Correlation between Acute and Short-Term Changes in Flexibility Using Two Stretching Techniques

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Abstract
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This study aimed to determine whether increases in flexibility following a single session predict increases in flexibility after a short-term stretching training program involving static stretching (SS) or proprioceptive neuromuscular facilitation (PNF) techniques. 70 adults (aged 18–30 years) of both sexes were randomly assigned to 2 groups: PNF (2 series of contract-relax stretching) and SS (static stretching for 1 min). Both stretching protocols were performed for 7 consecutive days. Active knee extension was evaluated before and after the first session and one day after the end of the intervention. Two-way ANOVA showed significant flexibility gains for both groups and no difference between them. The changes in flexibility after the first intervention session were strongly correlated with the changes after the training program in both groups (PNF r = 0.82, p = 0.001; SS: r = 0.82, p = 0.001). Linear regression showed that the increases in flexibility predicted the gains after both training programs (PNF: r² = 0.67, p = 0.001; SS: r² = 0.61, p = 0.005). In conclusion, the acute changes in flexibility after a single session of PNF and SS predict the gains in flexibility after longer-term training programs.

Introduction
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Flexibility is an important component for sports performance and also for maintaining an independent lifestyle with regard to daily activities [5, 8]. Systematic stretching exercises reduce the risk of injuries and increase performance by decreasing the resistance of structural tissues surrounding the joint, thereby enabling greater mechanical efficiency of movement [19, 23]. Several studies have analyzed the effectiveness of a number of stretching techniques [2, 3, 5, 8, 12, 14–16], analyzing the intervening factors, such as frequency [6], scope, the way tension was applied [4, 12, 20] or the duration of the training program [1, 21]. Static stretching (SS) and proprioceptive neuromuscular facilitation (PNF) are methods that are widely used and considered to be safe and easy to perform. The SS technique takes the muscle to its end range and maintains this position for a specified duration. On the other hand, PNF involves combinations of alternating contractions and stretching of muscle using techniques such as hold-relax and contract-relax [6, 10]. Interestingly, regardless of the stretching technique used, responses to a single stretching session varied widely among subjects, and this seems to be related to the different degrees of physiological and sensorial adaptation during stretching, such as muscle tissue viscoelastic deformation and connective tissue plasticity, and tolerance [18, 22]. Therefore, as adaptation to stretching exercises may result from an accumulation of a number of acute stretching stimuli, it is plausible to suppose that short-term gains in flexibility after a training program are related to the changes observed after a single session of stretching exercises. In other words, subjects with better acute responses are more likely to adapt better to training programs. In the clinical context, being able to predict gains in flexibility after stretching intervention facilitates the planning of treatment and enables the best stretching technique for each individual to be determined. Likewise, in sports, the prediction of longer increases in flexibility may be useful for identifying individuals with the potential for modalities that require flexibility. This study therefore aimed to determine whether increases in flexibility after a single session predict increase in flexibility after a short-term stretching training program using the SS or PNF techniques.
Methods

Subjects

70 young adults of both sexes, between the ages of 18 and 30 years, were recruited for the study. The sample size was determined by two-tailed GPower 3.1.7, with $\alpha=0.05$, $\beta=0.05$ (95% power) and a correlation coefficient of 0.70. Based on these data, an $n$ value of 21 subjects was calculated to be necessary. This number was increased by 30% to account for possible losses during the study, resulting in a final $n$ value of at least 28 individuals in each group.

The participants were included if they were right-handed, had not engaged in any physical activity program for at least 6 months, achieved less than 160° on the Active knee extension flexibility test for the right leg, and had no history of musculoskeletal injuries and/or surgery in the lower limbs, or any signs of inflammation or pain in the lower limbs or spine. We excluded those who missed any session.

All subjects signed a written informed consent form. The study was approved by the Ethics Committee for Research Involving Human Beings of the University of Pernambuco and it was conducted in accordance with recognized ethical standards and national as well as international laws [11].

Flexibility assessment

Active knee extension was assessed in the right leg. For the assessment, the participant was placed on a stretcher in supine position with the right hip flexed to 90° and the left leg kept in extension on the stretcher. 2 researchers maintained this position, while the volunteer was required to actively extend the right knee. A third researcher then conducted goniometry (Carci®, Brazil), positioning the device with the axis on the lateral femoral condyle, the fixed rod pointing in the direction of the greater trochanter and the movable rod in the direction of the lateral malleolus.

Experimental protocol

The volunteers were randomly divided into 2 groups, SS and PNF, and underwent 7 sessions of stretching on consecutive days. Each session started with the Active Knee Extension evaluation.

The SS and contract-relax PNF procedures were performed according to the protocols previously described [20,21]. For the SS, a pulley and rope system was used with one end attached to the right ankle and the other to a 7 kg weight. The load enabled SS, a pulley and rope system was used with one end attached to according to the protocols previously described [20, 21]. For the PNF, the therapist, who o...
increases in ROM after the first session predict more than 60% of the short-term gains in ROM for both SS ($r^2 = 0.61$, $p = 0.005$) and PNF ($r^2 = 0.67$, $p = 0.001$). The increases in ROM after the training program presented a moderate correlation with initial flexibility levels for both SS ($r^2 = -0.42$, $p = 0.001$) and PNF ($r^2 = -0.38$, $p = 0.04$) protocols.

Discussion

The main results of this study were: (i) increases in flexibility after the first stretching session predicted the flexibility gains after a short training program; (ii) this prediction was observed for both the SS and PNF methods.

The results of the present study indicate that both stretching methods increased ROM to a similar extent, which concurs with the findings of previous studies [8, 16, 21]. What is new is that this similar increase was observed after both the acute session and the longer-term intervention. The similar increases can be explained by the similar stretching time (60 s continuous for SS and 2 consecutive sets of 30 s for the PNF group), suggesting that the duration of the stretching stimulus is important, which is consistent with the recommendations given in current literature [7].

The main result of this study was that, regardless of the stretching method employed, there was a strong correlation between changes in flexibility after the first session and longer-term changes in flexibility after the training program, indicating that acute gains predict short-term increase in flexibility. Interestingly, the initial flexibility levels presented only a moderate correlation with the longer-term changes in flexibility. Taken together, these results suggest that the increases in flexibility in the first session of stretching exercises are the main predictor of increases in flexibility after further intervention, regardless of the initial flexibility levels of the subjects. In practical terms, the result indicates that the prediction of flexibility gains following intervention can be used for different subjects, regardless of their initial flexibility levels.

In the present study 2 stretching techniques were used: PNF and static stretching. PNF involves a mechanism of achieving new ROM end-point by using a hold-relax process of passively lengthening the muscle to the point of limitation and then performing isometric contraction. Static stretching involves taking the muscle to its end-range and holding it in this position for an extended period of time with a sustained force [16]. According to Riley & Van Dyke [17] both stretching methods are effective for increasing muscle extensibility, while each employing different physiological mechanisms. Active stretching techniques, such as PNF, induces sarcomere series turnover by increasing cytoplasmic calcium during contractile activity that indicates the pathways required to regulate the sarcomere series. On the other hand, passive static tension reduces muscle stiffness through connective tissue and decreases stretch-induced pain. However, Weppler & Magnusson [22] argue that since the early 1990s a number of researchers have tested these mechanical theories and none of them accept mechanical explanations for increased end-range
joint angles after single sessions and short-term stretching programs (less than 8 weeks) [9, 10, 13]. Considering that our participants followed a short intervention, not long enough to provide mechanical adaptations, muscle extensibility gains can be better explained by neural mechanisms, such as sensations of pain onset and pain or stretch tolerance [22]. It can therefore be hypothesized that the performance of both stretching techniques provided, over the course of the week, a reduction in pain on stretching and this may have contributed to changes in stiffness. Reduction in muscle tissue stiffness is due to connective tissue alteration: ubiquitous fibroblasts respond to tension and proteolytically remodel the connective tissues, thereby reducing stiffness. Stiffness is a continuously adapting property of skeletal muscles, which adjust day by day to the environment. Stiffness is a continuously adapting property of skeletal muscles, which adjust day by day to the environment.

In the clinical context, given that many patients undergo short rehabilitation programs, these results indicate that during the first session, which can be set up as an evaluation, the professional can estimate the gains to be obtained at the end of stretching training program. This enables the evaluator to consider whether the subject has exceeded or fallen short of the desired result by the end of the intervention, thereby enabling appropriate planning strategies to be adopted. Another potential benefit of these results is that single-session studies could be carried out to predict short-term effects. Thus, instead of longer protocols, acute stretching data may be sufficient to predict longer-term changes in behavior. However, this should be considered with caution, because the present study involved a short-term program, restricted to 1 exercise and 2 methods.

It is important to bear in mind that the present results relate to the protocol used in a young adult group and should not be extrapolated to other protocols and different subjects. Thus, other types of measures and a longer intervention (up to 8 weeks) would be needed for this purpose. Future studies should address whether similar results are observed using other protocols, with other populations, and with more training sessions. Furthermore, the discussion and comparison of the results of the present study are limited by the lack of similar studies. Therefore, given that stretching gains vary according to different combinations of variables, such as stretching technique, length of program, stimulus duration, intensity, frequency and the characteristics of the population, further studies should be conducted exploring different combinations of these variables.

Finally, based on the data presented in the present study, it can be concluded that both the static stretching and PNF methods can bring about significant gains in flexibility, that there is a strong correlation between the initial gain and final ROM, and that the initial gain is a variable that can predict around 60% of the gain achieved at the end of a sub-acute training program to improve flexibility.

**Conflict of interest:** The authors have no conflict of interest to declare.