THE EFFECT OF PNF STRETCHING COMBINED WITH A RESISTANCE TRAINING ON STRENGTH, MUSCLE VOLUME AND FLEXIBILITY IN NON-ATHLETE MALE STUDENTS

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Abstract
The purpose of this study was to determine the effects of PNF stretching combined with resistance training on performance during an 8-week training protocol in non-athlete male students. Twenty healthy non-athlete males (age 21.3 ± 1.3 years, height 174.7 ± 2.9 cm, weight 71.1 ± 2.4 kg) college students were randomly divided into a resistance training (RT) group (n=10), or resistance training combined with Proprioceptive neuromuscular facilitation (PNF) stretching (RT + PNF) group (n=10). The resistance training program was performed 3 days (Sunday, Tuesday and Thursday) each week for 8 weeks. The resistance training consisted of 3 lift (triceps pushdown, bench press and lateral pull down), 3 sets of 8 repetitions, and the initial weight was 80% of the pre-1RM. The 8 weeks stretching program consisted of 15 different PNF stretches designed to stretch all of the major upper-extremity muscle groups (pectoralis major, triceps, biceps, teres minor & major, deltoideus). Subjects were tested for performance before and after the 8-week period. The results of this study indicated significantly (P< 0.05) improvements in strength, muscle volume and flexibility from Post test occurred for both RT and RT + PNF groups when compared to Pre test. There were also no significant differences (P> 0.05) between groups. However, findings showed the RT + PNF group had slightly more improvements in strength, muscle volume and flexibility when compared to RT group. It can therefore, be concluded that within 8 weeks PNF stretching combined with resistance training was found can not necessarily be effective on muscle volume, strength and flexibility more than RT only.

Key words: resistance training, PNF, stretching, flexibility

Introduction
Athletes are searching for ways to improve their performance to provide them with an advantage over their opponent. Increasing one’s muscle mass, flexibility or strength is the most common way athletes are able to give themselves an advantage over other competing athletes. Resistance training has become a frequently chosen method for increasing strength, flexibility, muscle mass, power and speed, local muscular endurance, balance and for improving athletic performance (American College of Sports Medicine, 2001). Also stretching is commonly promoted as a method to improve flexibility, power, speed and performance in various sports and recreational activities (Surburg, Schrader 1997; Shrier, 1999). In practice, there are 4 different protocols for stretching training –static, ballistic, dynamic and proprioceptive neuromuscular facilitation (PNF) (Thomas et al 2004). In a recent review (Shrier, 2004), Shrier reports that only nine studies had examined the effects of regular stretching, with seven finding beneficial effects and two showing no effect. The no-effect studies dealt with tests of running economy, whereas the positive studies mainly dealt with improved joint range of motion. Of those factors related to performance (i.e., strength, speed, power, and endurance), the majority of studies have found improvements in strength. For example, Worrell et al. (Worrell, Smith & Winegardner, 1994) and Handel et al. (Handel et al, 1997) found increases in hamstring isokinetic torque.

Godges et al. (Godges et al, 1989) found increased trunk strength, and Wilson et al. (Wilson, Murphy & Pryor, 1994) found improvements in the bench press. In addition, Dintiman (Dintiman, 1964) reports improved sprint performance, and Hunter and Marshall (Hunter, Marshall, 2002) saw increases in a countermovement vertical jump. Unfortunately, neither Dintiman (Dintiman, 1964) nor Hunter and Marshall (Hunter & Marshall, 2002) report strength changes. Today, PNF along with static and ballistic stretching is commonly used to lengthen the musculotendinous unit and as a result increase the range of motion of a specific joint (Etnyre & Abraham 1986; Funk et al., 2003). Proprioceptive neuromuscular facilitation (PNF) comprises patterns and techniques specifically designed to treat neurologically impaired patients (Knott, Voss, 1956).

These techniques and variations thereof were later used in the treatment of orthopedic impairments, and today PNF stretches are widely used in sports medicine (Surburg & Schrader 1997; Shrier, 1999). A study conducted by Feland and Marin, showed significant improvements in hamstring flexibility via submaximal contractions using PNF stretching (Feland & Marin, 2004). A study conducted by Giordano, Sikora, and Jones concluded that one session of PNF stretching prior to participating in a 40-yard dash and vertical jump test showed no significant improvement in performance (Giordano, Sikora & Jones, 2005).
In correlation, information from a study done by Mayer et al. (Mayer, Pederson & Simons, 2005) indicated that PNF stretching was an effective way of increasing flexibility. Church et al. (Church, Wiggins, Mooe & Crist, 2001) and Bradley et al (Bradley, Olsen & Portas, 2007) noted a significant reduction in the vertical jump performance after PNF. However, other authors did not report significant PNF-induced decreases in muscle performance in activities involving maximal muscular contraction, explosive strength and jumping (Hunter & Marshall, 2002; Young & Elliot, 2001). Bieze et al., by a study indicated the chronic PNF stretching program there is some improvement in forty yard dash time (.06 sec) and vertical jump (.61 in) however, according to the p value; these was not significant differences (Andrew, Mike, Aaron & Stephanie, 2006). Notwithstanding strength and flexibility exercises being common components of many exercise programs, it is not clear at this time how best to include both of these elements in a single training program or if it is even prudent to do so. It has not been shown however whether resistance training combined with stretching training results in an alteration in the magnitude of strength gains when compared with a resistance training-only program. In addition, resistance training has been shown to increase flexibility (Leighton, 1964; Massey & Chaudet, 1956). This prompted us to investigate into that issue, i.e. into the effects of PNF on strength, flexibility and muscle volume, in order to gather information which would enable teachers, coaches, physical instructors and physiotherapists to better orient their students, athletes and patients. The responses to stretching and resistance training are similar, it is possible that if both resistance training and stretching are included in a training program, their effects could be additive. Thus, the purpose of this study was to determine the effects of PNF stretching combined with resistance training on strength, muscle volume and flexibility in non athlete male students.

Materials & Methods

Subjects
Twenty healthy non athlete male students (age 21.3 ± 1.3 years, height 174.7 ± 2.9 cm, weight 71.1 ± 2.4 kg) of University of Guilan volunteered to participate in this study. Subjects were randomly assigned to either a resistance training (RT) group (n=10), or resistance training combined with Proprioceptive neuromuscular facilitation (PNF) stretching exercises (RT + PNF) group (n=10). Before undergoing the tests, the subjects were given explanations about the assessment procedures, study objectives, and the possible benefits and risks. The Institutional Review Board of the University approved the research protocol. All subjects based on medical information questionnaire were healthy and none of hypertension, cardiovascular disease, diabetes, lipid disorders, kidney disease, liver disease, respiratory and bone injuries and did not exercise any supplement use in past 6 months.

Experimental design
Randomized study was employed using two experimental groups (RT and RT + PNF) who underwent 8 weeks’ training protocol. Before starting the training, pre-1 repetition maximum (1RM) values were obtained on the following exercises: bench press, triceps pushdown and lateral pull down. The resistance training program consisted of 3 lift: triceps pushdown, bench press and lateral pull down. The training consisted of 3 sets of 8 repetitions, and the initial weight was 80% of the pre-1RM. Rest times between sets were 2–3 minutes, and 3–5 minutes elapsed between the 3 different lifts. The resistance training program was performed 3 days (Sunday, Tuesday and Thursday) each week for 8 weeks. After the 8-week training program, post-testing for 1RM were repeated in the same manner in which they were performed during pre-testing. Also, The PNF stretching protocol designed to stretch all of the major upper-extremity muscle groups (pectoralis major, triceps, biceps, teres minor & major, deltoïdus) and consisted of four series of exerstions in which the muscles were contracted isometrically for 5 s and sustained, motionless, for 30 s in the movement position (beyond the discomfort threshold). The series were spaced by 20-s intervals. PNF stretching session lasted approximately 30 min and was performed 3 days (Saturday, Monday, Wednesday) each week for 8 weeks.

Strength measures
Upper body maximal strength was assessed by using 1RM actions. During testing session subjects performed a 1-repetition maximum (1-RM) strength test for the bench press exercises. The 1 RM tests were conducted as described by Hoffman/Hoffman, 2006). Each subject performed a warm-up set using a resistance that was approximately 40-60% of his perceived maximum, and then performed three to four subsequent attempts to determine the 1-RM. A 3– 5 minute rest period was provided between each lift. No bouncing was permitted, as this would have artificially boosted strength results. Bench press testing was performed in the standard supine position: the subject lowered an Olympic weightlifting bar to midchest and then pressed the weight until his arms were fully extended (Arazi, Hakimi & Hoseini, 2011).

Flexibility
Upper body flexibility measured by Two- armed “back scratch” Test. This test is done in the standing position.
Place one hand behind the head and back over the shoulder, and reach as far as possible down the middle of body back, your palm touching body and the fingers directed downwards. Place the other arm behind body back, palm facing outward and fingers upward and reach up as far as possible attempting to touch or overlap the middle fingers of both hands. An assistant is required to direct the subject so that the fingers are aligned, and to measure the distance between the tips of the middle fingers. If the fingertips touch then the score is zero. If they do not touch, measure the distance between the finger tips (a negative score), if they overlap, measure by how much (a positive score). Practice two times, and then test two times(Thomas et al, 2004).

**Muscle volume**
Upper body muscle volume was assessed by using upper arm muscle size. Upper arm circumference (millimeters) was measured to the nearset millimeter with a steel tape with the right arm hanging relaxed. The measurement was taken on the back of the arm and midway between the point of the acromion and olecranon process. Triceps skin fold (millimeters) was measured to the nearset tenth of a millimeter with a lange skin- fold caliper having a pressure 10 g/mm² of contact surface area. The measurement was taken on the back of the arm and midway between the point of the acromion and olecranon process while the arm was hanging relaxed(Frisancho, 1974). Estimates of muscle size were derived: 1) Arm muscle diameter (millimeters)= arm circumference (mm)/π - triceps skin fold(mm), 2) Arm muscle circumference (mm)= arm circumference (mm)- n (triceps skin fold), 3) Arm muscle area (mm²)= n/4( arm diameter²).

**Statistical analyses**
Statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) for Windows software (version 17.0; SPSS Inc.). Descriptive statistics were calculated as the mean and standard deviations (Mean ± SD). In addition, PRE - POST comparisons between groups(RT and RT+PNF) in performance measures were analyzed with independent student’s t-tests. The level of significance for this investigation was set at P<0.05.

**Results**
The mean changes in muscle volume, flexibility and muscular strength performance in RT and RT+ PNF groups are shown in table 1. Significant increases from PRE occurred for both RT and RT+ PNF in the upper body strength, muscle volume and flexibility. The average (+SD) 1RM values are presented in table 2. There was no significant difference between RT and RT + PNF for upper body strength 1RM (p = 0.22), muscle volume (p = 0.97), or flexibility (p = 0.72). However, results showed the RT + PNF group greater improved their strength, flexibility and muscle volume when compared to RT group.

**Discussion**
This study compared the effects of PNF stretching combined with resistance training (RT+ PNF) vs. a resistance training group (RT). The present research study results demonstrate that statistically (P< 0. 05) improved their strength, flexibility and muscle volume from Post test occurred for both RT and RT + PNF groups when compared to Pre test. There was also no significant difference (P> 0.05) between groups but results showed the RT + PNF group greater improved their strength, flexibility and muscle volume when compared to RT group. PNF stretching is more effective in the RT+ PNF group is of great interest. Likely that small non-significant difference was observed related to the effects of PNF stretching. The basis for PNF stretching is theorized to be through neural inhibition of the muscle group being stretched. The proposed neural inhibition reduces reflex activity, which then promotes greater relaxation and decreased resistance to stretch, and hence greater range of movement (Hutton. 1993). These findings were consistent to the some other studies(Surburg. Schrader 1997: Thomas et al 2004; Hunter, Marshall .2002; Church, Wiggins, Moore & Crist. 2001; Granit. 1950). However, other studies(Shrier, 2004; Bradley, Olsen & Portas. 2007) reports significant reduction in the performance after PNF stretching. Previous literature reviewed during the project did not parallel the study, thus comparing methods and results was difficult. The success of PNF stretches has largely been attributed to neurophysiologic mechanisms (Enthyre. 1989; Guissard, Duchateau & Hainaut 1988; Holt, Travis & Okita. 1970; Markos. 1979; Sady, Wortman & Blanke. 1982). Most of them are credited to the muscle spindle and the Golgi tendon organs and their reflex activity: Activation of the muscle spindle elicits contraction of the agonist and inhibition of the antagonist, sometimes referred to as the myotatic reflex or stretch reflex(Mayer, Pederson & Simons, 2005).

Activation of Golgi tendon organs elicits inhibition of the agonist (autogenic inhibition, or inverse myotatic reflex (Granit. 1950: Miyahara et al, 2005) while facilitating the antagonist (Etnyre. 2002; Plowman and Smith: 2002). The mechanism by which autogenic inhibition is purported to contribute to PNF efficacy. Increased inhibition from Ib-inhibitory interneurones, a result of the amplified Golgi tendon organ input, results in a reduced level of excitability of the homonymous target muscle, there by facilitating additional stretch (Ulrik et al. 2009). Autogenic inhibition (historically known as the inverse myotatic reflex or autogenetic inhibition) refers to a reduction in excitability of a contracting or stretched muscle, that in the past has been solely attributed to the increased inhibitory input arising from Golgi tendon organs within the same muscle (Laporte. Lloyd. 1952). The reduced efferent (motor) drive to the muscle by way of autogenic inhibition is a factor believed to assist TM elongation (Enthyre & Abraham, 1986; Markos. 1979; Prentice. 1983; Tanigawa. 1972).
Exploring the additional benefits of PNF stretching is also worthwhile because of the prevalence of issues within the body such as pain, instability, and injuries as a whole. PNF stretching is designed to maximize improvements in flexibility which aid in preventing or recovering from these issues. Finally, muscle volume, strength and flexibility pertain to assisting the vast majority of the population regardless of age, gender, or athletic skill level. Furthermore, variables such as the participants’ comfort levels, muscle soreness or fatigue from PNF exercises, diet, and rest were not controlled, which may have slightly affected the results. Another disadvantage of PNF stretching is that a partner is required to assist with the stretch (Prentice-William .1999). According to the results of this study, there was no significant difference between groups. Therefore, we cannot necessarily suggest that PNF stretching exercises combined with resistance training is effective. On the other hand, greater improvement (but not significantly) was observed in strength, muscle volume and flexibility of the RT + PNF group when compared to RT group. This observation is important because, nowadays the high level of muscular fitness can aid to achieve best performance. On this basis, coaches are searching ways to improve performance. However, these results have need to further study at future.

**Conclusions**

In conclusion, the results of this investigation suggested that 8-week resistance training combined with the PNF stretching increase muscle volume, flexibility and muscle strength (upper body strength) in non-athlete male students. But given that there was no significant difference between the applied methods. Thus, the PNF stretching combined with resistance training can not necessarily be effective on muscle volume, strength and flexibility.

**References**


Sažetak
Svrha ove studije bila je utvrđivanje efekata PNF stretchinga kombiniranog s izvedbom treninga izdržljivosti u trajanju 8 tjedana po protokolu za muškarce studente nesportaše. Dwadeset zdravih nesportaša studenata koledža (uzrasta 21.3 ± 1.3 g., visine 174.7 ± 2.9 cm, mase 71.1 ± 2.4 kg) slučajno su raspoređeni u grupu treninga izdržljivosti (RT, n=10) i grupu treninga izdržljivosti kombiniranog s proprioceptivnom neuromuskularnom facilitacijom i istezanjem (RT+PNF, n=10). Trenažni program izdržljivosti provodio se 3 dana svakog tjedna (nedjelja, utorak, četvrtak) kroz 8 tjedana. Sastojao se od tri podizanja (triceps pushdown, bench press, lateral pull down), tri skupa od po osam ponavljanja, s inicijalnom težinom od 80 % od jednog maksimalnog pokušaja. Program u trajanju 8 tjedana sa strechingom sadržavao je 15 različitih PNF istezanja dizajniranih da istegnu sve veće mišićne skupine gornjih ekstremiteta (pectoralis major, triceps, biceps, teres minor & major, deltoideus). Ispitani su testirani u izvođenju prije i poslije razdoblja od 8 tjedana. Rezultati ove studije pokazuju značajno (P< 0.05) poboljšanje snage, mišićnog volumena i fleksibilnosti u odnosu na prvo mjerenje i to za obje grupe, i RT i RT+PNF. Također, nije bilo značajnih razlika između grupa (P>0.05). Međutim, rezultati su pokazali da je RT+PNF grupa bila ipak nešto bolja u snazi, mišićnom volumenu i fleksibilnosti u odnosu na RT grupu. Može se dakle zaključiti da kroz 8 tjedana istezanje kombinirano s treningom izdržljivosti nije značajno bolje od samog treninga izdržljivosti.

Ključne riječi: trening izdržljivosti, PNF, istezanje, fleksibilnost

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