Immediate and late acute responses of flexibility in the shoulder extension in relation to the number of series and stretching duration

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ABSTRACT

The objective of this study was to investigate the relation between the number of series and duration of shoulder stretching exercises on the immediate and late acute effects on flexibility. Seventy individuals with ages ranging from 20 and 30 years with no previous flexibility training participated in this study. Randomly, 10 subjects composed the control group (CG) and the others were equally divided into three groups according to the duration of the stimulus, namely: 10 seconds (G10), 60 seconds (G60) and 120 seconds (G120). Later, each group was subdivided in relation to the number of series, namely: one (G10A, G60A, G120A) and three series (G10B, G60B, G120B). Flexibility was measured through an universal goniometer and the observations occurred shortly after, 90 minutes after and 24 hours after stimulation. The analysis of variance ANOVA identified significant association between the time of stimulus and the other variables ($p = 0.042$). No differences of flexibility were verified between experimental groups, but all groups exhibited values higher than CG. The temporal comparison of absolute values of flexibility for groups submitted to the same stimulus duration and number of series revealed significant differences only for G120A, G60B and G120B, between the first observation and 24 hours after. On the other hand, the analysis of the percentile values showed that the stimulation time and the number of series were associated with the duration of the flexibility acute increment. In this case, no differences between groups were verified, except between G60A and G60B in the observation after 24 hours. One concludes that stimulus duration may provide higher initial flexibility, regardless the number of series. However, the immediate gains of flexibility could not be maintained after 24 hours. No one knows, however, if progressive long-duration stimuli would provide long-term higher amplitude if compared with stretching exercises performed in shorter periods of time.

Key words: Training. Exercise. Physical fitness. Mobility. Joint.

INTRODUCTION

Flexibility may be defined as the maximal articular amplitude of one or more joints[1] or through the relation between the length and tension of a stretched muscle[2]. The flexibility training provides an increase on the length of the muscle-tendon unit. However, this increase is not quickly reversible in function of the viscoelastic properties of these tissues[3]. Information on the muscle viscoelastic properties, both in the flexibility training and in repeated contractions were reported, seeming to result in a passive decrease on tension in a neutral length[4]. Traditionally, methods such as the ballistic, the proprioceptive neuromuscular facilitation (PNF) and the static stretching are used for the flexibility training, where the last method mentioned is widely used due to its apprenticeship and application easiness. This method composes one of the strategies to increase the length of the conjunctive and muscular tissues, inducing to changes on the mechanical properties and leading to an increase on the maximal range of motion in different periods of time[5]. It is supposed that all training methods increase flexibility, but variations in their methodological components may compose differentiated strategies for training, thus changing the final results.

The time one remains in maximal extension in repeated exercises seems to be associated to changes in the mechanical strength with inverse relation to the tension applied[6,7]. With regard to the exercise prescription parameters, however, there is no agreement about the adequate duration. More, there is no conviction about the magnitude of the chronic and acute effects (immediate and late) of different combinations between number of series and stimulus duration. Magnusson *et al.*[6], for example, suggest that stimuli of the order of 90 seconds performed in at least five successive series with 30 seconds of interval between each are required for the adaptation with regard to the mechanical strength to extension. However, shorter times (between 30 and 60 seconds) between one and three series are frequently used in training sessions[8]. It has been demonstrated, however, that even an isolated series of static exercises may be effective on the modification of the range of motion, once the stimulus duration time is increased and the viscosity of the muscle-tendon units is improved with good use of the movement elastic energy[9-11]. The mechanical properties, therefore, seem to be associated with changes on the range of motion and on the flexibility training.

In this context, the objective of the present study was to investigate the reduction of flexibility in the shoulder extension movement associated with the immediate acute effects (until 90 minutes post-session) and late acute effects (24 hours post-session) to training as result of the stretching exercise with different series combinations and stimulus duration times.

MATERIAL AND METHODS

Before proceeding the data collecting itself, a pilot-study with 10 individuals was performed, always involving that same appraisers for the measurement of the shoulder extension with subject in sitting position and goniometer fixed to the humerus and at the axillary line. It was observed that in this position, the individual could not reach the desired posture, causing less reliability in the data collecting. Three consecutive test days were performed with individuals in ventral decumbent position; position in which the data obtained presented higher reliability due to the trunk stability. The three data collecting of the pilot-study presented an average intra-class correlation coefficient of 0.96 for all three measures.

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After the pilot-study, 70 individuals from both genders with ages ranging from 20 and 30 years (67 ± 12 kg; 169 ± 10 cm), healthy and physically active were selected. The individuals presented no lesions or symptoms in the shoulder and participated on no flexibility-training program in the time of the study. All individuals were volunteers and signed a consent form, according to resolution 196/96 of the Health National Agency for experiments in human beings after approval by the ethics committee of the institution.

The sample was distributed into three experimental groups and one control group by means of the Latin square technique. All experimental groups performed the same shoulder stretching exercise without any previous warm up exercise, but with differentiated number of series and stimulus duration and the interval between series was set in 30 seconds for all groups. The control group (CG) was composed of 10 subjects and the others were equally divided into three groups, according to the stimulus duration, namely: 10 seconds (G10), 60 seconds (G60) and 120 seconds (G120). Besides the division according to the duration time, a subdivision was also performed according to the number of series, thus characterizing groups A (one series) and B (three series) (figure 1).

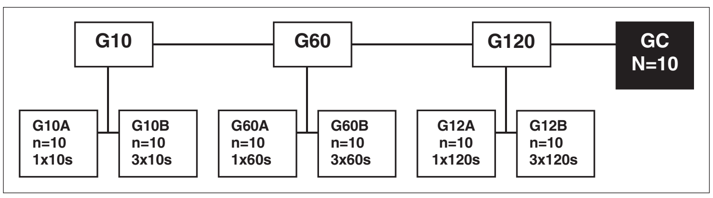


***Fig. 1** – Division of groups and subgroups. G10 (stimuli of 10 seconds), G60 (stimuli of 60 seconds) and G120 (stimuli of 120 seconds). Subgroups A (single series) and B (three series).*

The shoulder extension was selected as the exercise to be performed due to the facility to isolate it during the experimental period in function of its little utilization in daily tasks. The subject positioned in ventral decumbent position with arms along the body and the palm oriented medially, searched to reach maximal range of motion in the right shoulder by using the stretching passive method in a single attempt (figures 2 and 3). The measures were taken by two well-trained appraisers. Velcro tapes were used with the objective of maintaining the subject at the correct position during tests, while one of the appraisers stabilized the scapula. The measurement device used was a metal universal goniometer, protractor of 180 degrees with a single shaft, presenting one arm changeable and another arm still, adapted to the size of the joint evaluated.

***Fig. 2** – Initial position*

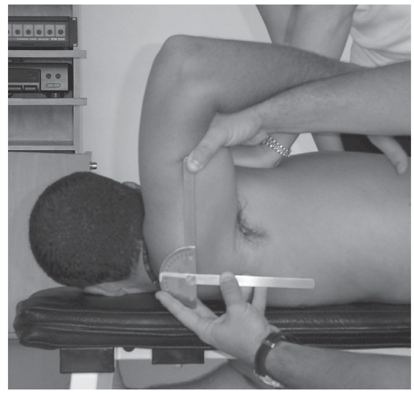


***Fig. 3** – Final position*

The experimental protocol followed the following stages:

a) Providing of information before tests, explaining the routine of activities at the data-collecting eve, especially with regard to the movements that should be avoided in the 24 hours before and after the tests.

b) Application of the experimental treatment, making sure that the subject was comfortably leant against the bench in ventral decumbent position. The appraiser isolated the joint, searching to stabilize the segment while applying the passive tension up to the maximal amplitude. The goniometer was placed laterally to the joint with its shaft centralized at the humerus' head, with 2.5 cm below the acromion lateral surface. The still arm was positioned parallel to the longitudinal axis of the trunk and the changeable arm, parallel to the humerus longitudinal axis, pointing to the lateral epicondyle.

c) Three flexibility measures were taken. The first measure shortly after treatment, the second 90 minutes after the first intervention and the third 24 hours after, always in the morning (between 6 am and 10 am).

The analysis of variance ANOVA was used for repeated measures with three inputs (number of series, stimulus duration and observation time) followed by *post-hoc* Scheffé test to verify intra and inter-groups differences in relation to the absolute values and to the percentile variations in relation to the first measure. In all cases, the significance level of $p < 0.05$ was adopted. The data treatment was performed through the software Statistica 5.5 (Statsoft®, USA).

RESULTS

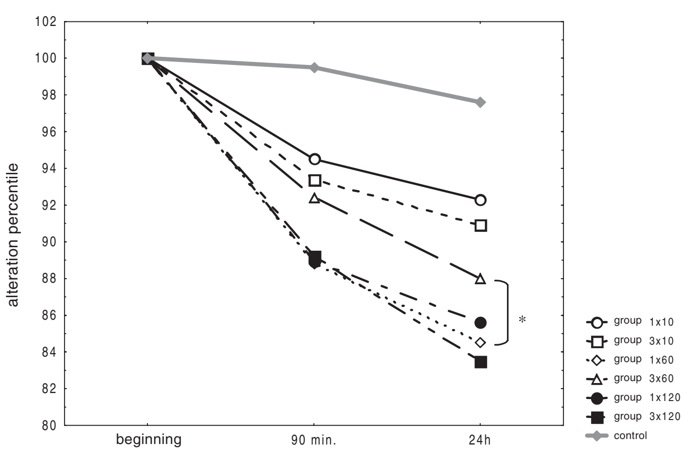
Table 1 presents the absolute results, identifying the testing situations. The analysis of variance ANOVA identified significant association between the stimulus time and the other variables ($p = 0.042$). The inter-groups comparison showed that the flexibility shortly after exercise was higher than the control group for all experimental groups. This situation did not occur in the other observations (90 minutes and 24 hours after exercise), situations in which significant differences were not identified. With regard to the intra-groups analysis, significant differences occurred only for G120A, G60B and G120B, between the first observation and the situation after 24 hours.

On the other hand, the analysis of the percentile values showed that the duration of the stimulus and the number of series influenced the flexibility. Differences in all experimental groups were observed after 90 minutes and 24 hours in relation to the first observation. No intra-groups differences were verified, except between G60A and G60B in the observation after 24 hours (graphic 1). Apparently, the duration of the stimulus provided higher initial flexibility, regardless the number of series. However, after 24 hours, the experimental groups trend to exhibit the same values as the CG. Thus, the immediate flexibility gains could not be maintained after 24 hours.

TABLE 1
Descriptive statistics for absolute values of flexibility in all experimental situations (shortly after, 90 minutes and 24 hours after training)

		Average	Standard deviation	Confidence interval of 95%
	Beginning	78.7	14.3	68.5-88.9
1 x 10 (G10A)	90 min	75.0	15.7	63.8-86.2
	24 h	73.1	14.3	62.9-83.3
	Beginning	83.3	9.9	76.2-90.4
3 x 10 (G10B)	90 min	77.1	6.7	72.3-81.9
	24 h	73.3	7.4	68.0-78.6
	Beginning	82.9	14.3	72.6-93.1
1 x 60 (G60A)	90 min	77.7	14.8	67.1-88.3
	24 h	75.6	13.9	65.7-85.3
	Beginning[a]	85.3	7.9	79.6-91.0
3 x 60 (G60B)	90 min	76.1	7.3	70.9-81.3
	24 h	73.5	9.2	66.9-80.1
	Beginning[b]	81.4	12.6	72.4-90.4
1 x 120 (G120A)	90 min	72.4	11.3	64.3-80.5
	24 h	68.9	11.3	60.8-77.0
	Beginning[c]	86.8	10.2	79.5-94.1
3 x 120 (G120B)	90 min	77.6	13.1	68.2-87.0
	24 h	72.4	13.9	62.5-82.3
	Beginning	75.5	10.5	68.0-83.0
Control	90 min	75.4	9.7	68.5-82.3
	24 h	73.8	9.5	67.0-80.6

[a] significant difference in relation to value after 24 hours of interval ($p = 0.024$)
[b] significant difference in relation to value after 24 hours of interval ($p = 0.017$)
[c] significant difference in relation to value after 24 hours of interval ($p = 0.006$)



* significant difference ($p = 0.011$) between G60A (one series of 60 seconds) and G60B (three series of 60 seconds) for observation performed 24 hours after training.

Graphic 1 *– Flexibility percentile behavior after 90 minutes and 24 hours in relation to measure performed after stimulus*

DISCUSSION

The objective of the present study was to investigate the immediate and late acute effect of different combinations of series and duration of the stimulus in exercise involving the shoulder extension movements. The results here obtained suggest that the effect of higher magnitude occurred when the duration time exceeded 60 seconds, regardless the number of series. However, these flexibility gains were proportionally decreased after 90 minutes and 24 hours of interval, with values trending to return to initial levels, equivalent to the values of the control group.

Bandy *et al.*[8] analyzed 93 individuals from both genders, performing stretching exercises for the ischiotibial muscles during five days a week, performing a total of six weeks. Using a goniometer for the measurement of the flexibility, no significant differences as result of the increase on the number of daily training sessions were observed (1-3 times). With regard to duration time of the stimulus, times of 30 and 60 seconds were used, which were equally effective in the amplitude gains. In a later study, the same authors compared 30 with 15 seconds and once again verified that 30 seconds of stimulus were more effective in the production of training acute effects[12].

Considering our results, some data seem to corroborate with the study of Bandy *et al.*[8], that a longer time of tension may produce more significant acute effects in the range of motion. However, the most important difference is the own musculature stimulation time. While Bandy *et al.*[12] applied stimulus of 15 to 30 seconds, stimulus of 10, 60 and 120 seconds were compared in our study. The best results were recorded as result of the stimulus with duration of 60 seconds or more on the absolute and percentile values considered for both the immediate and late acute effects. These results demonstrate that the longer the duration time of the stimulus is, the more effective the results will be. This conclusion agrees with findings from other study of Bandy *et al.*[8] in which it was verified that a duration time of 30 seconds would be the ideal time for amplitude gains.

The duration time seems to provide important physiological changes such as the remodeling of elastin and collagen molecules[3]. These changes may be associated with alterations on the muscle-tendon units and fascia, caused by the increase on the tissues elasticity through hysteresis. In other words, the range of motion would be influenced by the increase on the length of the tissue proportionally to the tension applied. In this context, the deformations would occur as the maintenance of the range of motion and the consequent decrease on the tension in the muscle, fascia and tendon also occur[13-16]. Such increases on the range of motion may yet be the result of the improvement of the neural activities[11,16]. In the attempt of understanding this mechanism, one of the hypothesis is related to the modifications on the neuromuscular mechanisms through the stimulation of the motor units and hence excitation of the alpha and gamma motoneurons. The neural effects initially provide an increase on the range of motion before the actuation of the reflex system with the later participation of the spindles and the autogenic and reciprocal inhibitory actions caused isometric contractions that occurred during the length increase process and tension generation during stretching[11,16]. However, these effects, initially important, seem not to produce significant results when compared with the hypothesis of reduction of the mechanical strengths. This reduction seems to occur due to changes on the viscoelastic properties of the soft and conjunctive tissues under constant stress during flexibility training[17].

The study of Madding *et al.*[18] compared different stimuli (15, 45 and 120 seconds) and reported that 15 seconds were effective for the development of the range of the hip abduction movement with the use of the static stretching method in only one series, thus finding no differences between these duration times. Shrier and Gossal[19], in a study with the static method, mentioned the comparison between duration times (15-30 seconds) with a single muscular group, verifying that 15 seconds were sufficient to produce changes on the muscular length. Thus, Shrier and Gossal[19] suggested that increases on the stimulus time would produce higher-amplitude immediate acute responses in function of the improvement on the body consciousness as the tension was maintained and the time was increased. In the present study, however, it was observed that stimulus times above 30 seconds produced better results than stimulus time of 10 seconds. This influence seemed to be more relevant than that of the number of series.

The study of Cipriani *et al.*[20] also used the static method, applied for 10 and 30 seconds. However, different combinations of exercise times were performed, with intervals during one day of training (many times with several hours of interval), but always aiming at a total of two minutes of stimulus at the end of the exercise. The effectiveness of the summation was demonstrated, indicating that fractioned stimuli during the day would provide an acute effect more intense if compared with a continuous training session. In our study, this fractioning was performed with the use of two protocols containing one and three series. If acute differences between these volumes could not be observed, it was given for the duration of the continuous stimulus. This could lead us to the following speculation: stretching exercises performed with extended stimuli would maintain their effects for a period of 24 hours, regardless their fractioning, thus suggesting a daily practice.

A possible aspect to be analyzed would be the potential influence of the repeated measures in the same individual on the results obtained. In other words, the performance of the movement tested could be understood as a new stimulus, what would aid on the maintenance of high ranges of motion as result of the renewed acute effect.

Other studies that investigated this topic[8,18] presented the same problematic, working with intervals between stimuli ranging from 15 second to one week. However, one must observe that in our study, the spacing between measures performed was large (90 minutes and 24 hours), what diminished the possibility that the repeated effects could invalidate the results. In all cases, the tendency was of flexibility reduction. Although the theoretical possibility does exist, in fact the duration of the measure performed was far lower the stimulus times adopted and training significant additional effects would not be easily produced.

Other limitation was due to the fact that the flexibility was not measured before intervention. Two reasons justify this choice: a) the acute influence of the measure on the range of motion, maybe contaminating the effects of the different training situations; b) the nature of the movement, unusual in the daily life and the fact that the volunteers did not train flexibility. So, there was no reason to think that important differences of flexibility existed among the individuals. On the other hand, this study aimed at the magnitude of the flexibility reduction at the period observed, rather than the immediate gains provided by the stimuli, reason why the values were examined as percentiles, considering as 100% of flexibility that level reached at the end of the stimuli in all groups. This correct choice seems to be confirmed through the values measured after 24 hours, once none of the experimental groups presented flexibility values significantly different from those exhibited by the control group.

CONCLUSION

Our results demonstrated that both the number of series and the duration time of the stimulus influenced the post-exercise flexibility values acutely. The highest alteration, however, occurred due to the duration time. The effect of the number of series seems to be associated with the duration time of the stimulus. The experimental groups with longer stimulus duration presented the best results after 90 minutes and 24 hours from the end of the exercise session. These results present application on the prescription of stretching exercises and their daily practice seems to be necessary for the maintenance or development of the flexibility in function of the late acute effects after 24 hours to present a tendency of returning to the initial values, even with variations on the number of series or on the duration time. In further studies, it would be interesting to evaluate in populations with different ages and objectives, the responses associated with other movements and the repercussion of the variables observed on the training chronic effects.

All the authors declared there is not any potential conflict of interests regarding this article.

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