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Original Research Article

The effect of proprioceptive neuromuscular facilitation and static stretching techniques on jumping performance and flexibility in non-athletic individuals

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Abstract

The aim of this study was to investigate the effectiveness of chronic period static and Proprioceptive Neuromuscular Facilitation (PNF) stretching techniques on flexibility and jumping performance in non-athletic individuals. Randomized trial, two groups PNF (n=45) and Static stretching (n=51). Range of Motion (RoM) values were taken before and after the program to test the vertical and long jump performance and the flexibility of individuals. A standing long jump (also referred to as a broad jump) and vertical jump test were used to measure the power in lower extremities. All subjects completed one of the two stretching protocols. A significant difference was found between the values of pre and post-stretching long board and vertical jumps in the static and PNF stretching group (*p*=0.001). No statistically significant difference was found between long board (*p*=0.740) and vertical jumping values (*p*=0.328) (the post stretching scores minus the pre stretching scores). The results suggest that jumping performances and flexibilities of individuals may be increased as a consequence of regularly and continually performed static and PNF stretching exercises. The study presents different training pogramme to literatüre.

Keywords: Long Board Jump, Muscle Stretch Exercises, Range of Motion, Vertical Jump

INTRODUCTION

The muscle power of the lower limbs is known to be one the most important factors that determine an athlete's physical condition and performance. The improvements in physical ability attained by healthy individuals using static and PNF stretching techniques may be insufficient for athletes (Theoharopoulos et al., 2009; Feland et al., 2001; Coutinho et al., 2004; Magnusson et al., 1996; Magnusson, 1998; Funk et al., 2003; Young et al., 2001; Carvalho et al., 2009).

A review of the research literature for both stretching techniques shows that many studies have been done on flexibility, ROM, peak torque, power, strength and other variables (Pazin et al., 2013; Marchetti et al., 2014). However, there are few studies that compare static stretching to PNF. Furthermore, it is seen that the studies on stretching techniques included in the literature are mostly about athletes; most programs studied one or two muscles and the application period mostly covers the acute period (O'Sullivan et al., 2009; LaRoche et al., 2006; Kutluk and Cüreklibatır, 1983).

The aim of the present study was to investigate the effectiveness on flexibility and jumping performances in the chronic period (regular training program) of both types of stretching when applied to quadriceps, soleus, hamstring and iliopsoas muscles, which are generally involved in jumping activities.

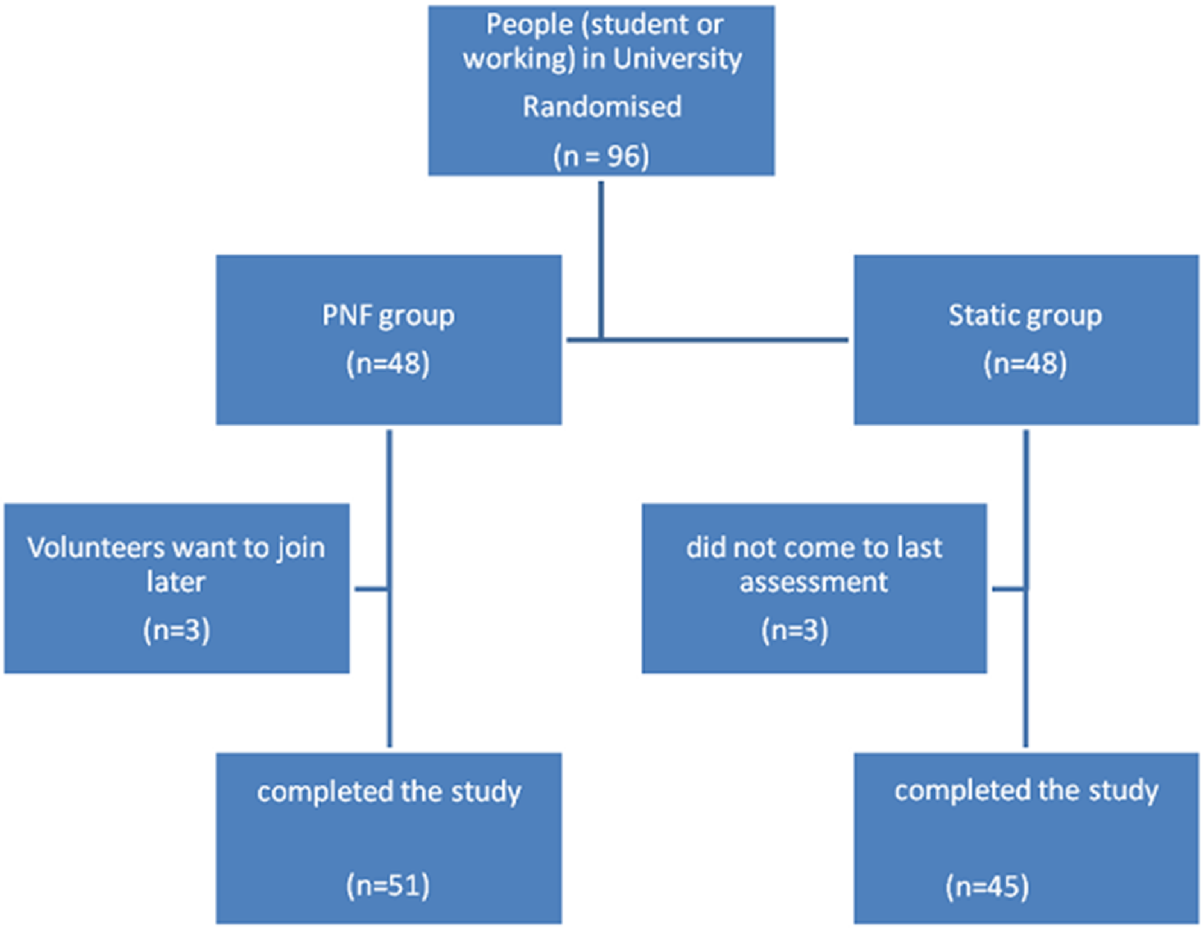

Figure 1. Flow diagram of representing patient recruitment and randomization procedure.

MATERIALS AND METHODS

Participants

The study included 96 volunteers recruited from a university population (Figure 1). Each participant completed an Informed Consent Form, which included an explanation of the purpose of the study. All procedures were approved by the Bolu Clinic Research Ethics Board. Exclusion criteria were: a recent injury or surgery to the lower limbs within the previous 6 months. Information such as age, gender, height and weight were recorded for statistical analysis.

Experimental design and procedures

The study used two allocated groups: PNF and static stretching on lower extremity. The subjects were randomly assigned to one of the two stretching techniques. Before the program was applied to people's evaluations.

Each subject's hip flexor length was measured in a supine position. Contralateral leg maximal hip flexion (maintained by the participant) and the test leg relaxed. In this position, angle of the hip is measured to assess length or flexibility of the hip flexor using a goniometer.

Angle of the ankle to assess flexibility of gastrocnemius muscle length was measured by having the subject lie prone, with the measuring foot hanging over the edge of the table. The investigator measured the degree of dorsiflexion at the ankle using a goniometer.

Measurement of knee extension ROM (range of motion) was then made with the subject lying supine, with the opposite leg straight on the table, and the leg being measured held somewhere between 90 and 100 degrees of hip flexion, in order to assure tightness of the hamstrings when the knee was extended.

A standing long jump (also referred to as a broad jump) and vertical jump test were used to measure the power in lower extremities. It was recorded in centimeters for data analysis. The test was performed with the following guidelines (Standing Long Jump Test (Broad jump) [internet] Topend Sports Network © (1997-2010).

The participant completed three attempts, with the longest distance being utilized for analysis.

For the vertical jump, the participants' standing reach was recorded before the initial jumps took place. To measure vertical reach, each subject stood beside the instrument and extended her dominant arm over her head without lifting her heels off the ground. This height was recorded and later subtracted from the maximum height jumped, in order to calculate the subject's vertical jump (Brandenburg et al., 2007). Participants performed each jump 3 times, and the average of the 3 trials was recorded.

Before performing the stretching program, the participants completed a general warm up on a bicycle ergometer with a load of 70 W for 15 min, followed by the stretching procedure. Once the warm-up was completed, the subject completed one of the two stretching protocols: Proprioceptive neuromuscular facilitation (PNF) hold-relax stretching or passive, static stretching. The program focused stretching on the following muscle groups: hamstring, iliopsoas, rectus femoris, gastrocnemius.

The hamstring group was stretched with the subject in a supine position with arms to their side. The researcher would then grasp the ankle and straight raise the leg to the point of mild discomfort. After this point, the subject was asked to perform a maximum voluntary isometric contraction of the hip extensors concentrically, against the researcher's resistance. The iliopsoas (hip flexors) were stretched with the subject in a supine position. The subject lay on a tall bench with the thigh hanging down off the end of the bench. The opposite thigh was raised toward the side of torso. The lower thigh was allowed to drop toward the floor (Stretching and Flexibility [internet] ExRx.net ©, 1999-2010). The rectus femoris muscle was stretched in a prone position. The researcher lifted the knee and pushed the ankle down toward the hip. For the gastrocnemius muscle, the isometric contraction was performed by pressing the foot against the researcher's hand.

PNF hold-relax stretching consisted of the following: (1). an isometric contraction (6 seconds), followed by; (2). relaxation; and (3). passive extension of the muscle or muscle group involved a second passive joint movement as far as possible without causing pain, and maintained for the lower extremity for 30 seconds and 15 seconds at the maximally extended position (Stretching and Flexibility [internet] ExRx.net ©, 1999-2010). This was done in 3 sets of 15 stretches for each muscle with 15 seconds rest between each stretching.

The static stretching protocol consisted of passive stretching of the muscles by the researcher in the same position as the PNF protocol, and was performed in the same manner (Marek et al., 2005; Power et al., 2004). The stretching exercises for all flexibility-training protocols consisted of static lengthening of the lower extremity muscles, maintained for 30 seconds at the position of maximum lengthening. This position of maximum lengthening was a terminal position, which was defined as the point at which the subject felt the stretch, without any pain.

Each subject participated in this stretching protocol three times a week for four consecutive weeks.

Statistical Analysis

The statistical analyses were performed with the Statistical Package for the Social Sciences (SPSS), version 11. The results are given as arithmetic average ± standard deviation ($\bar{x}$±SD). Initial and final measurements of continuous variables of PNF and static stretching groups were analyzed by Paired-Samples T test. In order to determine the difference values of PNF and static groups, an independent-samples T test was used. The level of significance was accepted as $p < 0.05$, $p < 0.001$ for all tests.

RESULTS

Data collected from the subjects included demographic information, activity level, flexibility and power. Table 1 shows that the socio-demographic data of the participants. In our study, a total of 51 individuals, 28 (54.9%) of which are men and 23 (45.1%) of which are women, were assigned to a static stretching group; 45 individuals, 10 (22.2%) of which are men and 35 (77.8%) of which are women, were assigned to a PNF stretching group. The average age of individuals involved in the study are 23.33± 4.98 years in the PNF group and 21.9± 1.80 years in the static stretching group. No significant difference was found between groups with respect to age, weight or BMI values (p>0.05), while a significant difference was found between individuals with regard to height (p<0.05).

A significant difference was found between the values of pre and post-stretching jumps and vertical jumps in the static and PNF stretching group ($p < 0.001$) (Table 2).

No statistically significant difference was found between long board jumping and vertical jumping values (i.e. the post stretching scores minus the pre stretching scores) (p>0.05) (Table 3).

A significant difference was found between the pre and post - stretching flexibility values of right and left quadriceps, right and left hamstring, right iliopsoas and right and left gastrosoleus muscles in the PNF and static groups ($p < 0.001$) (Table 4); flexibility values of right quadriceps, left iliopsoas and right gastro-soleus muscles of the groups (p<0.05) (i.e. the post stretching scores minus the pre stretching scores) (Table 5).

Table 1. The socio-demographic data of the participants

	Static stretching mean±SD	PNF mean±SD	t
Age (years)	21,9± 1,80	23,33± 4,98	-1,916
Height (cm)	170,14± 8,24	166,4± 6,86	2,394*
Weight (kg)	64,62± 10,97	61,22± 10,92	1,516
BMI (kg/m2)	22,21± 2,69	22,05± 3,29	0,258

(*) *p*<0,05, (t) independent t test: SD, standard deviations; (BMI) Body Mass Index

Table 2. The values vertical and long jump before and after PNF and static stretching

		Pre-stretching mean±SD	Post- stretching mean±SD	t
PNF		31.13 ±11.40	35.15± 12.16	-9.255**
Static stretching	Vertical jump (cm)	37.02±11.64	41.62±11.79	-11.727**
PNF		112.97± 24.89	120.68± 27.82	-4.618**
Static stretching	Long jump (cm)	126.92± 34.77	133.93± 37.94	-5.706**

(**) *p*<0.001, (t) independent t test: SD, standard deviations; PNF, proprioceptive neuromuscular facilitation

Table 3. The differences between static and PNF group of the values of vertical and long jump

	Static stretching mean± SD	PNF mean± SD	t
Long jump (cm)	7,01 ± 8,77	7,70 ± 11.19	-0,333
Vertical jump (cm)	4,59 ± 2,8	4,02 ± 2,91	0,984

(t) independent t test; (SD) standard deviations; (PNF) proprioceptive neuromuscular facilitation

Table 4. The values muscle (quadriceps, hamstring, iliopsoas and gastro-soleus) flexibility before and after PNF and static stretching.

	Group	Pre-stretching mean±SD	Post- stretching mean±SD	t
Quadriceps	PNF	132.11 ± 12.17	137.55 ± 6.07	-4.032**
R (º)	Static stretching	134.23 ± 6.69	136.33 ± 6.50	-5.489**
Quadriceps	PNF	133.86 ± 7.96	138.08 ± 5.45	-5.255**
L (º)	Static stretching	134.03 ± 6.79	136.04 ± 6.68	-6.084**
Hamstring	PNF	161.80 ± 14.50	170.66 ± 11.44	-6.452**
R (º)	Static stretching	156.00 ± 14.14.	161.52 ± 13.32	-5.024**
Hamstring	PNF	163.51 ± 13.61	169.27 ± 18.79	-2.425**
L (º)	Static stretching	156.86 ± 14.29	161.82 ± 13.14	-4.965**
Iliopsoas R	PNF	116.41 ± 12.59	121.80 ± 5.03	-3.448**
(º)	Static stretching	118.47 ± 5.52	120.58 ± 4.74	-4.657**
Iliopsoas L	PNF	117.48 ± 8.21	122.38 ± 5.57	-5.798**
(º)	Static stretching	118.07 ± 5.41	117.33 ± 15.33	0,375**
Gastrosoleus R	PNF	15.93 ± 4.47	18.26 ± 3.42	-7.131**
(º)	Static stretching	17.00 ± 3.81	18.32 ± 2.84	-5.980**
Gastrosoleus L	PNF	16.28 ± 4.26	18.55 ± 2.85	-5.575**
(º)	Static stretching	16.76 ± 3.91	18.12 ± 3.00	-5.216**

(**) *p*<0,001; (t) independent t test; (SD) standard deviations; (PNF) proprioceptive neuromuscular facilitation; (R) Right; (L) Left

Table 5. The differences between static and PNF group of the values of muscle (quadriceps, hamstring, iliopsoas and gastro-soleus) flexibility.

	Static stretching mean± SD	PNF mean± SD	t
Quadriceps R (º)	2,09 ± 2,72	5,44 ± 9,05	-2.385*
Quadriceps L (º)	2,00 ± 2,35	4,22 ± 5,38	-2.547
Hamstring R (º)	5.52 ± 7.85	8.86 ± 9.21	-1.896
Hamstring L (º)	4.96 ± 7.13	5.76 ± 15.94	-.0.312
Iliopsoas R (º)	2.11 ± 3.24	5.38 ± 10.48	-2.010
Iliopsoas L (º)	-0.74 ± 14.19	4.89 ± 5.66	-2.611*
Gastrosoleus R (º)	1.32 ± 1.58	2.33 ± 2.19	-2.556*
Gastrosoleus L (º)	1.36 ± 1.86	2,26 ± 2.72	-1.870

(*) p<0,05; (t) independent t test; (SD) standard deviations; (PNF) proprioceptive neuromuscular facilitation.; (R) Right; (L) Left

DISCUSSION

Maximum muscle power is determined either from measured or from assessed muscle force or work exerted during complex movements, such as jumping. The other approach is performance-based assessment of muscle power. For instance, maximum vertical jump has routinely been used in the assessment of movement performance and the recorded jump height as an index of muscle power (Kokkonen et al., 2007; Cramer et al., 2007; Aasa et al., 2003; Domire and Challıs, 2007; Seyfarth et al., 1999; Bazett-Jones et al., 2008).

The present study employed vertical and long jumping performance assessment methods in order to evaluate the performances of individuals. The results indicated an increase in both performance values as a result of stretching exercises applied.

The differing effects of static stretching, as reported in the literature, were summarized by Shrier *et al*. as follows: The variable effects were observed for (1) static, ballistic, and proprioceptive neuromuscular facilitation (PNF) stretches; (2) males and females; (3) competitive and recreational athletes; (4) children and adults; (5) trained or untrained subjects; and (6) with or without warm-up. Similar results were found across various study designs (Carvalho et al., 2009; Power et al., 2004; Kokkonen et al., 2007; Lamas et al., 2012; Shrier, 2004).

According to Schuback *et al*. the ideal parameters of stretching exercises are unknown (Schuback et al., 2004; Herbert et al., 2011). The duration, frequency and repetition number of stretching sessions produces differing effects of stretching. The parameters chosen for the present study are compatible with those used in other studies in the literature (Schuback et al., 2004; Wallman et al., 2005). Marek *et al*. also stated that active and passive ROM increases could be provided by both static and PNF stretching, but the EMG amplitudes of muscles were reduced and thus vertical jump heights of individuals might decrease (Marek et al., 2005). Feland et al. compared static and proprioceptive neuromuscular facilitation (PNF) and showed that all techniques were able to improve range of motion, but PNF was seen as the preferred technique (Feland et al., 2001; Schuback et al., 2004). Mahieu *et al*. compared the effects of static stretching with those of ballistic stretching (Wallman et al., 2005; Mahieu et al., 2007). However, they stressed that it would be more effective to use static and ballistic stretching together. Kırmızıgil B et al. found that ballistic stretching has positive effects on lower extremity explosive power production, whereas PNF and static stretching methods affected it negatively. To improve strength, ballistic stretching can be used during the warm up period (Kirmizigil et al., 2014).

In the present study, no difference was found between the two stretching applications (PNF and static).

Individual and organizational factors are effective on the range of joint motion (Power et al., 2004; Schuback et al., 2004; Kotzamanidis, 2006; Meylan et al., 2009; Gerodimos et al., 2008). According to Jaric *et al.,* human movements and abilities are affected by several confounding factors such as age, sex, body composition, level of physical activity and skill (Jaric, 2002). According to Meylan *et al*., BMI accounts for 76% of vertical jump ability, together with maximum isometric contraction (Meylan et al., 2009). In our study, no significant difference was found between height, weight and BMI values of individuals and jumping values. The results of the present study support previous findings in the literature suggesting that the anthropometric features of individuals do not affect their performance (Kotzamanidis, 2006).

According to Schuback et al. age, type of joint, muscle composition, different connective tissues and the size of tissue have a role in determining the extensibility of a muscle (Schuback et al., 2004). Carvalho et al. applied acute static and PNF stretching for 45 seconds to 5 muscle groups, comprising the quadriceps, ischium tibialis, adductors, abductors and triceps surae (Carvalho et al., 2009). They found that more change occurred in the PNF group compared to static stretching group with respect to the extensibility of muscles. A study by Power et al. applied static stretching to quadriceps, hamstring and plantar flexor muscles of 20 individuals for 270 seconds per muscle and evaluated hip extension ROM (Power et al., 2004). It was found that static stretching applied to these 3 muscle groups did not create any change in the flexibility of flexor muscles. In the present study, an increase was found in hip flexion ROM. We suggest that this difference may be due to our inclusion of hip flexor muscles in the stretching program.

The muscles having a part in the vertical jump performance as proposed previously were included in our study (Unick et al., 2005; Davis et al., 2005; Bobbert, 2001; Arvas et al., 2006). As a result of stretching programs applied to the quadriceps, iliopsoas, calf and hamstring muscles, an increase was found in the flexibility of muscles after 30-seconds. static and PNF stretches. No difference was found between groups with respect to flexibility. The results of the present study show that the differences between stretching programs applied as well as the muscles used affect the flexibilities of individuals.

CONCLUSION

The lack of agreement within the literature related to stretching programs is attributed to the non-existence of ideal frequency and duration for stretching. Furthermore, although stretching exercises are widely used and applied as a component of exercise training, there are a limited number of studies addressing the positive effects achieved by including regular stretching (for example, daily, two or three times a week) in training programs (Kokkonen et al., 2007; Davis et al., 2005; Kofotolis and Kellis, 2006). Future studies assessing individuals' quality of life may be carried out, on the basis that stretching exercises may increase functionality among sedentary individuals during the chronic period.

The stretching program applied and the muscles stretched within the scope of our study are similar to previous studies within the literature. With passive static stretching and hold-relax technique applied in 3 sets of 15 repetitions for 30 seconds per muscle, three times a week throughout 4 weeks, a performance increase (vertical, long jump) was found in the lower extremity as a result of isometric contraction of antagonist muscles after 30-second PNF stretching. We suggest that this stretching program may increase flexibility and thus daily activities among individuals who are active in their daily lives and, consequently, it may have positive effects on their quality of life.

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