A Comparison of Assisted and Unassisted Proprioceptive Neuromuscular Facilitation Techniques and Static Stretching

Meaghan E. Maddigan, Ashley A. Peach, and David G. Behm

School of Human Kinetics and Recreation, Memorial University of Newfoundland, St. John’s, Newfoundland, Canada

ABSTRACT

Maddigan, ME, Peach, AA, and Behm, DG. A comparison of assisted and unassisted proprioceptive neuromuscular facilitation techniques and static stretching. J Strength Cond Res 26(5): 1238–1244, 2012—Proprioceptive neuromuscular facilitation (PNF) stretching often requires a partner. Straps are available allowing an individual to perform PNF stretching alone. It is not known if a strap provides similar improvements in the range of motion (ROM) as partner-assisted PNF or static stretching. The purpose of this study was to compare assisted and unassisted (with a strap) PNF stretching and static stretching. Hip joint ROM, reaction time (RT), and movement time (MT) were measured prestretching and poststretching. Thirteen recreationally active adults participated in this study. The participants were subjected to 5 different stretch interventions in a random order on separate days. Stretch conditions included unassisted PNF stretching using (a) isometric, (b) concentric, and (c) eccentric contractions with a stretch strap, (d) partner-assisted isometric PNF, and (e) static stretching. The RT, MT, dynamic, active, passive hip flexion angle, and angular velocity with dynamic hip flexion were measured before and after the intervention. The ROM improved (p < 0.05) 2.6, 2.7, and 5.4%, respectively, with dynamic, active, and passive static-ROM, but there was no significant difference between the stretching protocols. There was a main effect for time (p < 0.05) with all stretching conditions negatively impacting dynamic angular velocity (9.2%). Although there was no significant effect on RT, MT showed a negative main effect for time (p < 0.05) slowing 3.4%. In conclusion, it was found that all 3 forms of active stretching provided similar improvements in the ROM and poststretching performance decrements in MT and angular velocity. Thus, individuals can implement PNF stretching techniques with a partner or alone with a strap to improve ROM, but athletes should not use these techniques before important competitions or training because of the impairment of limb velocity and MT.

KEY WORDS: flexibility, PNF, Theraband stretch strap, range of motion, reaction time

INTRODUCTION

Proprioceptive neuromuscular facilitation (PNF) stretching has been reported to provide greater increases in both active and passive range of motion (ROM) compared with static stretching (9,12,13,18,21,25,26,29). However, the research is not unanimous because other acute stretching studies have shown no difference in the ROM between an acute bout of static and PNF stretching (8,19,30). Furthermore, a 6-week training study did not show a difference between static and PNF stretching (31). Further studies are necessary to determine whether there are differences in the ROM with static vs. PNF stretching.

There are several types of PNF stretching. Each technique typically offers some combination of passive stretching and isometric contractions to ensure the greatest gains in the ROM (6,17,26). It is unknown whether PNF stretching using eccentric or concentric rather than isometric contractions may provide similar or greater flexibility benefits. The use of concentric or eccentric contractions with a PNF stretching protocol might provide some of the benefits associated with dynamic stretching. In contrast to the performance decrements associated with prolonged static stretching, dynamic stretching has been reported to either improve subsequent performance or have no consequential effects on subsequent performance (see review [2]).

The PNF stretching techniques are often prescribed for use with athletes in preparation for athletic performance or rehabilitation. Acute bouts of PNF stretching have increased concentric and eccentric isokinetic peak torque at 60 and 120°·s⁻¹ (30) and improving medial-lateral postural stability (24). Training studies of a 4-week duration using PNF stretching have reported increases in isokinetic peak torque and maximal isometric ankle force (15). Conversely, the implementation of PNF stretching within a warm-up has also resulted in subsequent impairments to vertical jump height.
(4,7). Marek et al. (19) described PNF-induced decreases in strength, power and muscle activation with slow (60°·s⁻¹) and fast (300°·s⁻¹) isokinetic velocities after 4 stretches of the leg extensors. Although reaction time (RT) and movement time (MT) impairments have been reported after acute static stretching (3), there has been no examination of the effect of PNF stretching on these parameters. Further research is necessary to examine whether PNF stretching is generally beneficial, detrimental, or inconsequential to subsequent performance.

This study introduces a stretch strap that was designed to make PNF stretching techniques a more viable option to improve ROM and overall flexibility for a single individual. The elasticity of the stretch strap provides resistance for muscle contractions potentially replacing the need for a partner. However, to date, it is unknown whether or not individuals can expect similar changes in ROM with this unassisted method as those, which have been found with assisted PNF and static stretching.

The purpose of this study was to compare and investigate the effects of a stretch strap employing either isometric, concentric or eccentric contractions (unassisted PNF) with partner-assisted isometric PNF and active static stretching on hip joint ROM, RT, MT, and dynamic angular velocity. The primary hypothesis proposed that unassisted PNF stretching would provide similar increases in the ROM as assisted PNF and active static stretching. Second, we hypothesized that RT, MT, and dynamic angular velocity would not be impaired after PNF stretching intervention but decrements would be associated with static stretching.

**METHODS**

**Experimental Approach to the Problem**

A repeated measures design was used to validate the hypothesis that increases in the ROM that occur with unassisted PNF stretching using a stretch strap are similar to the increases found with partner-assisted PNF and active static stretching techniques. This protocol was performed while simultaneously comparing the effect of different types of contractions during unassisted PNF stretching. Four repetitions of 5 different stretch conditions were implemented: (a) isometric, (b) concentric, and (c) eccentric contractions during unassisted PNF stretching with a strap, (d) partner-assisted PNF stretching employing isometric contractions, and (e) active static stretching. Five pretest measures were performed before each intervention. Standing left leg RT and MT were performed first. The subjects practiced their RT and MT before the pretest to reduce the effect of learning then completed RT and MT trials 5 times each. Following from the supine position, dynamic, active static, and passive static ROM measurements of the left hip joint were randomly allocated. Angular velocity was calculated from the dynamic ROM. Next, 1 of the 5 stretching techniques was randomly applied. The experiment involved stretching the left hamstrings through hip flexion from a supine position where the participants were fixed to a massage table using a strap around their waist. The left leg was chosen because of limitations of the testing apparatus. The 5 posttest measures (same as pretest), dynamic, active static, and passive static ROM were taken after the intervention, and because of procedural limitations, these were followed by RT and MT. The mean pretest and posttest RT and MT measures were used for analysis and dynamic angular velocity was calculated by the change in dynamic ROM over time.

**Subjects**

Thirteen healthy and recreationally active adults, 6 male (177.9 ± 9.11 cm, 85.7 ± 17.25 kg, 24.6 ± 2.12 years) and 7 female (167.8 ± 7.96 cm, 72.1 ± 14.40 kg, 23.7 ± 4.54 years), volunteered from the university community to participate in this study. All the participants filled out a Physical Activity Readiness Questionnaire form from the Canadian Society for Exercise Physiology to determine their general health status (1). If any health problems were reported, they were excluded from the study. Specifically, none of the participants in this study had injuries that limited ROM at the hip. The participants were permitted to drink water ad libitum before the experimental sessions. All the subjects had previous experience with static and PNF stretching. The participants also read and signed a consent form before commencement of the study. The Memorial University of Newfoundland Human Investigations Committee approved the study.

**Intervention Protocol**

Many of the interventions shared commonalities; the subjects all began in the same start position, lying supine on a massage table with their left leg resting on an exercise ball (TheraBand) 32 cm above the table. For the (a) isometric unassisted PNF, (b) concentric-unassisted PNF, (d) partner-assisted isometric PNF, and (e) active static stretch conditions, each participant was instructed to contract the antagonist (quadriceps) muscles to achieve maximum active hip flexion ROM. For the unassisted PNF with an eccentric contraction (#3), the subjects also commenced on the ball but rather than using a quadriceps contraction to raise the leg, they resisted the hip flexion movement that was controlled with the strap. The stretch intervention was then implemented. After the stretch intervention, the leg was passively returned to the ball position for 6 seconds.

Stretch interventions differed by type of contraction. With the active static stretch protocol (active since the leg was moved to maximum ROM by a quadriceps contraction), the participant was instructed to stretch their leg to the point of discomfort (POD) but not past, hold for 6 seconds and then reach for their toes. They were instructed to hold their position for 5 seconds then return to the start position for 1 ± 2 seconds. Next, they were instructed to again contract the antagonist (quadriceps) muscles to achieve maximum active hip flexion ROM and hold for 6 seconds.

For the unassisted PNF stretches, a TheraBand Stretch Strap was placed around the arch of the foot and the subject...
manually held the ends of the strap to provide resistance for the contractions after achieving maximum ROM. The individual moving their hands up or down the numbered loops to increase or decrease the tension on the strap can regulate the degree of ROM. For the (a) isometric unassisted PNF condition, once maximum ROM was achieved, the subject was instructed to contract their hamstrings for 5 seconds. After this contraction, they were asked to bring their leg back to the start position for 1 ± 2 seconds of relaxation and then using only the strap, with no muscle activation, the participants were instructed to stretch their leg to the POD but not past and hold for 6 seconds. An identical protocol was followed for (b) unassisted PNF concentric condition except the participant was instructed to contract their hamstring while moving their leg from maximum ROM to the starting position >5 seconds. The (c) unassisted PNF eccentric procedure differed from the above procedures as it required the participant to contract the agonist (hamstrings) muscles from the start position (on the ball) to the maximum hip joint flexion ROM >5 seconds without an initial quadriceps contraction to provide a maximum active hip flexion ROM. For the (d) partner-assisted isometric PNF technique, the subject actively moved their leg to maximum ROM and held for 6 seconds. Then, the subject performed a 6s isometric contraction using the examiner’s shoulder as resistance. The examiner returned the participants leg to the start position and instructed the participant to relax the muscles of the leg and thigh while the examiner passively flexed the leg to the point of mild discomfort.

All the contractions were performed at a subjective approximately 70% of maximum intensity (27). After the passive stretch, the subject returned the leg to the resting position on the ball and repeated the procedure 4 times (20). A 10-second recovery period was allocated between each stretch.

Testing Measures
The pretesting measures were the same for all the subjects, which involved measuring and recording both height and weight before beginning the study. Preintervention and postintervention measures were also the same across all the subjects and conditions. They included premeasures and postmeasures of dynamic, passive static, and active static hip flexion ROM and premeasures and postmeasures of both RT and MT.

Apparatus and Instrumentation
Hip flexion ROM in this study was measured directly, using an electronic goniometer and dynamic, active, and passive straight leg raise techniques. The greater trochanter served as a reference point for the axis of the goniometer. This reference point was marked on the goniometer using leg length to ensure accuracy and to limit variance in repeated measurements. This ROM technique involved placing the subject in a supine position, ensuring the knee remained in full extension (Figure 1). The subject’s leg was dynamically, actively, or passively raised to induce flexion at the hip with minimal hip rotation until the subject stopped or verbally indicated the POD had been reached. The POD was described to the participants as the point at which they first felt the onset of uncomfortable tension in the hamstrings. The dynamic ROM was achieved by asking the participant to perform a kicking motion with their left leg, with the subject’s shoulders secured to the table by an experimenter; the subject was instructed to kick as far and fast as possible. The active static ROM was achieved by asking the participant to contract their antagonist (quadriceps) muscles and raise their leg to their POD, hold for a second and lower, over a slow constant rate of speed (~3–5 seconds to achieve full ROM). Finally, the passive ROM was achieved by the experimenter moving the subject’s relaxed leg to the POD. During the leg raise, the participant was instructed to remain relaxed and not allow the opposite leg to move off the table.

The RT and MT have been described previously from this laboratory (5). Briefly, RT and MT were measured by an apparatus developed by the Memorial University Technical Services (Electronics, Newfoundland, Canada). The testing apparatus consisted of a stop clock (58007, Lafayette Instrument Company, Lafayette, IN, USA), an analog timer (L15-365/099, Triton Electronics, United Kingdom), a stop clock latch (58027, Lafayette Instrument Company) which connected the stop clock and the analog timer, a custom designed box (62 cm [length] × 15.5 cm [width] × 9 cm [height]) with the distance of 50 cm from the center of the start button to the center of the stop button, and a trigger plate for the start of task. The task entailed movement of the left leg in response to the illumination of an incandescent light bulb. The subject would start with their left foot placed on the start button. Upon illumination of the light signal, the subject would release the start button and move their leg and foot to touch the stop button. The RT was measured as the time between the illumination of light stimulus and release of the start button. The MT was measured as the time between...
the illumination of light stimulus and the touching the stop button. Five trials of RT and MT were performed with randomized time intervals between each.

**Statistical Analyses**

All data analysis was conducted using SPSS statistics computing program version 17.0 (SPSS Inc. © 1993–2007). Descriptive statistics (means ± SD) for all variables were calculated. Next, data were analyzed with Kolomogorov-Smirnov normality tests to ensure normality, and Mauchly’s test was conducted to make certain sphericity was not violated. F-ratios were considered statistically significant at the \( p = 0.05 \) levels. Between-test reliability was analyzed by comparing the pretest ROM measures of the 5 interventions, and angular velocity, RT, and MT with an intraclass correlation coefficient (ICC) at a 95% confidence interval. Data were analyzed using a 3-way analysis of variance (ANOVA) repeated measures design. The factors included condition (isometric, concentric, eccentric-unassisted PNF, partner-assisted PNF, and active static), measure (active static, passive static, and dynamic ROM), and testing (precondition and postcondition). A separate 3-way ANOVA repeated measures design was conducted for measures RT and MT. To investigate gender-related differences in the response to the stretch interventions a 3-way repeated measures ANOVA was used for each type of measure with the following factors; gender × condition × pre-post difference. An alpha level of \( p < 0.05 \) was considered statistically significant. If significant differences \( (p = 0.05) \) were detected, paired \( t \)-tests with correction factors for each additional condition were used to identify the significant change.

**RESULTS**

The ICC indicated that active static, passive static, dynamic ROM, RT, and MT achieved between-test (day-to-day) reliability coefficients of 0.91, 0.93, 0.96, 0.89, and 0.96 respectively. Overall, significant differences because of each of the stretching conditions occurred with measures of ROM, dynamic angular velocity, and MT. There were no significant main effects or interactions for pre-post differences for gender. The following results combine the data and analysis from all male and female subjects.

**Range of Motion**

There was a positive main effect for time \( (p < 0.05) \) with all stretching conditions for ROM measures preintervention \( (101 ± 2.8^{\circ}) \) and postintervention \( (104.6 ± 2.8^{\circ}) \) averaging a 3.5% improvement. However, there was no interaction between the stretch conditions or the type of ROM measure. An interaction effect \( (p < 0.05) \) was seen between the type of ROM measure (active static, passive static, or dynamic) and time (Table 1); with the passive stretch yielding the greatest percent increase in ROM postintervention.

**Dynamic Angular Velocity**

There was a negative main effect for time \( (p < 0.05) \) with all the stretching conditions for dynamic angular velocity. Dynamic angular velocity decreased 9.2% from preintervention \( (70.5 ± 4.03^{\circ} \text{s}^{-1}) \) to postintervention \( (64.01 ± 3.5^{\circ} \text{s}^{-1}) \). There was also an interaction effect between the individual conditions and the decrease in dynamic velocity (Figure 2).

**Movement Time and Reaction Time**

There was a negative main effect \( (p < 0.05) \) for MT, preintervention \( (0.47 ± 0.027 \text{ seconds}) \) and postintervention \( (0.49 ± 0.023 \text{ seconds}) \). On average participants were 3.4% slower after the stretching protocols in the MT trails. To present a typical response, Figure 3 shows a spaghetti graph illustrating that 11 of 13 participants experienced slower MT with the stretching intervention. The eccentric condition yielded the largest percent decrease at 4.4% and isometric condition yielded the smallest percent difference of 2%. There were no significant differences found in the participants RT prestretching to poststretching condition. The RT remained relatively consistent pre-intervention \( (0.24 ± 0.007 \text{ seconds}) \) and postintervention \( (0.25 ± 0.013 \text{ seconds}) \).

### Table 1. Main effect for time for maximum hip range of motion (degrees), collapsed over all conditions (mean ± SD).

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>Post</th>
<th>% Δ</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic</td>
<td>107.8 ± 2.63</td>
<td>110.6 ± 2.67</td>
<td>2.60</td>
<td>0.024</td>
</tr>
<tr>
<td>Active</td>
<td>94.7 ± 3.06</td>
<td>97.3 ± 3.05</td>
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<td>0.001</td>
</tr>
<tr>
<td>Passive</td>
<td>100.5 ± 2.84</td>
<td>105.9 ± 2.81</td>
<td>5.47</td>
<td>0.027</td>
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</tbody>
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**Figure 2.** The pretest and posttest average dynamic angular velocities (degrees per second) ± SD of the left leg after each of the 5 stretching conditions. Statistical differences pre-post condition denoted by \( * p < 0.05 \).
Assisted Vs. Unassisted PNF and Static Stretching

DISCUSSION

The key finding was the similarity of responses with all 3 stretching techniques (static stretching, traditional assisted PNF, and unassisted PNF with a stretch strap). Consistent with the first hypothesis, all stretching techniques induced similar significant increases in active static, passive static, and dynamic ROM. Furthermore, although there was no significant impairment in RT postintervention, there was a significant decrease in MT and dynamic angular velocity with all the stretching techniques.

Although PNF stretching has been reported to provide greater ROM increases compared with static stretching in some studies (9,12,13,18,21,25,26,29), other acute stretching studies have illustrated no difference in ROM between an acute bout of static and PNF stretching (8,19,30). Although the aforementioned studies that exhibited ROM differences were statistically significant, the magnitude of change in many of the studies were not large. For example, Feland and Marin (11) reported approximate passive static ROM increases of 5°, whereas others have reported improvements of 2–3.6° (9), 3–10° (23), and 75–11.8° (22). Agonist-contract-relax PNF stretching provided 4–6° greater ROM than static stretching for trained and untrained 45- to 55-year-old subjects, but there was no difference between the stretches for 65- to 75-year-old untrained subjects (12). Worrel et al. (30) did not find any statistically significant increase in the ROM of hamstrings after 4 PNF stretches. Etnyre and Lee (10) reported significant differences in various PNF techniques for men but no significant difference for women. The ROM increases in this study were 2.6, 2.8, and 5.4° for active static, dynamic and passive static stretches, respectively. The lack of significant differences between stretching techniques in this study provides evidence that 1 technique may not be predominantly better than the others. Furthermore, the significant improvements in ROM were achieved with only 6-second stretch durations with either PNF or static stretches.

A possible reason for the similarity of ROM results with PNF and static stretching in this study may be attributed to the technique employed with static stretching. From a supine position, the subjects actively flexed their hip to the maximum active ROM (active ROM defined as the maximum ROM achieved with a hip flexor contraction) and then the arms were used to stretch the leg farther to the point of maximum passive ROM. The initial contraction of the quadriceps to bring the leg up to its maximum active ROM could provide a similar neural reflexive contribution as the initial quadriceps contraction associated with the PNF stretches. Although not universally accepted, a number of studies have attributed some of the improvement in ROM with PNF stretches to the relaxation of the agonist (hamstrings) muscle by reciprocal inhibition from the antagonist muscle (quadriceps) (26). However, unlike the PNF stretches, the static stretch did not involve a hamstrings contraction. The unassisted PNF stretch using a stretch strap also employed a quadriceps contraction to place the leg in its initial maximum active ROM. Similar to the use of the arms with static stretching and the partner with partner-assisted PNF stretching, the stretch strap would then allow the subject to achieve maximum passive ROM. Unlike the static stretch, the stretch strap with unassisted PNF stretching did allow for a hamstrings contraction (isometric, concentric, or eccentric). Hence, the lack of significant difference in ROM among all 3 stretches might be attributed to the antagonist (quadriceps) contractions used to initiate the movement and the ability to place the hamstrings at the point of maximum passive ROM. The contractions used during the assisted and unassisted PNF stretches did not provide additional flexibility benefits.

Furthermore, the type of hamstrings contraction (isometric, concentric, or eccentric) performed with the unassisted PNF protocol had no differential effect on ROM or performance measures. It was thought that the inclusion of concentric or eccentric contractions with the unassisted PNF stretch might simulate the positive outcomes associated with dynamic stretches reported in a number of studies (see review: [2]). Contrary to those studies, all the stretches resulted in MT and dynamic angular velocity deficits. As the concentric and eccentric contractions were performed slowly (5-second duration), the positive effects associated with the more rapid movements of typical dynamic stretching were not realized.

Contrary to the second hypothesis, this study did show impairments in MT and dynamic angular velocity associated with both PNF and static stretching. The literature provides abundant evidence that static stretching can impair strength, power, velocity, RT, MT, jump height, and in a number of studies running speed or economy (see review: [2]). However, the PNF literature has not been as extensive regarding the effect of PNF stretching on subsequent performance. PNF stretching has been reported to improve concentric and
eccentric isokinetic peak torque at 60 and 120°·s⁻¹ (30) and improving medial-lateral postural stability (24). A PNF training study (4 weeks) demonstrated increases in isokinetic peak torque and maximal isometric ankle torque (15). However, using PNF stretching within a warm-up has also resulted in vertical jump height deficits (4,7). Marek et al. (19) described PNF-induced decreases in strength, power, and muscle activation with slow (60°·s⁻¹) and fast (300°·s⁻¹) isokinetic velocities after 4 leg extensors' stretches. Streepey et al. (28) performed 3 PNF stretches to the quadriceps and hamstrings and found a diminished sensitivity to knee movement. An increase in blood lactate concentration was reported after 10 repetitions of PNF stretching indicating a greater reliance on anaerobic metabolism, which could adversely impact subsequent performance (14). Based on these findings and others, the use of PNF stretching before training or performance should be viewed with caution.

This study demonstrated that partner-assisted PNF stretching, unassisted PNF stretching using a strap and static stretching provided similar increases in hip flexion ROM for both men and women. The commonalities among the 3 types of hamstrings stretches were the initial quadriceps contraction to bring the limb to the maximum active ROM and the subsequent movement to maximum passive ROM (either by a partner, strap, or arms). Similar to the bulk of static stretching literature, stretch-induced impairments occurred in subsequent performance (MT and dynamic angular velocity) with all 3 stretches. The implementation of concentric or eccentric contractions to the unassisted PNF stretching did not confer any further advantages to ROM or subsequent performance.

**Practical Applications**

Coaches, athletes, fitness and health enthusiasts can be assured that similar improvements in acute ROM for both men and women can be obtained when stretching alone. Partner-assisted PNF methods in this study did not result in significantly greater acute increases in flexibility. Individuals should note that the static stretching in this study was not purely passive and involved an initial quadriceps contraction, and thus, this somewhat active form of static stretching may be an important component, which helps to provide similar flexibility augmentation as PNF methods. Although the unassisted PNF stretch with a strap did not provide greater ROM benefits than the static stretching, the use of a strap for resistance could be used as part of a resistance-training program. The extent of resistance may not be sufficient for elite strength and power athletes, but the resistance stress should provide health benefits for individuals interested in improving or maintaining musculoskeletal health. According to Kraemer and Ratamess (16), strength adaptations can commence with as little as 40% of 1 repetition maximum load. Individuals using these stretching methods, as part of their warm-up before training or competition should be cognizant that performance decrements could occur. Hence, competitive athletes should use these techniques to improve flexibility in a separate stretching training routine and not immediately before training or competition.

**References**

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