Available online at **www.ijmrhs.com**

ISSN No: 2319-5886

International Journal of Medical Research & Health Sciences, 2018, 7(1): 1-10

Effect of Active-Assisted Stretching of 30 Seconds and 60 Seconds in Muscle Force

Mirian dos Santos Monteiro[1], Davi Cury Piai[1], Thais Ferreira Gomes[1], Matheus Masalskiene Pedrosa[1], Robson Felipe Tosta Lopes[1], Lucas Sartori Manoel[2], Alexandre Badan Collucci[2], Veridiana Wanshi Arnoni[2] and Bruno Ferreira[1]*

[1] *Department of Physical Therapy, University Center UNIFAFIBE, Bebedouro, São Paulo, Brazil*

[2] *Study Center Collucci, Collucci`s Clinical, Ribeirão Preto, São Paulo, Brazil*

**Corresponding e-mail:* brunof22@me.com

ABSTRACT

This study aims to analyze the interference of the active-assisted stretching technique in muscle strength. Participating in this study were 39 healthy and physically active individuals subdivided into three groups of active-assisted stretching G30 - 30 seconds, G60 - 60 seconds and CG - control. The muscular strength was evaluated using the isokinetic dynamometer, obtaining the analyzed conditions of torque peak, total work and agonist and antagonist relationship of the dorsiflexor and flexor muscles ankle. The values obtained were statistically analyzed by the SPSS from the "t-test for paired sample" ($p \leq 0.05$). When analyzing the effect produced by the stretching, it was observed that the 30-second elongation showed a reduction of the average of the muscular torque in all conditions analyzed, with the exception of the relation between the agonist and the left antagonist and the total work of the right plantar flexors, the G60 - 60 seconds group had a reduction in average muscle torque in all conditions analyzed, except for the relation between agonist and left antagonist that obtained an increase in muscle torque and the CG - control group, there was a reduction in the average of the muscular torque in all the analyzed conditions, except for the torque and total work of the left plantar flexor muscles that presented increase. Thus, it can be concluded that there were differences between the groups of active-assisted stretching of 30 and 60 and that the effect produced by stretching did not present a significant reduction of muscle strength.

Keywords: Isokinetic, Flexibility, Stretching, Muscular strength, Ankle

INTRODUCTION

Flexibility has been discussed in several studies and is defined as the ability of the muscle tissue to elongate, allowing one or more joints to move normally, providing accommodation of adjacent tissues [1,2]. It is a biomechanical property of the musculoskeletal system important in the physiotherapeutic treatment since its lack can cause muscle shortening, and therefore favor the diminution of the extensibility generating loss of the length of the motor unit facilitating the development of tissue lesions [3].

In this way, an alternative of physiotherapeutic treatment for the functional recovery of flexibility are the stretching techniques capable of increasing the tissue extensibility, as well as reducing muscle spasms and consequently alleviating the pain symptoms caused by the increase of muscle myoelectric activity [4-7]. Stretching is used in sports practices to prevent injuries and improve athletes' physical performance [8]. However, there is still much controversy in the literature about increasing flexibility and reducing the risk of injury. Since the application of static stretching before the exercises has a negative effect on the musculoskeletal system, resulting in impairment of movement and muscle strength [9].

Muscle strength is one of the most important components for structural stability of the joints, thus contributing to cartilage maintenance, improvement of neural activation and reduction of risks for injuries [10]. In muscle contraction, the biomechanical relationships between strength and elongation interact to allow the production of torque [11]. Torque is defined as the joint force that is able to generate movement in the joints from the traction developed by the muscle tissue [12,13].

Thus, an efficient method to evaluate muscle strength and function is the isokinetic force dynamometer, since it detects the joint torque within the total range of motion, generating a resistance proportional to the muscular torque, which is controlled by the speed of movement performed [14]. This equipment is considered a gold standard in the analysis of muscular strength, allowing also to verify other biomechanical parameters that are derived from the force, such as total work, speed, power, resistance among other analyzes [15].

Thus, this study aims to evaluate the response of muscle tissue to its force production after the application of active-assisted stretching for 30 seconds and 60 seconds. The hypothesis of this study is that the 30-second stretches are less aggressive to muscle strength compared to 60-second ones.

MATERIAL AND METHODS

Study Design

This is a self-controlled experimental cross-sectional study, which consisted in the evaluation of muscle strength by the isokinetic dynamometer and the performance of a muscular stretching intervention for three series of 30 seconds or 60 seconds in healthy individuals practicing physical activity at Clínica Collucci, in Ribeirão Preto - SP.

Participants

We selected 39 individuals of both genders by a convenience sample with an average age of 29±1 years, paired subject-to-subject, without a clinical diagnosis of musculoskeletal diseases or postural changes in the lower limbs clinically diagnosed. The participants of this research were divided into three groups of 13 participants from a random lot drawn by the researcher responsible for performing the stretches, thus forming the following groups: G30 - 30 seconds that performed active-assisted muscle stretching for 30 seconds, G60 - 60 seconds performed active-assisted stretching of 60 seconds, and finally the CG - Control, who did not perform any type of stretching. This study was approved by the Research Ethics Committee of the University Center UNIFAFIBE of Bebedouro - SP (number CAE: 67740917.5.0000.5387).

Individuals who participated in this study should meet the inclusion criteria: they are between the ages of 16 and 50 years; no musculoskeletal conditions diagnosed clinically or postural changes in the lower limbs; being physically active at least 3 times a week. Exclusion criteria were: pain in the locomotor apparatus during the evaluation week, use of medication in the evaluation week, muscle lesions previously diagnosed and/or associated chronic pathologies.

All the individuals participating in this study were submitted to the following protocol: bicycle heating, initial isokinetic evaluation, application of stretching or waiting time proportional to stretching, isokinetic reevaluation after five minutes of the stretching technique.

Isokinetic Evaluation

The participants of this research carried out two evaluations using the isokinetic dynamometer that occurred before and after the application of active-assisted stretching to the gastrocnemius and solear muscles through a second researcher who did not know which group the participants belonged to.

This analysis was performed according to the protocol described in the literature [16,17]. Initially, they underwent warm-up on a RXH 1500 horizontal exercise bicycle for 5 minutes with light exertion intensity according to the Borg scale. Then, an isokinetic evaluation was performed with the digital dynamometer Biodex 4 Pro (Biodex Medical System Inc., Shirley, NY, USA) of the ankle dorsiflexor and flexor groups, during the isokinetic dynamometry test the participants were positioned with hip flexion to 25º, extension of knee and ankle neutral to eliminate the action of hamstring muscles [18]. The tests were performed at the rate of 30º/seconds in the concentric mode for 5 repetitions.

The tests were initiated by the dominant ankle and the volunteers performed a series of 5 submaximal repetitions prior to each test to become familiar with the movement to be performed. During the test, the volunteer was asked for the maximum voluntary contraction, with verbal stimuli.

Stretching Phase

The active-assisted muscle stretching was performed with a 45º inclined wooden platform positioned in front of the backrest. During stretching, the lower limbs were left in knee extension and ankle dorsiflexion without withdrawal of the calcaneus from the platform. The volunteer was asked to tilt the body forward by increasing the tension of the muscle fibers [19,20]. The stretching was performed in three sets of 30 or 60 seconds, depending on the group of each volunteer, providing rest of 10 seconds between each series. At the end of the series the participants were repositioned in the isokinetic with an interval of five minutes to perform the second test.

The CG Group - Control that did not receive the stretching, was positioned in front of the backrest for 5 minutes, time proportional to the other groups that received the stretching techniques. After the end of this period the individuals of this group were repositioned in the isokinetic according to the interval of five minutes for the execution of the second test

Also, as a method of subjective analysis of muscle stretching discomfort, the Visual Analogic Scale (VAS) was used to quantify the levels of pain or discomfort during all muscle stretching exercises performed, so that it was possible to observe and maintain in similarity to each series of stretching performed, without the individuals reducing the intensity.

Statistical Analyses

The results obtained in the torque isokinetic analyzes were tabulated in the SPSS version 22.0 program and analyzed statistically from three statistical tests different from the objectives:

1. Comparison of the sample used in this study: the ANOVA test ($p \leq 0.05$) was performed to compare the characteristics of the population distribution and to identify if they were similar.
2. Comparison between the groups of each analyzed condition obtained in this study: we used the ANOVA test ($p \leq 0.05$) so that it was possible to compare each group within each condition analyzed in the isokinetic.
3. Analysis of the difference between pre- and post-stretching evaluation: the "t-test for paired sample" ($p \leq 0.05$) was used in order to observe the difference between the results obtained in the pre- and post-stretching isokinetic analysis for each group evaluated.

RESULTS

Population Distribution

The population distribution of the sample of this study was paired subject-to-subject by group G30 - Stretching 30 seconds, G60 - Stretching 60 seconds and CG - control, without stretching. There was no statistically significant difference (ANOVA test; $p \leq 0.05$) in the comparison of the variable age (G30=31 ± 2 years × G60= 26 ± 3 years × CG = 31 ± 1 years with p=0.24); weight (G30=71.66 ± 2.74 × G60= 65.70 ± 2.42 × CG = 75.32 ± 3.15 with p=0.06), stature (G30=1.71 ± 0.02 × G60= 1.68 ± 0.01 × CG = 1.72 ± 0.02 with p=0.47) and BMI (G30=24.38 ± 0.89 × G60= 23.16 ± 0.67 × CG = 24.99 ± 0.67 with p=0.23).

Comparison Between The Groups Of Each Analyzed Condition Obtained In This Study

In the comparison between the groups, in the average of the torque peak, we observed a greater peak of muscular torque for the G30 - 30 seconds group in the conditions analyzed right dorsiflexors pre-torque, right dorsiflexors post-torque and left dorsiflexors post-torque. The CG - Control group had a higher peak of muscular torque in the analyzed conditions, left dorsiflexors pre-torque, right plantar flexor pre-torque, right plantar flexor torque, left plantar flexor torque and left plantar flexor torque (Table 1). The values obtained in this analysis were not statistically significant ($p \leq 0.05$).

Table 1 Analysis of average torque peak of the dorsiflexor and plantar flexor muscles in the 30º/second isokinetic evaluation for G30 (30 seconds stretching), G60 (60 seconds stretching) and GG (control group) (ANOVA test; p ≤ 0.05)

Condition analyzed	Group	P-Value	Average	Standard error
Right dorsiflexors pre-torque	G30	0.95#	33.1	± 2.97
	G60		32.23	± 2.91
	CG		31.93	± 2.23
Right dorsiflexors post-torque	G30	0.95#	34.63	± 2.84
	G60		34.32	± 3.48
	CG		33.41	± 2.05

Left dorsiflexors pre-torque	G30	0.41#	33.78	± 2.51
	G60		31.55	± 2.49
	CG		58.1	± 26.75
Left dorsiflexors post-torque	G30	0.74#	34.5	± 1.60
	G60		32.06	± 2.66
	CG		32.15	± 2.41
Right plantar flexor pre-torque	G30	0.20#	104.76	± 8.80
	G60		92.61	± 6.03
	CG		112.3	± 8.15
Right plantar flexor post-torque	G30	0.21#	104.8	± 9.20
	G60		91.63	± 4.26
	CG		109.92	± 9.13
Left plantar flexor pre-torque	G30	0.20#	98.53	± 7.78
	G60		92.56	± 5.75
	CG		111.85	± 9.04
Left plantar flexor post-torque	G30	0.25#	109.62	± 7.97
	G60		93.54	± 5.95
	CG		110.2	± 9.35
#Non-significant values ($p \leq 0.05$)				

In the comparison between the groups, for the analysis of the total work, it was verified that the work of the G30 - 30 seconds group was higher work in the conditions analyzed after total work of right dorsiflexors, post-work of left dorsiflexors, pre- and post-work of right plantar flexors and total post-work of left plantar flexors. In the G60 - 60 seconds group, it was observed greater work in the conditions of total pre-work of right dorsiflexors and total pre-work of left dorsiflexores. The CG-control presented more work in the conditions evaluated before and after total work of right plantar flexors and total pre- and post-work of left plantar flexors (Table 2). The results were statistically non-significant ($p \leq 0.05$).

Table 2 Analysis of the total work of dorsiflexors and plantar flexor in the 30º/second isokinetic evaluation for G30 (30 seconds stretching), G60 (60 seconds stretching) and CG (control group) (ANOVA test; $p \leq 0.05$)

Condition analyzed	Group	P-Value	Average	Standard error
Right dorsiflexores total pre-work	G30	0.94#	37.34	± 3.33
	G60		38.33	± 4.01
	CG		36.63	± 2.83
Right dorsiflexores total post-work	G30	0.80#	36.64	± 3.52
	G60		33.19	± 4.59
	CG		34.77	± 2.70
Left dorsiflexores total pre-work	G30	0.83#	33.65	± 3.12
	G60		61	± 2.30
	CG		32.63	± 3.69
Left dorsiflexores total post-work	G30	0.68#	34.12	± 2.98
	G60		30.43	± 3.87
	CG		30.56	± 3.23
Right plantar flexor total pre-work	G30	0.2 1#	101.05	± 9.85
	G60		86.63	± 7.55
	CG		114.76	± 14.64
Right plantar flexor total post-work	G30	0.20#	96.52	± 12.68
	G60		71.46	± 9.01
	G30		98.17	± 12.75
Left plantar flexor total pre-work	G60	0.22#	78.83	± 10.07
	CG		72.36	± 9.04
	CG		98.66	± 13.30

Left plantar flexor total post-work	G30	0.48#	93.66	± 12.07
	G60		74.79	± 10.65
	CG		88.16	± 10.99
#Non-significant values (p ≤ 0.05)				

In the analysis of the relationship between agonist and antagonist of dorsiflexors and plantar flexors, a higher ratio was observed for G60-60 seconds in all conditions analyzed, except for the pre-relation condition between agonist and left antagonist that was higher for the G30- 30 seconds (Table 3). The results were not statistically significant ($p \leq 0.05$).

Table 3 Analysis of the average relation between agonist and antagonist for dorsiflexors and plantar flexor in the 30º/second isokinetic evaluation for G30 (30 seconds stretching), G60 (60 seconds stretching) and G3 (control group) (ANOVA test; p ≤ 0.05)

Condition analyzed	Group	P Value	Average	Standard error
Pre-relation between right agonist and antagonist	G30	0.14#	32.37	± 2.45
	G60		35.9	± 3.21
	CG		28.66	± 1.61
Post-relationship between right agonist and antagonist	G30	0.36#	33.12	± 2.59
	G60		36.87	± 3.56
	CG		31.49	± 1.63
Pre-relation between left agonist and antagonist	G30	0.92#	35.85	± 2.91
	G60		34.46	± 2.17
	CG		29.09	± 1.32
Post-relationship between left agonist and antagonist	G30	0.25#	32.03	± 2.18
	G60		34.74	± 2.04
	CG		30.01	± 1.68
#Non-significant values (p ≤ 0.05)				

Analysis Of The Difference Between Pre- And Post-Stretching Evaluation

In the analysis of the effect produced by the stretches, it was observed that the G30 - 30 seconds group presented a reduction in the average of the muscular torque in all conditions analyzed, except for the relation between left agonist and antagonist and total work of the right plantar flexor (Table 4). The results were statistically significant for the analyzed condition of total work of the left plantar flexor muscles ($p \leq 0.05$).

Table 4 Values of average muscle torque difference, the ratio between agonist and antagonist of the leg, and total work on plantar flexion and dorsiflexion movements of G30 - 30 seconds at 30º/second isokinetic velocity (paired sample t-test, p ≤ 0.05)

Condition analyzed	P Value	Average	Standard error
Torque of right plantar flexor muscles	0.75#	-0.57	± 6.60
Torque of left plantar flexor muscles	0.51#	-2.34	± 12.57
Right dorsiflexor muscles torque	0.71#	-0.46	± 4.40
Left dorsiflexor muscles torque	0.34#	-7.7	± 28.06
Relationship between right agonist and antagonist	0.76#	-0.5	± 5.99
Relationship between left agonist and antagonist	0.29#	1.56	± 5.09
Total work of the right plantar flexor muscles	0.58#	0.9	± 2.09
Total work of the left plantar flexor muscles	0.00 **	-113.37	± 12.01
Total work of right dorsiflexor muscles	0.64#	-7.25	± 12.83
Total work of left dorsiflexor muscles	0.50#	-3.83	± 20.11
#Non-significant values (p ≤ 0.05); * significant values (p ≤ 0.05); ** highly significant values (p ≤ 0.01)			

The group G60 - 60 seconds, obtained a reduction in the average of muscle torque in all conditions analyzed, except for the relation between left agonist and antagonist that obtained an increase in muscle torque (Table 5). The results were not statistically significant ($p \leq 0.05$).

Table 5 Values of average muscle torque difference, the ratio between agonist and antagonist of the leg, and total work on plantar flexion and dorsiflexion movements of G60 - 60 seconds at 30º/second isokinetic velocity (t-test for paired sample, p ≤ 0.05)

Condition analyzed	P Value	Average	Standard error
Torque of right plantar flexor muscles	0.61#	-1.5	±10.40
Torque of left plantar flexor muscles	0.30#	-0.57	±5.29
Right dorsiflexor muscles torque	0.26#	-2.01	±6.14
Left dorsiflexor muscles torque	0.97#	-0.03	±3.28
Relationship between right agonist and antagonist	0.43#	-4.06	±18.17
Relationship between left agonist and antagonist	0.76#	0.75	±8.86
Total work of the right plantar flexor muscles	0.66#	-5.3	±43.28
Total work of the left plantar flexor muscles	0.91#	-0.78	±24.92
Total work of right dorsiflexor muscles	0.30#	-7.66	±25.94
Total work of left dorsiflexor muscles	0.60#	-1.86	±12.67
#Non-significant values (p≥0.05)			

In the CG - control group, there was a reduction in the average of the muscular torque in all the analyzed conditions, except for the torque and total work of the left plantar flexor muscles, which presented an increase (Table 6). The results were statistically significant for the analyzed conditions of torque of the right dorsiflexor muscles, the relation between left agonist and antagonist and total work of the right dorsiflexor muscles ($p \leq 0.05$).

Table 6 Values of average muscle torque difference, the ratio between agonist and antagonist of the leg, and total work on plantar flexion and dorsiflexion movements of CG – Control at 30º/second isokinetic velocity (t-test for paired sample, p ≤ 0.05)

Condition analyzed	P Value	Average	Standard error
Torque of right plantar flexor muscles	0.83#	-0.48	± 8.24
Torque of left plantar flexor muscles	0.15#	2.88	± 6.89
Right dorsiflexor muscles torque	0.01 **	-1.83	± 2.21
Left dorsiflexor muscles torque	0.47#	-0.35	± 1.72
Relationship between right agonist and antagonist	0.43#	-4.06	± 18.17
Relationship between left agonist and antagonist	0.02 *	-2.55	±3.69
Total work of the right plantar flexor muscles	0.21#	-9.04	± 24.71
Total work of the left plantar flexor muscles	0.37#	5.53	± 21.84
Total work of right dorsiflexor muscles	0.00 **	-8.84	± 5.87
Total work of left dorsiflexor muscles	0.50#	-1.65	± 8.64
#Non-significant values (p≥0.05); * significant values (p ≤ 0.05); ** highly significant values (p ≤ 0.01)			

DISCUSSION

The muscular strength deficit in the ankle joint is one of the causes that can generate joint and muscular injuries since the compromise of the stability causes excessive movements that increase the risk of injury [21,22]. The ankle joint is important for human locomotion because it participates in several biomechanical phases of the gait, propitiating the development of the daily activities of the individuals [23]. In this study, we used this joint to determine the effect of stretching on muscle strength, since during the practice of some physical activities there is a need for the individual to develop activities related to jumps and races, as in football and basketball, increasing the need for use of this articular segment [25,26].

The analysis of muscle strength performed in this study used the isokinetic dynamometry apparatus that is considered reliable and reproducible to verify the strength of the muscular tissue, thus allowing to analyze the isotonic performance quantitatively in different body segments [15,24]. The analysis of the individuals participating in this study used the patient's positioning according to methodologies already proposed by other authors [18], in which the evaluated participant remained in dorsal decubitus position with knee extension and neutral ankle, however, there is no single position for the ankle isokinetic evaluation, and there may be variation in the angle and position of the individual participating in the study [26].

In the analysis of average torque peak between the groups evaluated in this study, we observed higher values for the group G30 - 30 seconds in the analyzed conditions of right dorsiflexors pre-torque, right dorsiflexors post-torque and left dorsiflexors post-torque and for the CG group - control under conditions analyzed left dorsiflexors pre-torque, right plantar flexor pre-torque, right plantar flexor post-torque, left plantar flexor pre-torque and left plantar flexor post-torque, corroborating with Abdel-Aziem; Mohammad [27], who observed an increase in torque peak for the flexor muscles of trained and untrained individuals and for the dorsiflexor muscles in untrained individuals after the application of static stretching. We believe that our results occurred in the G30 - 30 seconds group, since there was better accommodation of the muscle fibers, generating a better contact between actin and myosin due to modifications of the viscoelastic properties of the muscle tissue, which favors a better result in the force production because it benefits the biomechanical aspects of elastic energy of the muscular structures generating biomechanical and physiological adaptations for the exercise that was executed [28]. However, the CG - control group also presented better torque values for the plantar flexors bilaterally, we believe that these results occurred since there were no interferences regarding the inhibition of muscle tissue after stretching of muscle groups G30 - 30 seconds and G60 - 60 seconds.

In the analysis of the total work, comparing the groups it was verified higher a result of the group G30 - 30 seconds in the analyzed conditions right dorsiflexores total post-work, left dorsiflexores total post-work and left plantar flexor total post-work, in the group G60 - 60 seconds in the conditions right dorsiflexores total pre-work and left dorsiflexores total pre-work and CG - control group presented higher total work in the analyzed conditions total right plantar flexor pre-work, right plantar flexor post-work and left plantar flexor pre-work. This study corroborates with Luna, et al. [29], who performed an isokinetic analysis in runners and triathletes after static stretching and observed an increase in the performance of the total work of triathletes' plantar flexors. These results occurred because the muscle stretching performed in the G30-30 seconds group generated less inhibition of the muscle spindle, since the elongation generates neural adaptations of the muscular structures, inhibiting the post-synaptic autogenic responses of the Golgi tendon organ, reducing the transmission of the impulse of Ranshaw cells to motoneurons and inhibition of joint and cutaneous receptors [30], which provides an increase in the accommodation of the muscle fibers to the elongation and decrease of the sensation of discomfort for the individual who is receiving this technique [8].

Another important fact to note was that all the individuals participating in this study had a lower relation between the dorsiflexor muscles compared to the plantar flexor muscles, corroborating with Fousekis, et al. [31] who performed the analysis on soccer players and observed that the strength of the concentric plantar flexor muscles is superior to that of the dorsiflexor muscles. Also, in the study of Jeon, et al. [32], it was observed a greater strength of the plantar flexor muscles in relation to the dorsiflexors. We believe that these results occurred because the soleus muscle acts actively in the plantiflexion along with the gastrocnemius muscle, especially when the knee is positioned in extension, increasing the muscular force of plantar flexion [33]. Thus, the knee extension position used in this study may have influenced these results, since the gastrocnemius muscle is bi-articular and consequently its force execution is favored when the lower limb is positioned in extension generating more torque than when positioned with the knee because it is in greater mechanical advantage [18]. Another factor that may have led to these results is related to the physical training of lower limbs, which can develop a greater muscular force of plantar flexors due to the movements of jumps and races, leading to an asymmetry of forces between the musculature [34].

In the analysis of the effect on the stretching of 30 seconds and 60 seconds, it was observed that there was a reduction of muscle strength in all analyzed conditions and for all groups evaluated, except for the relation between left agonist and antagonist and right flexor total work in the group G30 - 30 seconds, relationship between left agonist and antagonist in the G60 - 60 seconds group and torque and total work of the left plantar flexor muscles in the CG - Control group. These results corroborate with the Fowles; Sale; Macdougall [26], who also observed the decrease of muscle torque in passive stretching to the ankle neutral position, which caused losses to the performance of high-performance athletes. Our study also corroborates Mizuno [8] and Ruan, et al. [35], which showed a reduction of about 6.5% in isometric strength, 3.9% in dynamic force, and also 2.0% in power during exercise after static stretching. We believe that these results occurred because the muscle stretching produces deleterious effects on the muscles to be worked, inducing a decrease in the execution of muscular force when performed before the physical training, since the elongation inhibits the muscle spindle that consequently reduces the firing of the tonic fibers when the muscle is maintained in continuous elongation as observed in the present study [36,37].

For the CG - control group the performance of two isokinetic analyzes during a short time of execution may have influenced the reduction of muscular strength, since it is believed that the isokinetic apparatus generates stress and fatigue on the muscular tissue, leading to the reduction of glycogen levels and creatine phosphate being important for the production of muscular energy. This hypothesis is justified because the type of analysis performed in the isokinetic apparatus induces a greater recruitment of type II muscle fibers, which are responsible for using a greater amount of glycogen, causing peripheral fatigue in the assessed muscle tissue [38].

Regarding the results that showed increased muscular strength in all groups evaluated, we believe that the inhibition of the antagonists facilitating the agonist's muscles has increased muscle extensibility and length-tension relationship generating improvement in strength performance.

CONCLUSION

In summary, this study found important differences in the performance of muscle strength after the application of the active-assisted stretching technique, which is important in any sports practice or physiotherapeutic treatment, since performing the stretching technique can induce muscular responses capable of generating uncommon biomechanical responses favoring the development of new mechanical responses in muscle tissue.

Thus, it was concluded that there were differences between the groups of active-assisted stretching of 30 and 60 seconds in relation to the control group, with an increase in muscle strength in the G30-30 seconds as well as in the total work and in the agonist and antagonist relationship. Regarding the effect produced by the elongation, it was observed that there was no significant difference after the assisted active stretching, however, the 30-second elongation produced better adaptations of the muscle tissue during the force execution, indicating that it presented less inhibition of the muscular tissue in comparison to the G60 - 60 seconds.

DECLARATIONS

Acknowledgement

We thank the Department of Physical therapy, Study Center and Research on Regional Development (CEPed) of University Center UNIFAFIBE – SP and Collucci Clinical – Ribeirão Preto - SP.

REFERENCES

[1] Medeiros, Diulian, and Lima, Claudia. "Influence of chronic stretching on muscle performance: Systematic review." *Human Movement Science,* Vol. 54, 2017, pp. 220-29.

[2] Yıldırım, M. Senduran, et al. "Comparison of effects of static, proprioceptive neuromuscular facilitation and Mulligan stretching on hip flexion range of motion: A randomized controlled trial." *Biology of Sport*, Vol. 33, No. 1, 2016, pp. 89-94.

[3] Michell, C. van Doormaal, et al. "No relationship between hamstring flexibility and hamstring injuries in male amateur soccer players: A prospective study." *The American Journal of Sports Medicine,* Vol. 45, No. 1, 2016, pp. 121-26.

[4] Hirata, Kosuke, et al. "Muscle-specific acute changes in passive stiffness of human triceps surae after stretching." *European Journal of Applied Physiology,* Vol. 116, No. 5, 2016, pp. 911-18.

[5] Heisey, Clare F., and Kingsley Derek. "Effects of static stretching on squat performance in division I female athletes." *International Journal of Exercise Science*, No. 1, 2016, pp. 359-67.

[6] Serefoglu, Abdullah, et al. "Effect of static and dynamic knee stretching: The isokinetic peak torques and electromyographic activities of the contrary muscles." *British Journal of Sports Medicine*, No. 16, 2017, pp. 6-13.

[7] Pooley, Sam, et al. "Static stretching does not enhance recovery in elite youth soccer players." *BMJ Open Sport & Exercise Medicine*, Vol. 3, No. 1, 2017, pp. 1-6.

[8] Mizuno, Takamasa. "Changes in joint range of motion and muscle–tendon unit stiffness after varying amounts of dynamic stretching." *Journal of Sports Sciences*, Vol. 35, No. 21, 2016, pp. 2157-63.

[9] Chiu, R. Tsz-chun, et al. "An investigation of the immediate effect of static stretching on the morphology and stiffness of achilles tendon in dominant and non-dominant legs." *PLoS ONE*, Vol. 11, No. 4, 2016, pp. 1-9.

[10] Mattos, Fernanda, et al. "Effects of aquatic exercise on muscle strength and functional performance of individuals with osteoarthritis: a systematic review." *Revista Brasileira de Reumatologia* (English Edition), Vol. 56, No. 6, 2016, pp. 530-42.

[11] Azizi, E. "Locomotor function shapes the passive mechanical properties and operating lengths of muscle." *Proceedings of the Royal Society B: Biological Sciences*, Vol. 281, No. 1783, 2014, pp. 1-7.

[12] Enoka, R. M. "Muscle strength and its development." *New perspectives. Sports Medicine*, Vol. 6, No. 3, 1988, pp. 146-68.

[13] Suzuki, Takahito, Kinugasa, Ryuta, and Fukashiro, Senshi. "Activation of plantar flexor muscles is constrained by multiple muscle synergies rather than joint torques." *PLoS ONE*, Vol. 12, No. 11, 2017, pp. 1-13.

[14] Kim, Chang-Gyun, and Jeoung, Bog J. "Assessment of isokinetic muscle function in Korea male volleyball athletes." *Journal of Exercise Rehabilitation*, Vol. 12, No. 5, 2016, pp. 429-37.

[15] Keep, Heather, et al. "Garland S. Validity of the handheld dynamometer compared with an isokinetic dynamometer in measuring peak hip extension strength." *Physiotherapy Canada*, Vol. 68, No. 1, 2016, pp. 15-22.

[16] Masuda, Kazumi, et al. "The relationship between muscle cross-sectional area and strength in various isokinetic movements among soccer players." *Journal of Sports Sciences*, Vol. 21, No. 10, 2005, pp. 851-58.

[17] Cvjetkovic Dragana D., et al. "Isokinetic testing in evaluation rehabilitation outcome after ACL reconstruction." *Medical Archives*, Vol. 69, No. 1, 2015, pp. 1-21.

[18] Farrag, Ahmed, and Elsayed, Wala. "Habitual use of high-heeled shoes affects isokinetic soleus strength more than gastrocnemius in healthy young females." *Foot & Ankle International*, Vol. 37, No. 9, 2016, pp. 1008-16.

[19] Radford, Joel, et al. "Effectiveness of calf muscle stretching for the short-term treatment of plantar heel pain: a randomised trial." *BMC Musculoskeletal Disorders*, Vol. 8, No. 1, 2007, pp. 1-8.

[20] Jeon, In-cheol, et al. "Ankle-dorsiflexion range of motion after ankle self-stretching using a strap." *Journal of Athletic Training*, Vol. 50, No. 12, 2015, pp. 1226-32.

[21] Webster, Coutney, and Nussbaum Maury A. "Localized ankle fatigue development and fatigue perception in adults with or without chronic ankle instability." *Journal of Athletic Training*, Vol. 51, No. 6, 2016, pp. 491-97.

[22] Cho, Byung-Ki, et al. "The effect of peroneal muscle strength on functional outcomes after the modified broström procedure for chronic ankle instability." *Foot & Ankle International*, 2017, pp. 1-8.

[23] Olmo, Jesús, et al. "Identification of feigned ankle plantar and dorsiflexors weakness in normal subjects." *Journal of Electromyography and Kinesiology*, Vol. 19, No. 5, 2009, pp. 774-81.

[24] Kannus, P. "Isokinetic Evaluation of Muscular Performance." *International Journal of Sports Medicine*, Vol. 15, No. 1, 1994, pp. 11-18.

[25] Fowloes, J.R, Sale D.G, and Macdouglall, J.D. "Reduced strength after passive stretch of the human plantarflexors." *The American Physiological Society*, Vol. 89, No. 3, 2000, pp. 1179-88.

[26] Abdel-aziem, Amr A., and Mohammad, Walla S. "Plantar-flexor static stretch training effect on eccentric and concentric peak torque - a comparative study of trained versus untrained subjects." *Journal of Human Kinetics*, Vol. 34, No. 1, 2012, pp. 1-12.

[27] Salvini, Tania F., et al. "Effects of electrical stimulation and stretching on the adaptation of denervated skeletal muscle: implications for physical therapy." *Brazilian Journal of Physical Therapy*, Vol. 16, No. 3, 2012, pp. 175-83.

[28] Luna, Natalia M. S., et al. Greve J. "Isokinetic analysis of ankle and ground reaction forces in runners and triathletes." *Clinics*, Vol. 67, No. 9, 2012, pp. 1023-28.

[29] Guissard, Nathalie, Duchateau, Jacques, and Hainaut, Karl. "Mechanisms of decreased motoneurone excitation during passive muscle stretching." *Experimental Brain Research*, Vol. 137, No. 2, 2001, pp. 163-169.

[30] Fousekis, K, Tsepis, E, and Vagenas, G. "Multivariate isokinetic strength asymmetries of the knee and ankle in professional soccer players." *The Journal of Sports Medicine and Physical Fitness,* Vol. 50, No. 4, 2010, pp. 465-474.

[31] Jeon, In-cheol, et al. "Ankle-dorsiflexion range of motion after ankle self-stretching using a strap." *Journal of Athletic Training*, Vol. 50, No. 12, 2015, pp. 1226-32.

[32] Tijs, Chris, et al. "Synergistic Co-activation Increases the Extent of Mechanical Interaction between Rat Ankle Plantar-Flexors." *Frontiers in Physiology*, Vol. 7, No. 414, 2016, pp. 1-8.

[33] Croisier, Jean L., et al. "Strength imbalances and prevention of hamstring injury in professional soccer players." *The American Journal of Sports Medicine*, Vol. 36, No. 8, 2008, pp. 1469-75.

[34] Ruan, Mianfang, Zhang, Qiang, and Wu Xie. "Acute effects of static stretching of hamstring on performance and anterior cruciate ligament injury risk during stop-jump and cutting tasks in female athletes." *Journal of Strength and Conditioning Research*, Vol. 31, No. 5, 2017, pp. 1241-50.

[35] Opplert, Jules, and Babault Nicolas. "Acute effects of dynamic stretching on muscle flexibility and performance: An analysis of the current literature." *Sports Medicine*, 2017, pp. 1-27.

[36] Blum, Kyle P., et al. "Force encoding in muscle spindles during stretch of passive muscle." *Plos Computational Biology*, Vol. 9, No. 13, 2017, pp. 1-24.

[37] Oliveira, Anderson S., et al. "Isokinetic eccentric resistance training prevents loss in mechanical muscle function after running." *European Journal of Applied Physiology*, Vol. 113, No. 9, 2013, pp. 2301-11.

[38] Herda Trent J., et al. "Acute effects of static versus dynamic stretching on isometric peak torque, electromyography, and mechanomyography of the biceps femoris muscle." *Journal of Strength and Conditioning Research*, Vol. 22, No. 3, 2008, pp. 809-17.