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Short title: Functional training for stability

Effects of Grouped versus Alternating Functional Training on Shoulder Girdle and Lumbar-pelvic Girdle Stability: A Randomized Controlled Trial

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Effects of Grouped versus Alternating Functional Training on Shoulder Girdle and Lumbar-pelvic Girdle Stability: A Randomized Controlled Trial

Objective: We verified the effect of 10 weeks of structured FT grouped by muscular actions (GFT) or alternating actions (AFT) on scapular and lumbar-pelvic girdle stability. Method: One hundred and twenty adults (60 men; 60 women) were allocated into three groups, GFT (n = 40) that performed the actions in sequence (squat - squat - pull - pull), AFT (n = 40) that performed alternate actions (squat - pull - squat - pull) and the control group (CG, n = 40). The shoulder girdle and pelvic girdle stability was assessed using the Octobalance Upper Body Test. Results: The GFT increased stability after the intervention and compared to the CG ($p = 0.003$) as assessed by the relative range of the right (ES: 0.53) and left (ES: 0.57) hemispheres. Besides, most results were within the instrument's error value and the magnitude of the effect was moderate to trivial among the experimental groups. Conclusions: Therefore, ten weeks of functional training performed in a grouped sequence promoted improvements in scapular and lumbar-pelvic girdle stability.

Keyword: Knee Osteoarthritis, Balance Test, Reproducibility.

INTRODUCTION

The lumbar-pelvic-hip complex consists of musculoskeletal and ligamentous structures that stabilize the spine and pelvis (Chang et al., 2017). Moreover, weaknesses and imbalances in the musculoskeletal structures affect pelvic function, as well as the function of the shoulder and adjacent structures (Pogetti et al., 2018; Radwan et al., 2014). Thus, exercises to improve trunk stability and strength are considered essential in physical training, rehabilitation or injury prevention programs (Andersson et al., 2017).

From this perspective, functional training (FT) is a strong alternative to increase strength and trunk stability (Da Silva-Grigoletto et al., 2019; Shahtahmassebi et al., 2019), together with improving performance and reducing the incidence of injuries (Distefano et al., 2013; Mesquita et al., 2019). This method is based on multi-component exercises (agility, balance, endurance, strength and muscle power) integrated in the same training session requiring intense activation of trunk stabilizing muscles in tasks similar to activities of daily living, work and sport (Da Silva-Grigoletto et al., 2020; La Scala Teixeira et al., 2017).

The sequence of exercises for FT can be grouped by muscle actions with exercises that refer to the same functional action in sequence (e.g., squat followed by squat) or alternating, with the functional actions being alternated during the circuit (e.g., squat followed by pushing). The impact of the sequence of FT exercises has not been previously explored.

Impairments in the interaction or integration of trunk, pelvic and scapular muscular coordination can affect functional performance (Tarnanen et al., 2012; Vega Toro et al., 2016). Functional training is a possible strategy to enhance the coordination between trunk, scapular and pelvic girdle in daily actions (Becker et al., 2018). Despite the numerous investigations demonstrating the effectiveness of FT in improving performance in daily activities (De Resende-Neto et al., 2019), its effects on the stability of the shoulder girdle and lumbar-pelvic girdle are still unclear.

Another point is the difficulty in assessing the interaction between the scapular, pelvic and trunk actions due to the complex neuromuscular issues involved. The current tests subject the individual to dynamic challenges for the trunk seeking to bring the tests closer to reality. In this line, the Upper Body Test was validated recently with excellent reproducibility (Gonzalo-Skok et al., 2015), in this test the subject remains in a position of three supports (Bird dog) and with one hand moves the arm in different directions challenging the abdominal muscles and the stability of the scapular and pelvic girdle during movements.

Therefore, we verified, through a new form of evaluation, the effects of functional training either with a grouped or alternating sequence on scapular and pelvic girdle stability in untrained young adults. It was hypothesized that the grouped sequence training would be more effective than the alternating sequence for improving scapular and lumbar-pelvic girdle stability due to increased muscle stress when we group an action (three same exercises consecutively).

METHODS

This was a controlled and randomized trial, lasting 16 weeks. Weeks 1-2 and 15-16 were designed to assess the stability of the shoulder girdle and lumbar-pelvic girdle, weeks 3-4 to familiarize themselves with the exercise program and weeks 5-14 to apply the training protocol. In addition, nutritional monitoring was carried out by recall to control one of the intervening factors.

Participants

Based on a statistical power analysis (see statistical analysis section) 120 asymptomatic young adults (60 men; 60 women) without restrictions for the practice of high intensity FT were recruited through digital media and randomly allocated to three different groups, according to their initial levels of stability, that´s mean both groups there was the same among of individuals stable and unstable. They were allocated to grouped functional training (GFT: n = 40; 23.8 ±

5.0 years), alternating functional training (AFT: n = 40; 25.9 ± 6.4 years and control group (CG: n = 40; 24.5 ± 5.14 years. Individuals without recent neurological, cardiac or orthopedic injuries (<1 year) were included and after the intervention, participants with low attendance (<85%) or who missed the assessment were removed from the analyses (figure 1).

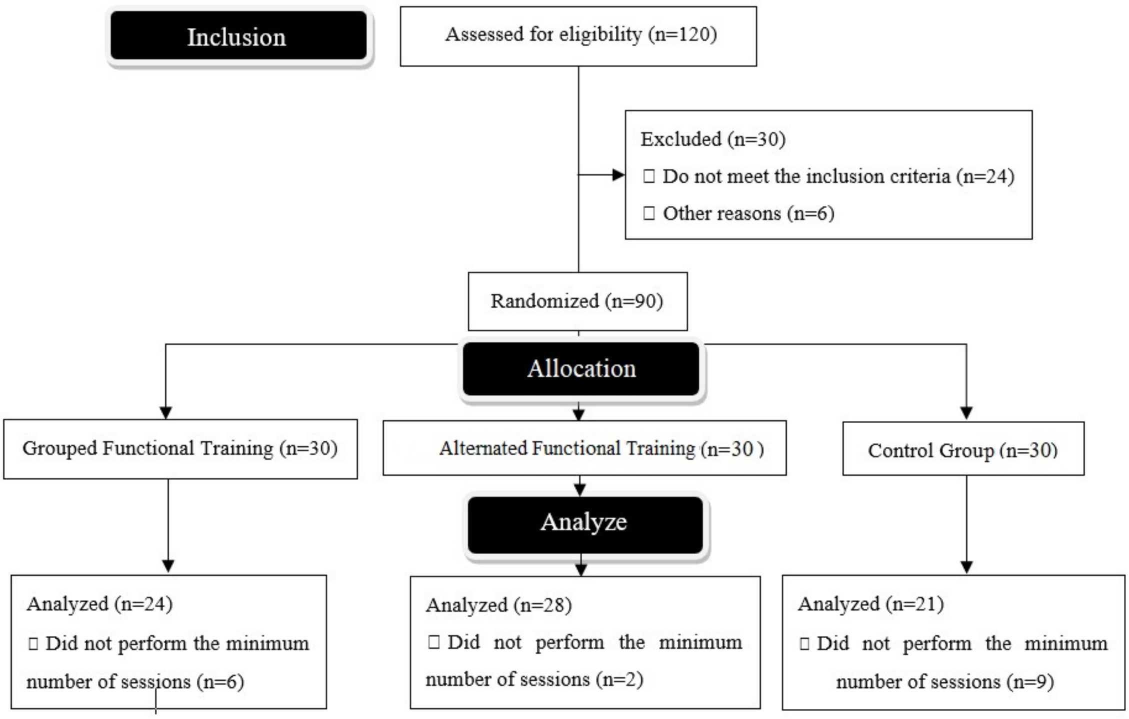

Figure 1. Flowchart.

The eligible individuals underwent an initial interview to record demographic, behavioral and health status. After clarifying the possible risks and benefits associated with the research, volunteers were asked to sign a Free and Informed Consent Form. This study followed the recommendations proposed by CONSORT (Schulz et al., 2010), was approved by the Research Ethics Committee of the Federal University of Sergipe (053820/2017) and is in accordance with the Declaration of Helsinki for research with humans.

Procedures

Participants completed 30 training sessions, lasting 60 minutes, three times a week and a minimum recovery time of 48 hours between sessions. Each FT session was divided into four blocks. In the first block of each session, the preparation of the movement was performed (10 min), with exercises for mobility of the main joints of the body, activation of the stabilizing muscles of the trunk in addition to coordinating exercises. For core activation, ventral and lateral plank exercises, bridge and bird dog exercise were used (Imai et al., 2014). Coordination was stimulated with verbal commands or gestures guided by the instructors, in which the subjects should perform actions of squatting, jumping and moving in the shortest possible time (reaction time), in addition to gait exercises in the frontal and sagittal planes.

The main part of the session was divided into two major circuits (Neuromuscular I and Neuromuscular II), each consisting of six exercises. In neuromuscular I (20 min), the exercises were directed to the agility and muscle power of the lower and upper limbs, through exercises with light or moderate loads performed at high speed of displacement, medicine ball pitches, initially in the transversal plane, with progression to the front.

In neuromuscular II (25 min), the maximum dynamic force was stimulated through the execution of the functional patterns of pushing, pulling, crouching, carrying and their variations. They were used from exercises with body weight and variable resistance, such as push-ups and the action of pushing with elastic bands of different densities and unilaterally. The pull pattern varied between pull-ups (pulls) with the use of suspension straps initially in vertical postures to horizontal positions and the use of elastic and free weights. Finally, the crouching pattern used basic bilateral squats to unilateral executions and use of external loads (Olympic bars, kettlebell).

Precisely in neuromuscular II, there was a methodological differentiation in the organization or sequency of exercises in a grouped or alternated patterns by muscular actions. GFT carried out the actions in the following sequence: crouch - crouch - pull - pull - push - push. On the other hand, AFT performed the exercises alternately as follows: squat - pull - push - squat - pull - push.

The fourth block, cardiometabolic (5 min), consisted of high intensity interval exercises (HIIT), with equal effort and recovery time (density) between the groups, as well as the activities developed (i.e., interval running).

The intensity of the main blocks was monitored and normalized between the groups using the Borg effort scale (CR-10), in which the individuals mentioned a score referring to the degree of effort (Arney et al., 2019). The scale was applied after each of the four training blocks. An intensity ranging from 6 to 9 for training was established for all training sessions. The effort / recovery ratio (exercise execution time and recovery), used in the last three blocks mentioned above, was initially 30 s / 30 s (1-3 weeks), 40 s / 20 s (4-7 weeks), 45 s / 15 s (8-10 week).

The tests were performed pre- (week 0) and post-intervention (week 10) in the afternoon. The measurements were taken by researchers blinded in relation to the exercise protocol, always adjusting the devices and instructing the individuals in the execution of the tasks. All individuals wore sportswear and were verbally encouraged during the assessments.

The measurements of body mass and height were performed using an anthropometric scale and a stadiometer (Welmy, R-110, São Paulo, SP, Brazil), respectively. In addition, the body mass index (BMI) was calculated using the weight divided by the height squared.

Upper Body Test: This test evaluated the stability of the scapular and lumbar-pelvic girdles using OctoBalance® (Check Your Motion®, Basic Model, Albacete, Spain). Octobalance is a validated instrument with good reproducibility (0.87 to 0.94) with values from 4.4 to 4.6 for detecting minimal changes in the evaluation standards and 3.3 to 3.8 the side of the body (reaching of the shoulder to the upper and lower body regions). The values obtained were expressed in values relative (%) to the length of the upper limb (Fontes et al., 2020).

For evaluation, the length of the upper limbs of the subject in an upright posture was measured from the acromion to the radio´s styloid process. For this measurement, the shoulder was flexed at 90º, with the elbow maintained in extension and the wrist in hyperextension (Gorman et al., 2012). Three tests were performed followed by three more measures to measure the distances obtained in each movement pattern of the Upper Body Test. An interval of 30 s was provided between each measurement based on the procedures suggested by Gonzalo-Skok et al. (2015). Two movement patterns were used for each body hemisphere, supralateral and inferolateral (figure 2). The test began with the participant on their hands and knees. Their hands rested on the OctoBalance® fixed platform on the side indicator arrows, knees on a thin layer of foam with 90° flexion for the hips, knees, ankles and shoulders (Figure 2A). To assess the left supralateral pattern, a hip and knee extension on the left side was requested, followed by movement of the right upper limb, as shown in figure 2B. Then, the initial position was resumed and the evaluation for the left inferolateral pattern was performed, again with hip and knee extension movement of the mobile platform by the right upper limb obliquely across the body as shown in figure 2C. After evaluating the left side, a contralateral evaluation was performed.

Figure 2. Upper Body Test assessment positioning: A. Initial position; B. Final position of the left medial superior pattern; C. Final position of the left lateral inferior pattern.

All participants were instructed to maintain posture at the time of assessment, thus avoiding trunk rotation, flexion of the lower limb in elevation, partial uncoupling of the shoulder joint and flexion of the elbow for the supporting limb. Additionally, the participants were instructed to maintain voluntary activation of the abdominal muscles, to ensure the position of the trunk, and to breathe normally.

The test trial was invalidated and repeated for a maximum of three times in the following situations: a) pushing the mobile platform sharply; b) move the mobile platform intermittently; c) lose balance during the test movement or failing to return to the initial support; d) Do not move the platform obliquely in line; e) exaggerated elbow flexion (approximately 15º) occurs in the supporting member; f) losing hip extension; or g) to raise the lower limb ipsilateral to the side that displaces the mobile platform (Fontes et al., 2020). The Upper Body Test index for each pattern was obtained by using the arithmetic mean of the values obtained in each direction and pattern, divided by the length of the limb corresponding to each side, and then multiplied by 100.

Statistical analysis

The data were treated and analyzed using the Statistical Package for the Social Sciences (SPSS - version 22) software. The sample calculation was performed based on the results of Fontes et al. (2020), using G*power version 3.1.9.2 (Faul et al., 2007), requiring a sample of 23 individuals per group to obtain 80% statistical power. Assuming a sample loss during the intervention, an additional 30% was added in an attempt to ensure sufficient statistical power.

The distribution of the data was verified using the Kolmogorov-Smirnov test, while the homogeneity of the variances was assessed by the Levene test. Inferential analyses were performed using a 2-way ANOVA (3x2) for repeated measurements, followed by the Bonferroni post-hoc test to assess the interaction between the three group and time (pre- and post-intervention) factors.

The effect size (ES) was analyzed to determine the magnitude of the effect independent of sample size; ES was estimated by the difference from the standardized mean (ES = (Post mean - Pre mean) / Standard deviation pre) and classification proposed by Cohen (1988).

Classifications were interpreted based on the following criteria: <0.2 trivial effect; 0.2–0.49 small effect; 0.50–0.8 moderate effect; and >0.8 large effect. For all analyzes, the statistical significance adopted was p <0.05.

RESULTS

The general characteristics of the participants at the beginning of the study are shown in Table 1. No statistically significant main effect differences were found between the groups.

Table 1. General characteristics of participants in the (CG, n = 21) at the beginning of the intervention.

Characteristics	**GFT (24)**	**AFT (28)**	**CG (21)**	**p**
Age (years)	23.8 ± 5.0	25.9 ± 6.4	24.5 ± 5.14	0.31
Height (cm)	165.1 ± 7.2	164.74 ± 6.8	163.7 ± 8.7	0.88
Body mass (kg)	67.4 ± 9.8	68.2 ± 10.8	65.6 ± 9.8	0.30
BMI (kg/m^2)	24.65 ± 3.15	25.41 ± 3.82	23.99 ± 3.14	0.28

Note. BMI: body mass index; GFT: grouped functional training group; AFT: alternate functional training; CG: control group. Values presented as mean ± standard deviation.

A significant interaction demonstrated that only the GFT increased stability after the intervention and also when compared to the CG (p = 0.003) in the relative percentage range of the right and left hemispheres. In addition, most results showed to be within the instrument's error value and the magnitude of effect observed for the experimental groups ranged from moderate to trivial (figures 3 and 4).

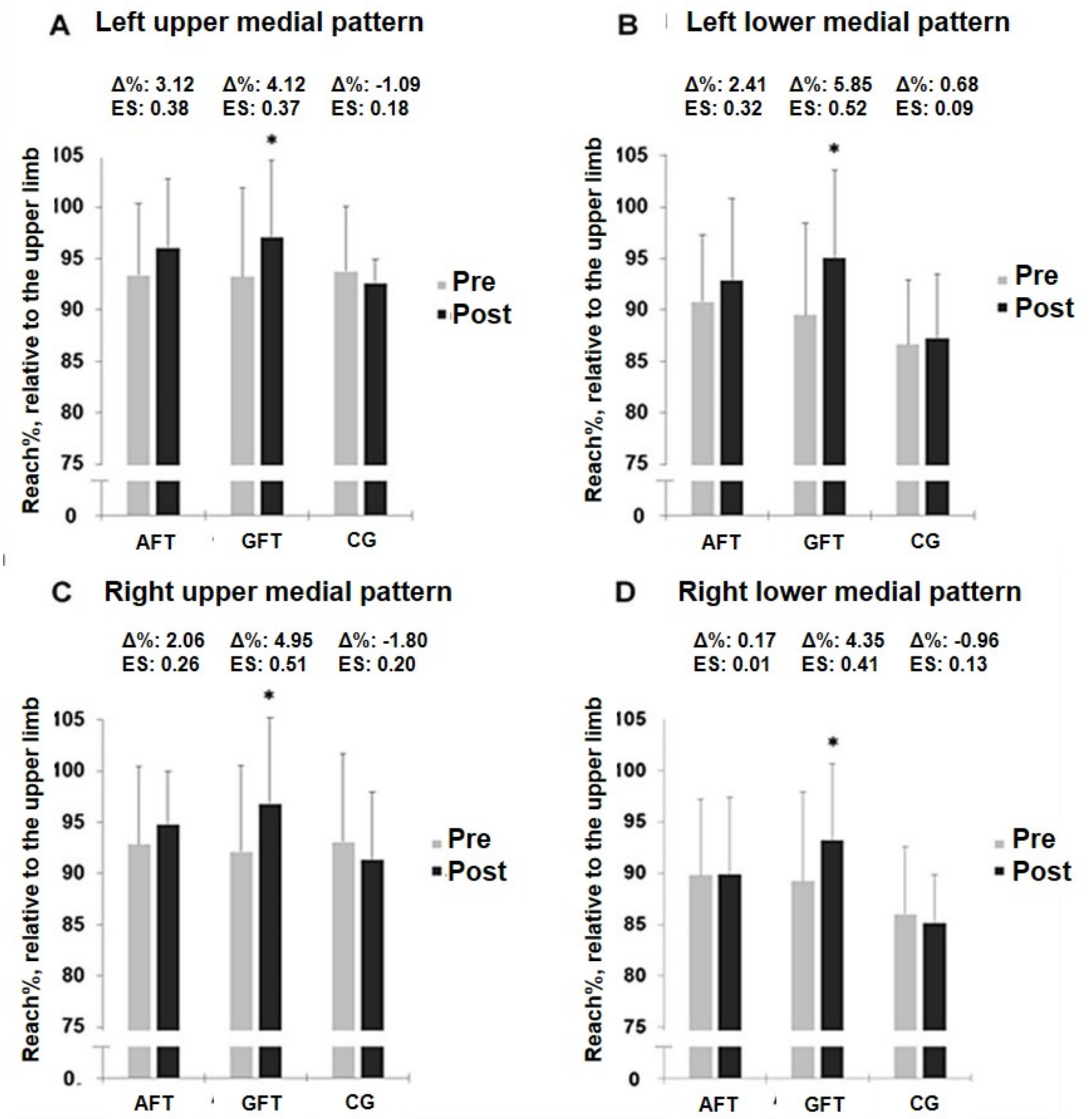

Figure 3. Effects of the groups on the percentage reach relative to the upper limb in the Upper Body indices for each evaluated standard. Note. * p <0.05 for intragroup comparison (pre versus post).

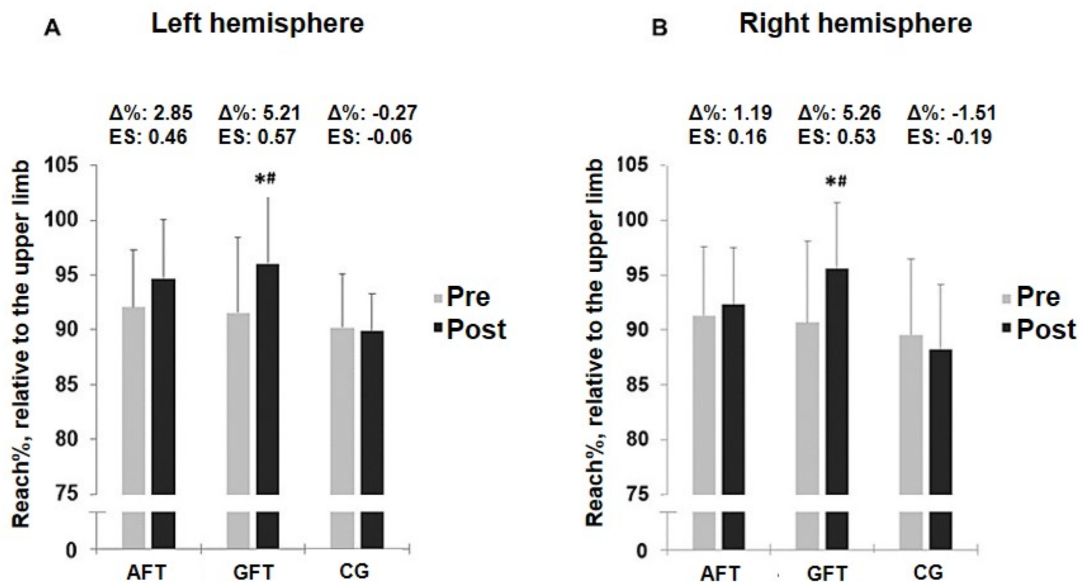

Figure 4. Effects of the groups grouped functional training (GFT, n = 24), alternate training (AFT, n = 28) and control (CG, n = 21) on the percentage reach relative to the upper limb in the Upper Body indices for each body hemisphere. Note. * $p < 0.05$ for intragroup comparison (pre versus post). ES = Effect Size; Δ = percentual change.

DISCUSSION

The main finding of this study is the improvement caused by GFT in the stabilization of the scapular and lumbar-pelvic girdle after 10 weeks of training, both in the right and left hemispheres. For all the evaluated patterns, low effect size and modifications between the pre- and post-test were obtained, which are within the error range of the evaluation instrument (4.4-4.6). This may be due to the low intensity of the training, however, it seems that the assessments of the both of side body are more sensitive to assess the stability of the shoulder girdle and pelvic girdle.

Thus, the improvement obtained by the GFT can be explained by the greater perceived exertion of training resulting from the consecutive execution of the same exercise, which can generate greater metabolic acidosis and thus provide important adaptations in muscle resistance and activation threshold of stabilizers (Brentano et al., 2017), confirming the initial hypothesis.

In relation to the effects of performing high-intensity exercises on functional test scores for the upper limbs, Salo and Chaconas (2017), using the Y-Balance Test, observed a significant reduction in the scores after a high intensity, fatigue-inducing, resistance training protocol for upper limbs. However, this acute overload, if repeated over time, can generate a positive adaptation for stabilization of the shoulder girdle and pelvic girdle that provides better scores in the evaluation for the both side body (Marginson et al., 2005). In addition, the increase in exercise exertion in the present study may have promoted changes in the tonic control of synergistic structures so that the execution of the exercise is maintained over time (Brennecke et al., 2009).

Furthermore, when exposed to high exertion (consecutive performance of the same exercise) and consequently to greater fatigue, the lumbar muscles are capable of making changes in the spatial distribution of muscle activity. These changes indicate relative adaptations in the intensity of muscle contraction and can be attributed to the variation in the control of motor units within a muscle and possibly between muscles (Farina et al., 2008). Asymptomatic people show greater variability in muscle activation, suggesting that adequate motor variability is necessary to optimize and maintain motor performance in dynamic actions and this plays an essential role in the distribution of mechanical loads along the spine and consequently to delay the fatigue.

In addition, during segmental movements performed on a daily basis, such as the movement of sitting and getting up from a chair14, the reduced motor variability of trunk muscles is associated with increased muscle fatigue and decreased resistance (Abboud et al., 2014; Roth et al., 2019). Thus, we suggest that the GFT group was exposed to greater trunk fatigue and this stress provided greater training of the motor variability of the trunk muscles, which reflected in better performances in the Upper Body Test.

The slight difference in pelvic and scapular stabilization found in the GFT group, even in the absence of specific exercises for trunk stabilization during training, can be partially explained by the integrative multi-segmented characteristic with typical FT accelerations and decelerations, providing a greater challenge to trunk stabilization. Such changes favor improvement in motor control (Davin & Callaghan, 2016). As an example of functional actions, when using the push pattern, during push-up exercises, the recruitment of the various muscles of the trunk, shoulder and arms occurs in an integrated and simultaneous manner with the aim of controlling movement (Marcolin et al., 2015). In addition, the use of suspension exercises with instability (i.e., suspension bands) provides greater activity for the trunk or core muscles, in an attempt to counterbalance uncoordinated movements, promoted by the instability of the support base (Cugliari & Boccia, 2017; Escamilla et al., 2010).

The elevation of the contralateral upper and lower limb with the testing necessitates deep stabilizers and scapular muscle activation (Pirouzi et al., 2013). The stabilization of the lumbar-pelvic region is also important, due to the asymmetric positioning of the support base during the Upper Body Test. There is an asymmetric abdominal muscle activation, so that there is an increase in spine stiffness (Okubo et al., 2010). Thus, the stability in the test position is explained by the mechanism of the anti-rotational action exerted by the oblique muscles, in which there was a high muscle activity of the contralateral internal oblique and of the ipsilateral external oblique, in relation to the upper limb in support at the base. In this sense, Okubo et al. (2010) verified by means of electromyography that there is an ideal cooperation between the activation of the oblique muscles (contralateral internal oblique and the ipsilateral external oblique) to maintain the neutral posture of the pelvis and spine, when balancing the internal and lateral forces of shear that are imposed on the spine and promote the reduction of forces that are attributed to the spine.

In addition to this process of muscular cooperation, Vera-García et al. (2015) described trunk stabilization as a multifactorial process that results from the interaction between sensory, motor and neural systems, to maintain coordination of movements and maintenance of posture. This interaction is also necessary to ensure when the stabilizing muscles will contract for the production and transfer of forces to stabilize the body segments when performing functional tasks34. This concept can be called the timing´s core. Thus, the assessment of the ability to stabilize the scapular and lumbar-pelvic girdles in this study was carried out using the Upper Body Test, showing the interaction between the core's timing and the movement of the upper and lower limbs in a stable manner.

In this perspective, to our best knowledge, this is the first study that analyzed the effects of the methodological organization of functional exercises on scapular and lumbar-pelvic girdle stability. This fact makes it difficult to compare the results found with the current literature. From the labor point of view, after 10 weeks, the supervised and organized FT in a grouped manner promoted a succinct improvement in the scapular and lumbopelvic stability in active young adults. Thus, it seems that grouping exercises for the same muscle function in a training program can provide increased intensity that lead to long-term stability of the shoulder girdle and pelvic lumbar.

Some limitations of the present study must be considered. The first of them, regarding the lack of control for individuals' physical activities beyond the training period, which can be different between the subjects and thus influence the magnitude of adaptations to training. However, this aspect increases the external validity of the intervention. Another point was the lack of quantification of the training volume, which makes our conclusions difficult. However, there was a desired repetition range during the 10 weeks of intervention (8 and 12 repetitions per exercise). Thus, further studies with longer intervention periods are needed to verify changes in the physical adaptations of young adults to map possible deficits for stabilization of the scapular and lumbar-pelvic girdle and thus prescribe interventions focused on training or rehabilitation of these circumstances.

CONCLUSIONS

It is reproducible to perform the Lower Body Test with the Octobalance® platform for the evaluation of the dynamic balance of lower limbs in women with knee osteoarthritis. It was also possible to identify values of minimum detectable difference, values to be used as a form of prognosis and improvement of these individuals.

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