THE RAPID STRETCH STIMULUS DOES NOT ENHANCE MUSCLE STRENGTH IN ACTIVE INDIVIDUALS FOLLOWING A 4-WEEK PROPRIOCEPTIVE NEUROMUSCULAR STRENGTHENING PROTOCOL.

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Proprioceptive neuromuscular facilitation (PNF) a technique widely used as a training modality among physically active individuals. PNF in the upper limb is combined with the rapid stretch stimulus at the beginning of every repetition of resistive diagonal PNF. The stretch stimulus is applied at the palm of the hand & fingers in the opposite direction to activate receptors. The aim of the study was to evaluate the effects of stretch stimulus with PNF exercises over 4-weeks for improvements in muscle strength. Eight participants were recruited & randomly divided into the CG, n=4 with no stretch stimulus & EG, n=4 with addition of stretch stimulus. Muscle strength of elbow flexors & maximum grip strength was measured. Mixed ANOVA showed that the rapid stretch stimulus is not sufficient in this small group to improve strength when combined with PNF diagonal strengthening ($p>0.05$).

KEYWORDS: proprioception, grip strength, diagonal proprioceptive neuromuscular facilitation

INTRODUCTION: Muscles have optimal patterns in which they exhibit their maximum amount of activity (Sullivan, 1980) and various resistance techniques are used for the purpose of exercising, improving strength component, blood supply and increased range of motion in the joint (Shin, 2015). Among them is one technique known as the proprioceptive neuromuscular facilitation (PNF) which incorporates functional diagonal patterns with resistance in the form of movement which elicits motor response in the muscles to enhance the neuromuscular control and function (Kisner, 2017). PNF has gained recognition among physically active groups as a training modality to improve muscular endurance (Page, 1993). PNF exercises can be performed as a way of strengthening to improve the muscle motor unit recruitment pattern (Sullivan, 1980). These exercises utilize diagonal or spiral patterns in the upper extremities, lower extremities, and the trunk. Page, et al., 1993, used the PNF diagonal patterned exercises with a TheraBand in baseball players to investigate improvement in strength and electromyography (EMG) studies of the rotator cuff muscles after four weeks of training.

Before these patterns are performed, a rapid stretch stimulus can be provided to the distal most body segments to place them in a lengthened position to activate the muscle and joint receptors. This signals the specific muscle groups to contract efficiently during the exercise phase (Kisner. et al., 2017). The stretch stimulus can be defined as an overpressure or stretch given in the opposite direction to the most distal joint just beyond the point of tension in an agonist group of muscle which is already in an elongated state (Kisner., et al., 2017).

For this study, we used the rapid stretch stimulus as an intervention before the beginning of the D2 PNF pattern. PNF D2 pattern begins in extension to flexion in the dominant upper limb (Figure 1, A-B). The movement starts with shoulder, elbow, and wrist extension. The resistance is then applied via TheraBand in the direction of flexion with contraction of shoulder, elbow, wrist, and fingers in agonist muscle (Figure 1, A).

To our knowledge, this is one of the few studies which analysed the effects of stretch stimulus on increments in muscular strength. The aim of this study was to combine the rapid stretch stimulus with resistive PNF D2 pattern exercises in the upper limb to assess improvements in muscle strength. We used repetitive rapid stretch stimulus before the initiation of each diagonal pattern to see if it enhanced muscle strength in elbow flexors and finger flexors after 4- weeks.

METHODS: ***Subjects:*** Eight participants (2 males, 6 females) were recruited on volunteer basis with mean age of 23.3 ± 1.9 years, mass of 81.2 ± 22.6 kilograms and mean height of 168.8 ± 8.6 centimetres with no previous injury to the upper extremity for past 12 months. The participants were recreationally active. Testing was done before and after a 4-week intervention. Before the pre-testing began, a familiarization session was given to the participants to get acquainted with the equipment and testing procedures. They were also screened for general health and activity levels. The study was approved by the University Institutional review board and all the participants completed informed consent.

Figure 1A: D2 extension

Figure 1B: D2 flexion

Study Design: Participants were divided into experimental group EG (Intervention- rapid stretch stimulus given by the researcher) and control group CG (no stretch stimulus). The participants were matched according to their gender and height and randomly assigned into the EG (n=4) or CG (n=4). This was immediately followed by the D2 extension to flexion (Figures 1A, 1B) pattern in which resistance was provided by the TheraBand of a specific load. The resistance of the TheraBand was decided initially with a low load in the colour schemed bands. The initial load was specific to each participant where they could comfortably finish the repetitions of diagonal PNF. The participants in the initial session performed repetitions on low load TheraBand and moved to higher resistance only when they were able to complete the required repetitions with ease.

Testing (pre-post): The variables tested before and after four weeks of training include strength in the form of isometric and isokinetic concentric/eccentric elbow muscle strength and isometric hand grip strength. This was measured with Biodex dynamometer (System 4 Pro™), and grip strength was measured with Lafayette handheld dynamometer (Lafayette IN, USA).

The Biodex dynamometer measured the strength in elbow musculature of the dominant hand. Both isometric and isokinetic components were tested in sitting position with shoulder in 30 degrees of flexion and slight abduction with forearm in supination (Ekstrand, 2015). Isometric strength testing was done by maximum voluntary contraction in agonist direction for three repetitions with five seconds of contraction at zero degrees/second speed and 60 seconds rest in between each repetition. The position for testing isometric elbow contraction with elbow at 90 degrees. Isokinetic strength testing was performed by the participants with three repetitions in the direction of concentric and eccentric biceps contraction at 180 degrees/ second speeds (Ekstrand, 2015) by asking the participants to keep flexing against the dynamometer handle irrespective of the direction. The peak torque was extracted for isometric and isokinetic (concentric/eccentric) strength for biceps (N. m). The grip strength in the dominant hand was measured using the hand-held dynamometer in a seated position with shoulder flexed at 30 degrees and slightly abducted (Shepstone, 1985). The elbow joint was supported on a firm surface in 90 degrees of flexion and mid prone position with wrist in slight extension between 0-15 degrees (Ekstrand, 2015). The position for the dynamometer was perpendicular to the wrist and fingers curled around with a comfortable grip. Grip strength measurement was done with isometric strength testing for three repetitions with 60 seconds of rest period in between by asking the subject to pull the grip by using their maximum strength. The readings from the dynamometer were noted for analysis.

Intervention/ training: The participants performed the D2 extension to flexion pattern in standing position as seen from Figure: 1A- 1B under the supervision of the trainer for 12 sessions using resistance from TheraBand for 4-weeks. Before each PNF pattern, the trainer applied a rapid stretch stimulus to EG at the wrist and fingers on the palmar side in the direction opposite to the movement thereby elongating the distal muscles followed by the movement.

The participants performed the activity independently for three sets and progression of 10, 15, 20 and 25 repetitions with a rest period of 60 seconds in between the sets. They started D2 PNF pattern in extension followed first by concentric muscle activation in shoulders, elbows, wrists, and fingers. They finished the movement by returning to starting position with eccentric contraction. The participants only progressed to higher repetitions if they were able to comfortably finish the whole previous set. The training was focused on improving elbow flexor and handgrip strength.

Statistical Analysis: The data was analysed on IBM SPSS version 25 software for appropriate measures. A mixed model ANOVA with repeated measures was used to evaluate the changes in strength. The p value was set at < 0.05 for the results to be statistically significant.

RESULTS & DISCUSSION: There were no significant differences in strength after four weeks of training with PNF diagonal exercises. There was also no difference in isometric, isokinetic strength, and maximum grip strength between EG and CG after 4-weeks training with resistive PNF D2 exercises with counter stretch movement as intervention.

Table 1: Results for strength after four weeks of resistive PNF strength training beginning with quick stretch for both control (CG) and experimental groups (EG). Shows mean, standard deviation (±), and effect size (η_p^2 (time*group)) for isometric strength, eccentric, concentric strength for elbow flexors and maximum grip strength for finger flexors.

	Pre-testing		Post-testing		Effect Size
	CG	EG	CG	EG	
Isometric (N. m)	44.3 ± 14.8	46.6 ± 24.4	44.7 ± 13	51.7 ± 26	0.10
Eccentric (N. m)	30.5 ± 8.2	28.5 ± 7.5	28.8 ± 6.4	27.7 ± 7.3	0.02
Concentric (N. m)	33.6 ± 4.9	32.1 ± 11.2	31.3 ± 3.7	37.1 ± 21.6	0.10
Maximum grip strength (lbs)	71.0 ± 20.4	83.0 ± 26.8	72.0 ± 22.3	92.0 ± 41.4	0.10

The results of this study showed no significant improvements in strength, post 4-weeks of resistive PNF training with rapid stretch stimulus. The rapid stretch stimulus was given as an intervention in EG, and it did not enhance muscle strength of the elbow flexors and hand grip muscles. There were also no differences in the EG and CG after 4-weeks of resistive D2 PNF training using stretch stimulus as an intervention ($p>0.05$). However, there was a non-significant increase in isometric, concentric and maximum grip strength in EG (Table, 1). This maybe partially due to the intervention of the stretch stimulus given at the beginning of each resistive D2 PNF. However, this needs further evaluation with a larger group. The study also did not control for participants' recreational activities which might account for the increments in muscle strength.

The current study confirms that the stretch stimulus combined with D2 resistive PNF is not sufficient to improve the strength in the tested muscles. We speculate the three main reasons for this; 1) the sample size of the study was small, and the results are preliminary. Further analysis with a larger sample is needed to observe significant results, 2) the focus of the D2 pattern PNF is on shoulder muscles. This training does not have much impact on the elbow, wrist, and finger muscles, even with stretch stimulus given on the palm and fingers and therefore no improvements are observed, 3) The 4-weeks duration can be the limitation. To support the same idea, a study by Pereira., et al., in 2012 used PNF diagonal patterns in lower limb but for ten weeks which had advanced effects in knee extensor strength in older adults and hence, four-weeks is a shorter duration to elicit changes in strength. Page et. al. 1993, also used PNF diagonal patterned training in baseball players to determine improvements in the concentric and eccentric strength of the rotator cuff muscles (Page, 1993). They used the

D2 extension to flexion pattern with TheraBand as resistance. The study was conducted for 6 weeks, and they concluded that the diagonal pattern exercises increase strength in the eccentric direction for rotator cuff muscles.
The difference in the present study is that instead of shoulder muscles, elbow and finger flexors were tested for isometric/isokinetic strength for concentric and eccentric contraction. While training, the participants moved their shoulder whereas, while testing the elbow joint was in motion and therefore there was more involvement of shoulder muscles during training and less of elbow muscles and vice versa in the testing. Page., et al, 1993, in their work stated that when their participants produced more concentric force during the training, they had developed increased strength in the eccentric component of the rotator cuff after six weeks. But this was not evident in the present study where there was no change in both the concentric as well as eccentric strength of elbow flexors. Most of the studies discussed above only used PNF training to observe changes in muscle strength. However, the focus of the present study was to investigate changes in muscle strength when a rapid stretch stimulus was applied with every D2 PNF repetition. And therefore, it can be stated that the intervention and training used in this study were not sufficient to improve any strength components in the elbow and handgrip muscles even when the stretch stimulus was applied at the palms and fingers to activate muscle receptors.

CONCLUSION: The preliminary results show that rapid stretch stimulus followed by a resistive D2 PNF pattern training is not sufficient to elicit improvement in strength. This training modality would not be recommended if the goal of training is improving strength, in physically active healthy individuals. The diagonal patterned exercise as supported by earlier research may have increments in strength, but this study analysed rapid stretch stimulus with D2 PNF and the results of this study indicate that this training method is not enough to demonstrate changes. This could be with respect to both the duration of training which was four-weeks, and the intervention of stretch stimulus provided in the beginning of the training.

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