statistically significant difference between the groups post-intervention (Fig. 5C). In the closed eyes analysis, there was no statistically significant difference between the groups ($p > 0.05$, Fig. 5D).

4. Discussion

This study verified the influence of a core strengthening protocol on balance in university judo athletes. The results demonstrate that: 1) A reduction in right/left foot pressure in the eyes-closed analysis was observed in the experimental group but not in the control group; 2) In both groups there was a reduction in peak hindfoot pressure, in the eyes-open analysis; 3) In both groups total CoP area increased after interventions in the eyes-closed analysis; 4) Laterolateral and anteroposterior oscillation increased in experimental and control groups in the eyes-open analysis. These findings show that athletes submitted to core strengthening presented fewer changes in the analyzed parameters when compared to the control group. This may suggest that the protocol performed in the present study improved the balance of the university Judo athletes.

According to Sikorski (2010), judo athletes need to efficiently control their dynamic posture, since the techniques of this martial art are based mainly on constant displacements that aim to disturb the opponent's balance in order to cause them to fall. During offensive movements, the postural regulation of experienced

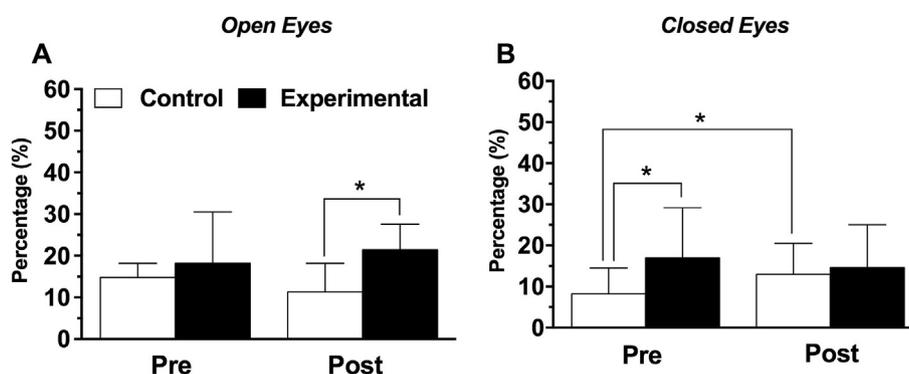


Fig. 2. Right/left foot relative pressure ratio in eyes-open (panel A) and eyes-closed evaluations (panel B), pre and post intervention. The white columns indicate the control group and the black columns the experimental group, the asterisks denote the significance levels ($*p < 0.05$). A: Control versus experimental [Mann-Whitney; pre ($p = 0.053$) and post ($p = 0.044$)]; Control (Wilcoxon, pre and post $p = 0.805$); Experimental (Wilcoxon, pre and post $p = 0.708$). B: Control versus experimental [Unpaired *t*-test; pre ($p = 0.002$) and post ($p = 0.507$)]; Control (paired *t*-test, pre and post $p = 0.034$); Experimental (paired *t*-test, pre and post $p = 0.641$).

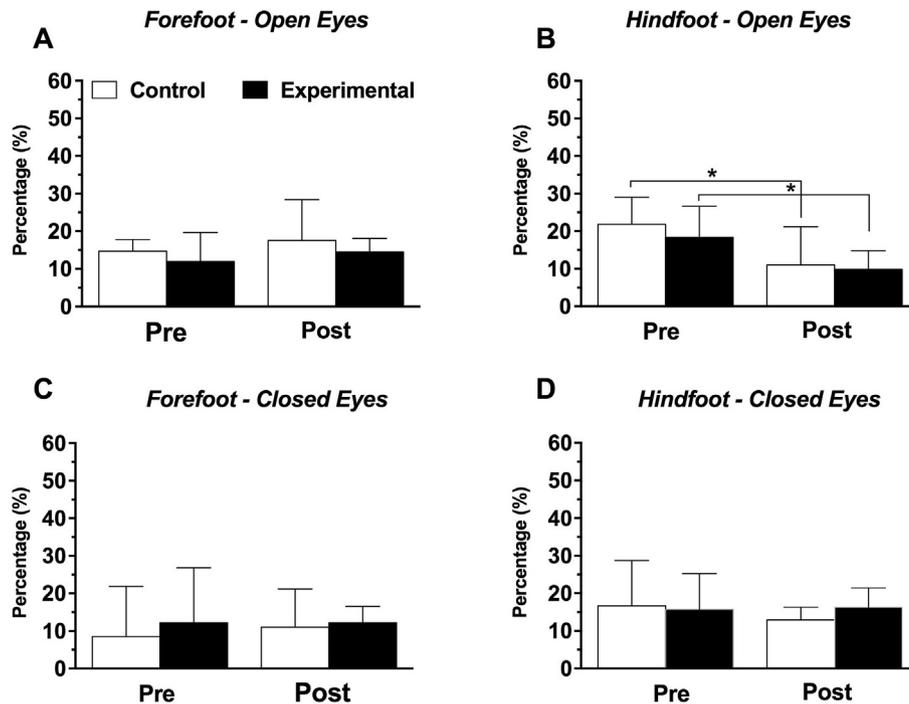


Fig. 3. Right/left forefoot and hindfoot pressure ratio, pre- and post-intervention. Forefoot with eyes-open (panel A); Hindfoot with eyes-open (panel B); Forefoot with eyes-closed (panel C); Hindfoot with eyes-closed (panel D), pre and post intervention. The white columns indicate the control group and the black columns the experimental group; the asterisks denote the significance levels ($*p < 0.05$). A: Control versus experimental [Mann-Whitney; pre- ($p = 0.261$) and post- ($p = 0.197$)]; Control (Wilcoxon, pre- and post- $p = 0.467$); Experimental (Wilcoxon, pre- and post- $p = 0.633$). B: Control versus experimental [Mann-Whitney; pre- ($p = 0.627$) and post- ($p = 0.659$)]; Control (Wilcoxon, pre- and post- $p = 0.029$); Experimental (Wilcoxon, pre- and post- $p = 0.042$). C: Control versus experimental [Mann-Whitney; pre- ($p = 0.105$) and post- ($p = 0.899$)]; Control (Wilcoxon, pre- and post- $p = 0.603$); Experimental (Wilcoxon, pre- and post- $p = 0.422$). D: Control versus experimental [Mann-Whitney; pre- ($p = 0.749$) and post- ($p = 0.141$)]; Control (Wilcoxon, pre- and post- $p = 0.597$); Experimental (Wilcoxon, pre and post $p = 0.558$).

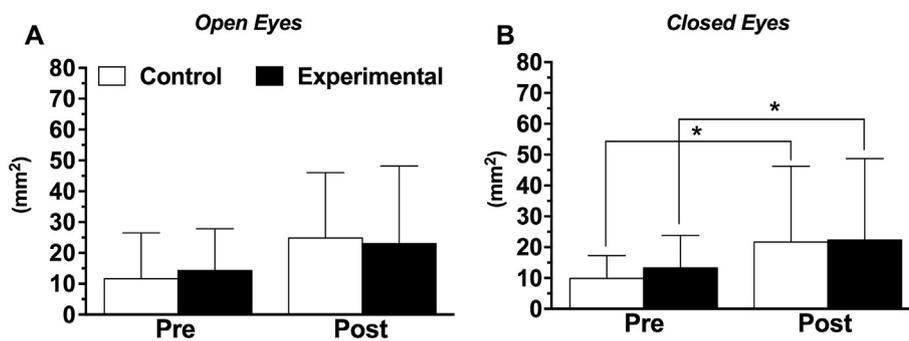


Fig. 4. Body's center of pressure (CoP) total area. Eyes-open (panel A) and eyes-closed evaluations (panel B), pre and post intervention. The white columns indicate the control group and the black columns the experimental group, the asterisks denote the significance levels ($*p < 0.05$). A: Control versus experimental [Mann-Whitney; pre- ($p = 0.982$) and post- ($p = 0.847$)]; Control (Wilcoxon, pre- and post- $p = 0.258$); Experimental (Wilcoxon, pre- and post- $p = 0.055$). B: Control versus experimental [Mann-Whitney; pre- ($p = 0.289$) and post- ($p = 0.826$)]; Control (Wilcoxon, pre- and post- $p = 0.033$); Experimental (Wilcoxon, pre- and post- $p = 0.007$).

athletes in combat sports is generally much more efficient than that of beginners; and judo training supposedly helps the acquisition of complex abilities and tactical excellence, which are often associated with effective postural control (Perrin et al., 2001).

Maintenance of postural control requires sensory perception of body movements, integration of sensory motor information into the central nervous system, and appropriate motor response. The position of the body in relation to space is determined by the integration of the visual, vestibular and somatosensory systems, whereas muscular control and the dynamic maintenance of balance, involve the coordinated activity of the muscular kinetic chains, which are circuits of organized muscles in directions and planes in which the propulsive forces of the body propagate (Alonso et al., 2008; Freitas and Przyssienzy, 2008). In this sense,

the present study was conducted to assess the effect of core strengthening on balance in eyes-open and -closed evaluations, to help pin-point the influence of the visual system on the results. The fact that better results were obtained in the experimental group in the eyes-closed evaluations, may be associated with increased awareness and control of the central muscles, leading to less body oscillation and, consequently, less time required to achieve postural stability (Martins, 2010).

According to Monteiro and Evangelista (2015), one of the principles of balance training is to prepare the body in an integral, safe and efficient way by strengthening its core or center. In this context, recent research has been investigating the use of core strengthening in sports, as a means of maintaining and/or improving muscle strength, balance, stability and performance. On this basis,

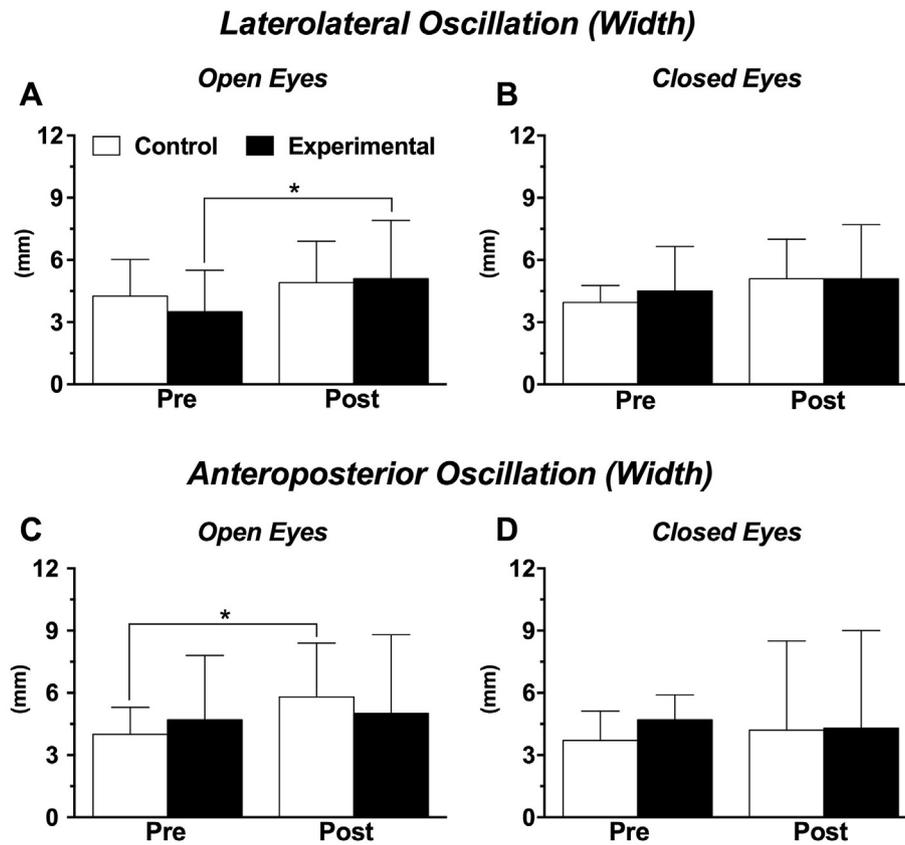


Fig. 5. Laterolateral and anteroposterior CoP oscillations (width) pre and post intervention. Laterolateral (A–B) and anteroposterior (C–D); eyes-open (A–C) and eyes-closed evaluations (B–D). The white columns indicate the control group and the black columns the experimental group, the asterisks denote the significance levels ($*p < 0.05$). A: Control versus experimental [Mann-Whitney; pre- ($p = 0.164$) and post- ($p = 0.556$)]; Control (Wilcoxon, pre- and post- $p = 0.380$); Experimental (Wilcoxon, pre- and post- $p = 0.009$). B: Control versus experimental [Mann-Whitney; pre- ($p = 0.366$) and post- ($p = 0.633$)]; Control (Wilcoxon, pre- and post- $p = 0.074$); Experimental (Wilcoxon, pre- and post- $p = 0.162$). C: Control versus experimental [Mann-Whitney; pre- ($p = 0.052$) and post- ($p = 0.741$)]; Control (Wilcoxon, pre- and post- $p = 0.004$); Experimental (Wilcoxon, pre and post $p = 0.557$). D: Control versus experimental [Mann-Whitney; pre- ($p = 0.163$) and post- ($p = 0.937$)]; Control (Wilcoxon, pre- and post- $p = 0.124$); Experimental (Wilcoxon, pre- and post- $p = 0.346$).

in the study carried out by [Samson et al. \(2007\)](#) tennis players with a strengthened core have functional strength and dynamic balance during continuous movements and during movements in which complex skills are required. In addition, [Sumulong \(2003\)](#) observed similar effects in swimming athletes, demonstrating that strengthening the core as well as providing strength gain also allows for proper body alignment and increases central power, consequently there is greater speed, less effort and greater efficiency.

However, to the best of our knowledge there are no studies that investigated the effects of core strengthening on balance in judo athletes. [Silva \(2011\)](#) compared the strength of the transversus abdominis and multifidus muscles between judo athletes and sedentary individuals with the help of a stabilizer. [Alonso et al. \(2008\)](#) compared balance in judo athletes and sedentary individuals, using the Biodex® balance system. [Lien and Tang \(2003\)](#) demonstrated that judokas have better balance control and postural adaptations to external disturbances than non-judokas. [Sá and Pereira \(2003\)](#) added that judo training increases balance. However, [Perrin et al. \(2001\)](#) compared dancers and judokas and found that judokas had better postural control, with lower center of gravity oscillation, regardless of visual information or proprioception disturbances. In none of the studies mentioned herein, there is an association between the two variables analyzed in this study (core strengthening and balance). Besides, none of the aforementioned studies compared judo athletes with their own peers – with

and without core strengthening interventions.

What is observed in the literature is that, for high level athletes, regardless of the modality practiced, strengthening of the central muscles is essential to obtain strength, neuromuscular control and balance of the lumbopelvic-hip complex, since muscle weakness or lack of neuromuscular control can lead to postural instability and less efficient movements ([Fredericson and Moore, 2005](#); [Santos et al., 2009](#); [Carvalho et al., 2011](#)). In judo, postural balance (static and dynamic) is fundamental for a good attack and defense, and, consequently, athletes and practitioners are trained to develop balance in combat reactions ([Alonso et al., 2008](#)).

In the present study, computerized baropodometry (Medi-capteurs®) was used. This system measures imbalances of the body in space, constituting reliable data and objective measurements ([Moreira, 2004](#); [Anjos 2006](#)). In posturographic analysis, stabilometry was used for the graphical measurement of CoP oscillations, both in the anteroposterior and laterolateral directions. According to [Medi-capteurs \(1998\)](#) research laboratory, individuals with displacements above 5 mm are classified with tendency to orthostatic imbalance. The smaller the oscillations, the greater tendency to balance in the orthostatic position. In the present study, in the eyes-open stabilometric analysis, the experimental group showed an increase in laterolateral displacement, whereas in the control group, antero-posterior displacement was increased in eyes-closed analysis. Thus, data from the present study suggest that in the open-eye analysis, the experimental group worsened postural

control by increasing sagittal axis oscillation and the control group worsened postural control by increasing frontal axis oscillation. It was concluded that clinically strengthening the core could produce a specific effect on postural control.

Postural control has been modeled as an inverted pendulum. CoP displacement on the anterior-posterior plane is believed to be controlled primarily by ankle musculature, and CoP displacement on the lateral plane is believed to be controlled primarily by hip musculature (Gage et al., 2004; Vieira et al., 2009). Passive properties of muscle tissue may contribute to the process of postural stability (Kuczyński, 2001). Different levels of passive muscle stiffness may be related to different postural strategies activated by the Central Nervous System (Winter et al., 2001). For example, ankle joint muscle stiffness allows the maintenance of balance during anterior-posterior excursions of the center of mass (Winter et al., 2001). Hip joint muscles (i.e. hamstrings) contribute to stability and balance in the sagittal plane (Moorhouse and Granata, 2007). It is commonly assumed that the amplitude of postural sway is a valid measure of postural stability. Postural control is reflected in a small postural sway area in quiet standing and in the ability to approximate the center of pressure either the border of the support surface (Błaszczyk et al., 1994). The distance separating the COP from the border, called the margin of safety (Błaszczyk et al., 1994; Pai and Patton, 1997), has been proposed to quantify mechanical stability (Hof et al., 2005). According to these authors, increasing the amplitude of the COP displacements on either sagittal or frontal axis, means a reduction of the margin of safety and may be interpreted as a change in postural stability (Błaszczyk et al., 1994).

The core strengthening protocol may have had an influence on CoP displacement, since core training aims at better postural control and the maintenance of good trunk alignment, with synergism with the abdominal muscles, for balance of the pelvis, which may justify the improvement of the experimental group in the stabilometric analyzes. This is possibly due to an improvement in muscle tone, which decreases muscle fatigue during activities in a shorter amount of time (Marés et al., 2012). In addition, all central stabilizing muscles are deep, mono-articular and have segmental insertions, being involuntarily activated 30–50 ms before voluntary movement of the extremities, allowing postural adjustments of the trunk and keeping the lumbar spine in a neutral position, regardless of the load and direction of movement, ensuring a more harmonious final movement with minimal energy expenditure. In short, deep muscles provide a stable trunk support by relieving the load on the spine, allowing the superficial muscles to perform the movement itself (Moura et al., 2015). Such benefits obtained with the strengthening of the core can contribute significantly to the practice and performance of judo athletes.

4.1. Limitations

The training phase of the athletes may have influenced the results. To avoid the influence of fatigue as well as other stressors that occur during the training season, a similar study should be conducted in the pre-season and/or post-season for comparison of results.

Additionally, because the study was conducted with such a specialized group of athletes, sample size was relatively small. A multicenter trial involving Judo athletes from different universities may be a good alternative.

5. Conclusion

The present study offers a new research approach with judo athletes, one that seeks to understand the effects of core

strengthening on balance control. Although the results obtained herein showed that core strengthening presents certain benefits, such as total right/left foot ratio pressure, right/left fore and hind-foot ratio pressure, as well as anteroposterior width measurements which were statistically smaller in the experimental group; this data alone is not enough to confirm that core strengthening improves postural oscillation in university judo athletes. Larger sample sized trials are recommended.

5.1. Clinical relevance

- The benefits produced by the strengthening of the core in the balance of judo athletes highlight the possible utility of implementing this approach in the long-term training routine of athletes.
- Stabilometric analysis could be used to monitor the improvement of balance during the training period.

Declarations of interest

None.

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