CHANGES IN RANGE OF MOTION RESULTING FROM VARYING INTENSITIES OF ISOMETRIC CONTRACTIONS DURING PROPRIOCEPTIVE NEUROMUSCULAR FACILITATIONS

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The objective of this study was to investigate changes in flexibility in males and females during proprioceptive neuromuscular facilitations (PNF) of the erector spinae and the hamstrings musculature at different intensities in a series of 4 repetitions of a single exercise bout. In four randomized trials, the 15 subjects (11 males and 4 females), aged 18-59 years performed a PNF flexibility exercise protocol using two intensities of isometric contraction. There were no significant differences between angles (range of motion) after repetition #1, #2, #3 or #4 between the MVIC and 50% MVIC trials. No trends were established between changes in flexibility and intensity of effort.

KEY WORDS: stretching, neurophysiology, molecular restructuring

INTRODUCTION: Reviewing the literature on this subject reveals that: 1.) although some degree of conflict exists among experts, most evidence supports proprioceptive neuromuscular facilitations (PNF) and its derivatives as being the most effective way to improve flexibility, 2.) although much theoretical speculation is evident, no single model has been accepted that explains PNF effects. One fundamental assumption regarding PNF stretching techniques is that maximum or near maximum isometric contractions are necessary to elicit the greatest improvements. This effort was always requested by the therapist/partner but the actual forces exerted were never directly measured. With these facts in mind, the purpose of this study was to investigate changes in flexibility in both male and female subjects resulting from PNF stretching of the erector spinae and the hamstrings musculature using different intensities of isometric contractions, in a series of 4 repetitions of each exercise bout.

METHODS: Fifteen subjects (11 males and 4 females), aged 18-59 years participated in the study. Active angle of the trunk and isometric torque of the erector spinae were measured using the FlexAbility trunk extensor machine; and active angle of the right thigh and isometric torque of the hip extensors, (hamstrings) were measured using the FlexAbility lower body machine. These apparati take the place of the therapist/partner while the exercising individual performs a specific PNF routine based on the "reversal of antagonists", as put forth in the book "*Scientific Stretching for Sport - 3S*" (Holt, 1974). The back machine required the subject to be seated with the trunk posture aligned 90 degrees to the horizontal plane. The feet were braced against an adjustable platform positioned to establish an absolute knee angle of 145 degrees, and with hips outwardly rotated. The subject then actively moved into trunk flexion maintaining a relative straight alignment of the trunk (scapulae adducted, elbows flexed), with the subsequent angular displacement recorded from the liquid crystal display (LCD), once the arm of the machine moved to touch the back. Once angular displacement was recorded the subject began the exercise protocol. The hamstring machine required that the subject lie in the supine position with the pelvis firmly held to the top padded platform of the machines. The subject actively moved one leg (straight at knee joint) into maximal hip flexion. Once the machine's arm was in place, the LCD provided the acquired angle. Once the angular displacement was recorded the subject began the exercise protocol. Subjects were instructed to perform a series of 4 repetitions of the 3S protocol on either the back or hamstrings machines. Each repetition involved a move to maximum flexion of the trunk or leg, (machine followed to contact body). Once the machine arm was positioned, the subject began an isometric contraction, this involved a 4 second build-up of intensity of the isometric of the erector spinae, or the hamstrings

musculature, followed by an 8 second hold of the isometric contraction, then a 5 second move to reposition, (relax the agonist, 2 seconds, then contentrically contract the antagonist, 3 seconds). Angular displacements and isometric torques were recorded during this procedure.
While using the back or hamstrings machine, subjects were instructed to exert either a perceived near maximal voluntary isometric contraction (MVIC), or a 50% MVIC during the isometric contraction portion of the repetition. Subjects were randomized to 1 of 4 testing sequences:

Sequence 1. MVIC back, 50% MVIC back, MVIC hamstrings , 50% MVIC hamstrings (n = 4)
Sequence 2. MVIC hamstrings, 50% MVIC hamstrings, MVIC back, 50% MVIC back (n = 4)
Sequence 3. 50% MVIC back, MVIC back, MVIC hamstrings, 50% MVIC hamstrings (n = 3)
Sequence 4. 50% MVIC hamstrings, MVIC hamstrings, MVIC back, 50% MVIC back (n = 4)

The statistical significance of the results were determined by ANOVA comparisons between angles during the series of 4 repetitions at MVIC and at 50% MVIC for each machine.

RESULTS: No significant differences were found between angles at MVIC and 50% MVIC for each repetition (Table 1). However, significant ($p<0.05$) changes occurred from repetition #1 through to repetition #4 in all 4 trials.

Table 1 Average Range of Motion Resulting from a Series of 4 Repetitions of MVIC or 50% MVIC of the Erector Spinae and Hamstrings (n = 15)

	Erector spinae		Hamstrings	
	MVIC	50% MVIC	MVIC	50% MVIC
	ROM	ROM	ROM	ROM
(degrees)	(degrees)	(degrees)	(degrees)	
after 1st rep	25±7.5	25±7.9	77±25.3	80±15.6
after 2nd rep	30±6.9*	30±7.4*	94±14.9*	96±10*
after 3rd rep	33±7.5*	33±7.4*	100±14.4*	101±17.3*
after 4th rep	35±7*	34±6.8*	104±12.7*	104±16.8*

Notes: *significant, $p < 0.05$ (compared to 1st repetition, same intensity and muscle group)
Force applied: back MVIC = 703 newtons (average across all subjects).
back 50% MVIC = 347 newtons (average across all subjects).
hamstrings MVIC = 583 newtons (average across all subjects).
hamstrings 50% MVIC = 289 newtons (average across all subjects).

No significant differences between intensities (ie., MVIC versus 50% MVIC, same repetition and muscle group).

DISCUSSION: There are two theoretical models that attempt to explains PNF effects; neurophysiology and molecular restructuring. We will address each in turn.
Neurophysiology: During a 3S stretch, it would appear that an isometric contraction of a stretched agonist for an extended period of time would cause activation of it's neuromuscular spindle, and Golgi tendon organ (GTO). During a 3S protocol, it has been speculated that the

activity of both the neuromuscular spindle and the GTO cause a decrease in the agonists resistance to further lengthening when the antagonist follows with a concentric contraction. The more intense the initial isometric, the more complete this effect is supposed to be. This would mean that a maximal isometric should lead to a greater increase in ROM. That is, the neurophysiological basis of PNF would suggest a maximum isometric contraction of the agonist would allow for a greater ROM of the agonist than a lesser intense contraction.

Molecular Restructuring: However, the failure to demonstrate increased ROM in this study at different intensities of isometric contraction under the same time constraints, indicates that other more subtle variables in the mechanism(s), along with neurophysiologic, are needed explain the changes in soft tissue elasticity which leads to greater joint extensibility from this form of PNF training. The data presented here is consistent with the postulation that any level of isometric contraction above 50% MVIC causes physical disruption of either the gross structures, the intermolecular cross-links and/or the imtramolecular cross-links between fibers in peri-articular connective tissue.

Enforcing this hypothesis is the fact that in the past, it has been suggested that stretching at a low resistance requires more time to produce the same amount of joint extensibility than stretching with a higher resistance. In this study, identical time frames at MVIC and 50% MVIC produced similar ROM.

Following an isometric contraction in the lengthened state, as is the case during the 3S protocol, it is likely that morphologic changes occur. That is, relationships between structures (macro and/or micro) are re-instituted and a new resting length is established. In response to these new biophysical relationships, neurologic responses at all levels are adjusted. Elongation of the soft tissue may be simply one of, or a combination of, semi-permanent re-setting of the coiled chains of the elastic tissue in response to the applied force, or semi-permanent re-setting of the wrapping of the collagen fibers with the braking of cross-links, or a lengthening of the sarcomere. Of these, the most likely to elongate would be the elastic fibers of the fascia.

There are several limitations to this study:

1.) no direct evaluation of the neurological components, (GTO, muscle spindle, etc.).
2.) the lack of control over performance motivation of subjects.
3.) no measure of the proposed elongation of the soft tissue.

These limitations do not in themselves dismiss the results of this study. They do point to the need for more sophisticated studies to fully define the mechanism(s) of PNF. Only after detailed observations of the dynamic biological responses to PNF, can the riddle of the mechanism(s) of soft tissue elongation resulting from PNF stretching be solved.

CONCLUSION: In the past, one fundamental assumption regarding PNF stretching techniques is that maximum or near maximum perceived isometric contractions (PMVIC) are necessary to elicit the greatest improvements. However, the present study refutes this assumption.

REFERENCES:

Holt, L.E. (1974). *Scientific Stretching for Sport (3S)*. Halifax, Nova Scotia: Sport Research Ltd.

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