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CO-CONTRACTION OF TIBIALIS ANTERIOR AND SOLEUS MUSCLES DURING EXERCISES WITH DIFFERENT CONDITIONS OF INSTABILITY

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This study aimed to compare the level of co-contraction of shank muscles during five different types of instability. Six healthy male adults performed ten balance exercises, five double leg and five single leg, while myoelectric activity of tibialis anterior and soleus was collected. Significant differences were identified in the level of muscular co-contraction between exercises performed on the BOSU and exercises performed without instability devices. It is conclude that there is a trend toward progression of balance exercises to increase the joint ankle stability, allowing physical therapists and physical educators to develop more efficient training programs aiming at improving levels of MCC and prevent injuries.

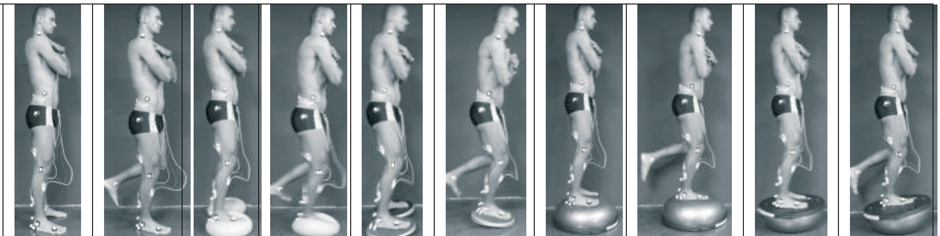
KEYWORDS: Biomechanics, Electromyography, Muscle Co-Contraction, Joint Stability.

INTRODUCTION: The balance training on different surfaces has been used in order to prevent musculoskeletal injuries and improve athletic performance (Myer et al, 2005; Leporace et al, 2010a). The main proposal of this kinf of training is to improve the proprioceptive pathways and neuromuscular control, increasing joint stability (Anderson & Behm, 2005). Although its effect on performance is not proved yet, balance training is commonly prescribed for elderly (Cheung et al, 2008), orthopedic and neurological patients (Almeida et al, 2007; Alonso et al, 2009) aiming at prevent and rehabilitate injuries.
Among the strategies used to perform these exercises, the most common are platforms with different conditions of instability, associated with different conditions of vision (open or closed eyes) and external perturbation, while simulating specific sport techniques (Leporace et al, 2009). Apparently, the use of unstable surfaces is one of the most used strategies to induce improvements in the ability to maintain joint stability (Anderson & Behm, 2005). According to Williams et al. (2001), muscle co-contraction (MCC) is one of the mechanisms related to the control of joint stability. It is characterized by the simultaneous activation of antagonic muscles crossing a joint, increasing dynamic stiffness. Therefore, the study of the mechanisms of MCC during exercises is essential to the understanding of the role of each muscle to provide joint stability. Several studies have analyzed MCC in the Core region (Leporace et al., 2010b), shoulder (Faria et al., 2009) and knee (Fonseca et al., 2001) joints.
Despite the proved effect on injury prevention and rehabilitation, little is known about the mechanisms that rules the dynamic joint stability of the ankle during different conditions of instability. Nowadays, the prescription of balance exercises is based on practical experience and theoretical knowledge. The first step to select balance exercises with a scientific basis is to study the MCC of different muscles, to understand the mechanism related to control of joint stability. Therefore, the aim of this study was to compare the level of co-contraction of tibialis anterior and soleus muscles during the execution of exercises with different conditions of instability.

METHODS: Six healthy male adults (83.8 ± 8 kg, 1.82 ± 0.08 m, 27.2 ± 6.3 years) were recruited by convenience to participate in this study. All subjects had previous experience on balance exercises and none of them reported any musculoskeletal and neurological injuries

in the trunk and lower limbs. The group performed ten balance exercises (Figure 1) in a random order while myoelectric activity of soleus (SOL) and tibialis anterior (TA) muscles were captured.
The duration of each exercise was 20 s and a two minutes rest interval between exercises was allowed to prevent fatigue. Before the beginning of each exercise the subjects performed one set of 10 s of each exercise to familiarize with the tasks. Thereafter, the participants were instructed to maintain a static posture during exercise, keeping the arms crossed in front of the chest. All exercises were performed twice.
Silver/silver chloride (Ag/AgCl) electrodes (KOBME, Bio ProtecCorp, Korea) were positioned over the soleus and tibialis anterior muscles of the dominant leg, according to Cram et al. (1998). Before application of the electrodes, the skin was prepared by dry shaving the area and cleansing with alcohol to reduce surface impedance. To prevent movement artifact interferences in the signals, the electrode cables were fixed to the skin using adhesive tape (3M Ltda, Brazil).
Electromyography was obtained at a sample rate of 2 kHz (EMG 100B, BIOPAC Systems Inc.), amplified (differential bipolar amplification, input impedance = 2MV, common mode rejection rate = 110 db, gain = 1000), converted from analog to digital (12 bit, MP100 WSW BIOPAC Systems Inc).
Electromyography signals were filtered using a fourth-order band pass Butterworth (20–400 Hz), applied in the forward and reverse directions to prevent phase distortions. RMS values were calculated at every 50 ms during the 10 central seconds (5 s to 15 s) of the exercises and the signal was normalized by the average of the three greatest peak values of each muscle among all exercises.
MCC was calculated through the overlapping area of the normalized EMG tracing curves from the SOL and TA (Fonseca et al., 2001, Faria et al., 2009). The EMG signals of these muscles were temporally overlapped and the common area under the two EMG tracings calculated. The curve developed from the overlapping area of the EMG muscles pair allowed the estimation of a mean value of co-contraction, during the reported period of time, resulting in a MCC around ankle. Thus, MCC depends on the magnitude and timing of the EMG signals of the analyzed muscle pair. A MATLAB program (MathWorks, USA) was used to process the EMG signals, to identify the overlapping EMG areas and to quantify the co-contraction. The ankle MCC was obtained as the mean of the overlap area.
The MCCs were compared among the ten exercises using the Kruskal-Wallis with a post hoc of Dunns. The level of significance was set at $\alpha = 0.05$. Statistical analysis was performed with GraphPad Prism version 5.0.

Figure



Exercise	Double leg Ground (DG)	Single leg Ground (SG)	Double leg Dynadisc (DD)	Single leg Dynadisc (SD)	Double leg Gyroplane (DGP)	Single leg Gyroplane (SGP)	Double leg BOSU bladder side up (DBBU)	Single leg BOSU bladder side up (SBBU)	Double leg BOSU bladder side down (DBBD)	Single leg BOSU bladder side down (SBBD)

Figure 1: Name, legend and picture of the exercises used in this study

RESULTS: The TA/SOL MCC for each exercise is shown in Figure 1. The Kruskal-Wallis test reported significant differences among exercises (p = 0.004). The Dunn's test identified differences betwenn DBBU e SG e entre SBBU e SG.

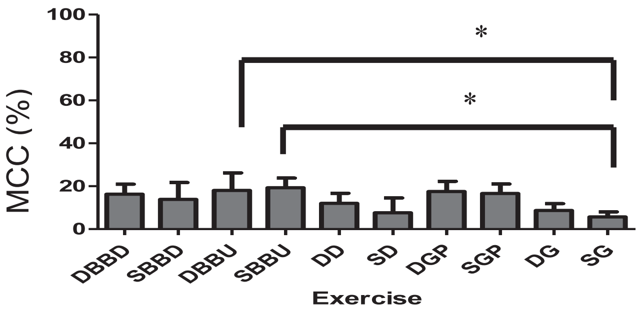


Figure 1: MCC between the tibialis anterior and soleus in each exercise. *p<0.05.

DISCUSSION: The results of this study suggest that the MCC generated varies depending on the type of exercise performed. To our knowledge, there are no studies in which the ankle MCC has been compared in different types of balance exercises. Research on this subject tend to consider only the level of contraction of each muscle and compare them with each other (Kidgel et al, 2007) or between exercises (Laudner, Koschnitzky, 2010), which does not appear sufficient to produce enough information for a proper exercise prescription. Notably, when the exercise goal is to increase the degree of joint stability, the study of the specific status of MCC among antagonists provides important insights into the strategies used by the Central Nervous System to increase the dynamic stiffness (Gardner-Morse, Stokes, 2001; Duan et al, 1997).

Regarding the MCC TA x SOL, DBBU and SBBU exercises showed higher levels of MCC compared to the exercises that were not performed on unstable platforms (DG and SG), thus, representing a greater threat to the ankle joint stability. The greater activity of both agonist and antagonist to stabilize the joint may be due to the stimulus generated by the instable nature of BOSU, which, for the ankle, was higher than in other equipments.

The balance training in unstable platforms is commonly prescribed for individuals with injuries, such as in the lumbar (Borghius et al., 2008), knee (Alonso et al., 2009) and ankle (Michell et al., 2006, Coughlan & Caufield, 2007), with the aim of improving the proprioceptive acuity and dynamic joint stability (Anderson & Behm, 2005, Hill et al., 2009). When this type of training is prescribed for athletes, the main goal is to decrease the risk factors for injuries and rehabilitation, because the decrease in joint stability and proprioception provide changes in neuromuscular control. Which leave the joint more susceptible to injury (McGuine & Keene, 2006). According to Oliver & Di Brezzo (2009) the integration of balance exercises into a training program led to an improvement of postural control and sports activities in female athletes, helping to prevent injuries. However, the effect of such training on sport performance still remains controversial.

The MCC was low in all exercises, proving that indeed, for maintaining joint stability, it is not necessary to apply high magnitude of force (Williams et al., 2001). The joint stability may be influenced by other aspects related to MCC, as pre-activation and timing of activation among antagonic muscles (Williams et al., 2001).

Concerning the selection of platforms with the greatest degree of instability, this study did not find significant differences between exercises performed on both sides of BOSU, which is in agreement with Laudner & Koschnitzky (2010) that found no differences in the individual muscle activity of the medial gastrocnemius, tibialis anterior and peroneus longus.

According to Kiggell et al. (2007) the use of proprioceptive platforms, as the minitramp and duradisc, is equal effective in improving postural control after ankle injuries. This finding corroborates to the results of the present study that also suggest an absence of differences in the level of MCC with the use of platforms of different materials (wood, plastic and rubber). It is not known the differences of several unstable platforms on injury prevention and sport performance. Perhaps, to change the status of joint stability, other conditions must be taken

Portuguese Journal of Sport Sciences
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into account, as the degree of freedom allowed by the platforms. However, further studies are necessary to prove this hypothesis.
The results of this study suggest that for a pedagogical progression in terms of difficulty, balance exercises can be selected initially without the use of unstable platforms, as SG, progressing to exercises as DG, DD, SBBD, DBBD, SGP, DGP, advancing to DBBU and SBBU. We assume as a limitation of the study the low sample size.

CONCLUSION: We conclude that there is a trend toward progression of balance exercises to increase the joint ankle stability, allowing physical therapists and physical educators to develop more efficient training programs aiming at improving levels of MCC. We suggest that studies be conducted to answer similar questions related to lumbar, hip and knee joints. It would also be important to quantify the joint kinematics and the levels of instability generated by each platform to allow a correlation with the level of muscle response.

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