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Gastrocnemius Exercise Programme in the Dynamic Balance

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Abstract

Standing balance control is an essential component of most daily and sports activities. The gastrocnemius (GMs) play a key role in controlling the body sway on the base of support, during the orthostatic position. This study aims to assess the influence that a medium/high intensity exercise training (single session) directed towards gastrocnemius has on the dynamic balance in unipodal support. Four healthy young subjects (21 ± 1 years old) were evaluated and participated in this study after signing a written consent. Before and after applying an average/high intensity exercise program (30 minutes) specific to the gastrocnemius, movement activity parameters on lower limb extremity were evaluated, such as range of motion (ROM), calf muscle volume and dynamic balance. When comparing the results between the pre and post-training phases (phase 1 and phase 2), changes in the dynamic balance were observed in the posterolateral ($p = 0.012$) and anterior ($p = 0.027$) reach. Passive ROM of plantar flexion and dorsal flexion showed no changes. An average/high intensity program can modify some motion components in the dynamic balance of the foot due to fatigue and, consequently, it seems to stimulate a proximal postural response of dynamic postural strategies.

Keywords: *Gastrocnemius; Dynamic Balance; Exercise; Balance; YBT*

Introduction

The foot dynamic joint stability is one of the most important factors for protecting the body from injuries during daily life and sports activities performed in the standing position [1]. The main anatomical function of the gastrocnemius is the plantar flexion and the flexion of the knee, playing an essential role in controlling the body oscillation in the standing position [1,2]. We review observational and experimental studies and most of them document the role of interest in promoting a high-intensity exercise for the development of gastrocnemius motor skills and we realize that, few studies address the influence of this type of exercise on automatic muscle control that also occurs in the limb extremities [2,3].

According to the task and the structural characteristics of each individual, gravity causes an anterior inclination tendency by placing the centre of mass in front of the tibiotarsal joint, being the stability guaranteed in this position through the posterior antigravitational muscles of the leg (soleus and gastrocnemius) [2]. During the performance of multiple daily tasks involving load on the lower limbs (posture and movement), the synergy between these 2 muscles contributes to the overall stability, weight transfer on the base of support, activation of the extensor muscular chain and particularly, in the eccentric control of the activities performed with gravity influence [3]. This dynamic contraction leads to the activation of many cortical areas, as sensorimotor information, the alignment of the trunk, the stability limits and the postural control [4]. The gastrocnemius (GMs) and soleus muscles, have a common insertion through the Achilles tendon, present different architectures and different functions, considered important in the global movement and in the ankle joint acceleration ability. Both participate in the plantar flexion, but only the GMs have the ability to collaborate with the knee flexion (biarticular muscle), leading to the absence of a permanent link of dynamic contraction between them [3]. In a normal gait cycle, there are two vertical peaks of ground reaction force and, as in the standing, both muscles are active in the stance phase of gait [5]. However, it is known that the force generated by the multiple muscles that influence the range of motion of the ankle complex, allows the dynamic stability in small displacements on the support base. In the standing position, to maintain a global posture and displace the centre of mass on the support base, the involvement of other movements such as the knee flexion is required [6,7]. The majority of studies investigate the ability of the body to perform an anterior dislocation during gait, however, the biggest stability difficulties arise in the unipodal load transference ability, in a disease condition [8]. On the other hand, unipodal support assessment is considered a method to quantify balance capability [9].

Aim of the Study

The aim of this study was to assess the influence that a medium/high intensity exercise training (single session) directed towards gastrocnemius has, on the dynamic balance in unipodal support.

Methods

This study was carried out in accordance with the recommendations of World Medical Association's (Declaration of Helsinki) and respective amendments and the protocol was approved by the ethics committee of the Higher School of Health of the Portuguese Red Cross. All subjects gave written informed consent in accordance with the Declaration of Helsinki.

Four healthy individuals with (21 ± 1 years old, mean weight of 62 ± 14.1 kg and mean height of 1.66 ± 0.16 m), of both genres (three men and one woman), without changes in normal ankle ROM, participated in this study. The volunteers had no previous clinical history or any acute vestibular, cardiac or respiratory pathology.

The evaluation of the different parameters was performed before and immediately after the training exercise program. The evaluation and the intervention were always carried out under the same environmental (25°C ± 1) and postural conditions.

After a period of stabilization for 10 min sitting, resting heart rate was measured using an oximeter (Contec, CMS50N) in order to calculate the appropriate individual heart rate at the level of average/high intensity exercise [10]. The muscle volume of the leg was measured with a measuring tape (1.5m fiberglass - japanese butterfly) in supine position, with the hip in neutral position and the knees in full extension. They were scored in 1 point from 10 cm below of the fold of the popliteal fossa. The perimeter was measured in the muscular womb to calculate the muscle volume [11].

The plantar flexion and the dorsal flexion range of motion of the ankle were evaluated in the support limb, and the amplitude measured with a goniometer (Goniometer Angle Medical Ruler Rule Joint Bend Measure Plastic PVC 8'' 200 mm, Enrad-nonius), having been performed according to Cynthia C. Norkin [12].

For the dynamic balance it was used the Y Balance Test™ (YBT) (Move2Perform, Evansville, IN, USA) that allows the evaluation of the dynamic performance in unipodal support, during the performance of a complex balance activity [6].

The selected variables and parameters were compared in the same phase between right and left lower limb with Mann-Whitney test and the Wilcoxon signed-rank test (IBM SPSS Statistics for Window) was used for phase comparisons. A 95% confidence interval was adopted.

Intervention protocol

In order to specifically recruit the gastrocnemius muscles all selected exercises had to integrate knee flexion, associated with plantar flexion activity. The training began with a jump rope, which required various care throughout its use, such as the positioning of the arms and head and the ability to perform a landing smoothly and without blunt impact, thus ensuring the effect of spring on the ankle and knee. In addition to be the correct technique to avoid trauma, the presence of knee flexion was also guaranteed [13]. The intervention lasted 30 minutes and the 4 volunteers performed plantar flexion activation exercises, with knee flexion, in 4 series and with 30 seconds of rest between each series. Each series had 12 repetitions of exercise and the active rest periods between each series allowed the prevention of muscle fatigue, not interfering with the quality of movement execution [6].

Results and Discussion

Several physiological feedback mechanisms are necessary to maintain postural control in the standing position, with greater complexity for unipodal support [14]. This preliminary study aimed to assess the influence that a medium/high intensity exercise training (single session) directed towards gastrocnemius has, on the dynamic balance in unipodal support.

According to the literature, parameters such as perimetry, goniometry and muscle activation only exist in the presence of unilateral, asymmetric pathology or when there is a difference in limb length [15]. One of these studies assesses the growth of lower limbs up to 24 years of age and at no age, differences were found between right and left limbs [16]. The first result of this study is related to the possible difference between sides. Being a small sample, the Mann-Whitney U test was used to compare 2 independent samples. There were no significant differences ($p > 0.05$) between right and left members (Table 1) so, for statistical analysis in the comparison between phases, 8 members were considered.

	Phase 1		Phase 2	
	Right	Left	Right	Left
Perimetry (/cm) Mean ± sd	30.9 ± 1.3	31.0 ± 1.4	31.6 ± 1.8	31.3 ± 1.5
p-value	0.317		0.180	
Gonio_DF (/°) Mean ± sd	15.3 ± 3.4	15.3 ± 0.5	18.5 ± 2.4	15 ± 4.2
p-value	1.000		0.109	
Gonio_PF (/°) Mean ± sd	52.8 ± 8.6	51.3 ± 6.3	54.5 ± 8.2	51 ± 6.5
p-value	0.180		0.197	
YBT_A (/cm) Mean ± sd	48.5 ± 6.3	49.0 ± 6.8	47.4 ± 6.1	47.8 ± 7.5
p-value	1.000		1.000	
YBT_PL (/cm) Mean ± sd	86.4 ± 20.3	86.3 ± 18.4	90.3 ± 23.2	92.5 ± 22.4
p-value	0.273		0.273	
YBT_PM (/cm) Mean ± sd	95.1 ± 18.1	96.6 ± 17.4	98.1 ± 24.0	98.6 ± 20.8
p-value	0.715		0.581	

Table 1: *Result averages obtained during phase 1 and phase 2 for the right (R) and left (L) lower limbs for the perimeter; goniometry of Dorsal Flexion (DF) and Plantar Flexion (PF); and YBT in Anterior (A), Posterolateral (PL) and Posteromedial (PM) reaching. Statistical comparison between right and left sides. *: Statistically significant (p < 0.05).*

In the comparison between phases, the results were analysed to verify whether, with a single demanding training between medium/high intensity exercise, aimed at gastrocnemius activity, could result in changes performance of dynamic balance performance since, most of the studies carried out, focus on changes in individuals with sensory, motor and central nervous system pathology [16]. The differences identified in perimetry (muscular volume of the GM) reveal a statistical increase in volume (p = 0.046) in the measurement performed immediately after the end of the exercise training. This result is congruent with the results found in other studies that analyse the physiological mechanisms initiated with exercise, particularly in the circulatory system that initializes a serial metabolic activation of the skeletal muscles compared with the rest periods [17]. The increase in blood flow in the skeletal muscles is achieved by vasodilators formed locally in the muscular tissue, namely through the release of vasoactive metabolites from the active muscular cells. The glycogen reserved in the muscles is a polymer of high molecular weight that, during exercise, stimulates multiple osmotically active components, leading to the entrance of water in the skeletal muscle cells [17,18]. This is a complex process that requires further studies to demonstrate a long-term role of these mechanisms, even after the end of the exercise training program.

Although the literature talks about the possibility of an increase in ROM may occur due to the increase in temperature because the elastic properties of collagen in muscles and tendons [19] in our study these differences were not found. The evaluation of the ROM showed (Table 2), in the goniometry performed passively, that there no changes in the passive plantar flexion (PF) and in the dorsal flexion (DF) (p = 0.498 and p = 0.307 respectively). These results are in line with several studies that show differences only with pathologic conditions such as chronic ankle instability since this behaviour is related to the regulatory and defence mechanisms generated by the healthy organism [1].

	Phase 1	Phase 2
Perimetry (/cm) Mean ± sd	30.9 ± 0.1	31.4 ± 0.2
p-value	0.046*	
Gonio_DF (/°) Mean ± sd	15.3 ± 2.1	16.8 ± 1.3
p-value	0.498	
Gonio_PF (/°) Mean ± sd	52 ± 1.6	52.8 ± 1.2
p-value	0.307	
YBT_A (/cm) Mean ± sd	48.8 ± 0.3	47.6 ± 1.0
p-value	0.027*	
YBT_PL (/cm) Mean ± sd	86.4 ± 1.3	91.4 ± 0.5
p-value	0.012*	
YBT_PM (/cm) Mean ± sd	95.8 ± 0.5	98.3 ± 2.3
p-value	0.182	
Kv_A (/°) Mean ± sd	36.7 ± 7.8	37.0 ± 5.9
p-value	0.914	
Kv_PL (/°) Mean ± sd	33.5 ± 6.3	30.8 ± 7.1
p-value	0.026*	
Kv_PM (/°) Mean ± sd	30.3 ± 7.3	31.5 ± 4.7
p-value	0.320	

Table 2: *Results (mean ± standard deviation) of each studied variable. Statistical comparison between the phase 1 and the phase 2. *: Statistically significant (p < 0.05).*

To assess dynamic stability, the Y Balance Test was used as a measuring instrument, which corresponds to one of the most reliable instruments to assess dynamic stability [20]. This evaluation was done in three directions - anterior, posterolateral and posteromedial, before and after the training program (Table 1). Regarding the anterior direction, in this study we verified a significant decrease in phase 2 compared with phase 1 (p = 0.027). As for the results obtained in the posterolateral direction, a considerable increase was obtained (p = 0.012) after the training program. In the posteromedial range, there was no significate difference in the range (p = 0.182) when comparing before and after the training program. According to a study, the muscle strength and fatigue can be considered as physiological factors capable of influencing the results obtained from the YBT, adding that the return to baseline values requires about 10 minutes of recovery from fatigue [7]. Other studies report that the involvement of the muscles located in the ankle region have an important role in the sway, especially in the sagittal plane and that the fatigue state of the GMs, can affect neuromuscular performance and reduce recruitment of motor units [21].

During the execution of the YBT photos were collected and, to help understand the ROM angles reached dynamically, we used the Kinovea program. In an analysis of the results of the ROM values (measured with the Kinovea software) during the performance of the YBT we found that, in the PM direction there are no changes in ROM (p = 0.914). This direction is also the one with the greatest balance requirement as it limits the use of dynamic postural strategies on the side contralateral to the loaded limb. The YBT results showed significant differences in the other 2 directions. In the standing position, postural adjustments occur primarily in the central regions of the body in the face of lateral imbalances. These regions seem to respond with greater amplitude in postural control, thus supporting the automatic mechanisms of the foot [9]. In the direction A, the angles recorded with the Kinoveia software do not present any differences (p = 0.914) but a significant increase in reach with lower limb PL were measured in YBT (p = 0.027). This result leads to believe that, the postural control in an extreme situation of oscillation over the limits of stability, together with the presence of fatigue in the GMs muscles, is strongly supported by more proximal regions [16]. In the daily practice of the Physiotherapist, the assessment of the physiological boundaries of automatic movement allows the intervention to be guided, since there is a frequent tendency to replace automatic movement with volunteer movement. Further studies are needed to understand what the influence of fatigue in the distal muscles of the lower limb, leads to the recruitment of the automatic proximal movement.

Conclusion

Gastrocnemius activity is essential for dynamic postural control in the standing position. A medium/high intensity training in these muscles seems to trigger a set of physiological mechanisms based on their state of fatigue, which seems to promote an alternative recruitment of the proximal dynamic postural strategies. Further studies are needed to understand what the influence of fatigue in the distal muscles of the lower limb, leads to the recruitment of the automatic proximal movement. This can be an intervention strategy used in the standing position in individuals with changes in dynamic postural control.

Declaration of Competing Interest

The authors declare that they have no competing financial, professional or personal interest that might have influenced the performance or results described on this manuscript.

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