

Effect of Proprioceptive Neuromuscular Facilitation Stretch Techniques on Trained and Untrained Older Adults

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The effects of proprioceptive neuromuscular facilitation (PNF) on joint range of motion (ROM) for older adults are unknown, and few studies have investigated changes in joint ROM associated with age. This study examined PNF stretch techniques' effects on knee-joint ROM in trained (T) and untrained (UT) older adults. Knee-joint ROM was tested in T and UT adults age 45–55 and 65–75 years using 3 PNF stretch techniques: static stretch (SS), contract-relax (CR), and agonist contract-relax (ACR). The 45–55 UT group achieved significantly more ROM than did the 65–75 UT group, suggesting an age-related decline in ROM. The 65–75 T group achieved significantly greater knee-extension ROM than did their UT counterparts, indicating a training-related response to PNF stretch techniques and that lifetime training might counteract age-related declines in joint ROM. The ACR-PNF stretch condition produced 4–6° more ROM than did CR and SS for all groups except the 65–75 UT group, possibly as a result of lack of neuromuscular control or muscle strength. ■

Key Words: training, PNF, range of motion

There has been surprisingly little research investigating the effects of exercise as a method to prevent an overall decline in joint range of motion (ROM) known to occur in older adults. Of the investigations reporting age-related declines in joint ROM (Boone & Azen, 1979; Dummer, Vaccaro, & Clarke, 1985; James & Parker, 1989), none have investigated the effects of proprioceptive neuromuscular facilitation (PNF) stretch techniques.

PNF was first developed to aid in the rehabilitation of patients with severe brain trauma to hasten their return to a normal and functional lifestyle (Knott & Voss, 1956). PNF techniques made use of proprioceptive stimulation for the strengthening (facilitation) of a particular agonist muscle group or for relaxation (inhibition) of the antagonist muscle group (O'Connell & Gardner, 1972). One principle of PNF is that voluntary muscle contractions can be performed in

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combination with muscle stretching to promote muscle relaxation (Knott & Voss, 1968). Consequently, PNF stretches have become a commonly used modality to induce muscle relaxation and thereby overcome resistance to movement and subsequently increase joint ROM.

Resistance to musculotendinous stretching involves both the mechanical viscoelastic properties of muscle and connective tissue and the neurological reflexive and voluntary components of muscle contractions (Condon & Hutton, 1987; Magnusson et al., 1995; Osternig, Robertson, Troxel, & Hansen, 1988, 1990; Taylor, Dalton, Seaber, & Garrett, 1990). PNF stretch techniques are believed to reduce reflexive components that stimulate muscle contraction and thereby enable joint ROM to increase (Prentice, 1983). Little is known about the effects of PNF on older individuals, and studies investigating the effects of age-related changes in muscle tissue on ROM in older populations have yielded conflicting results. It has been reported that biological changes associated with aging are related to a loss of joint ROM in populations past the fourth decade of life (Boone & Azen, 1979; Dummer et al., 1985; James & Parker, 1989; Misner, Massey, Bembien, Going, & Patrick, 1992; Smith & Walker, 1983). These studies measured active ROM of several joints including the shoulder, elbow, forearm, wrist, hip, knee, ankle, and foot and found that a consistent decline in the mobility of joints occurred with aging. Two other studies, however, in which active ROM was measured for the age groups 25–74 and 60–84 years, reported that loss of ROM could not be attributed to aging and any decline in joint mobility should be considered abnormal (Roach & Miles, 1991; Walker, Sue, Miles-Elkousy, Ford, & Trevelyan, 1984).

To date there have been no investigations concerning the effects of chronic training on the age-related decrease in joint ROM observed in elderly populations, and no studies have been conducted to assess the effect of PNF stretch techniques on older adults. The physiological changes associated with aging in trained older populations might lead to differential responses to PNF stretching techniques compared with their same-age counterparts, because voluntary muscle contractions are performed in combination with muscle stretching to promote muscle relaxation. Aging has been demonstrated to be associated with muscle atrophy (Rogers & Evans, 1993) and alterations in collagen type (Kovanen & Suominen, 1989), as well as a reorganization of the motor unit (Doherty, Vandervoort, & Brown, 1993), which might alter the response of older muscle to application of PNF stretch techniques. Furthermore, investigations have demonstrated that chronic exercise results in reduced muscle atrophy and an increased strength-gain potential (Brown, McCartney, & Sale, 1990). Therefore, this study was conducted to investigate the effects of age and training on the effectiveness of PNF stretch techniques. Specifically, the purpose of the study was to measure the effects of three types of PNF stretching techniques on knee-joint-extension ROM in endurance-trained and untrained older adults.

Methods

PARTICIPANTS

Sixteen endurance-trained (T) and 16 untrained (UT) men volunteered to participate in the study. Sample size was determined to be adequate according to Kraemer and Thiemann (1987), and the mean power value for comparisons was 85%. No

participant had a prior history of lower extremity infirmity or pathology within the year preceding testing or at the time of testing, and none were suffering from osteoarthritic or musculoskeletal disease that could have affected their ability to perform the tests. No participant was currently taking any medication specifically designed to affect musculoskeletal tissue (i.e., anti-inflammatory drugs, pain relievers, or arthritis medication).

The 32 participants were classed into four age groups of 8 participants each according to age and training status: 45–55 years T and UT and 65–75 years T and UT. The T participants were competitive master-level endurance runners who had been undergoing regular training (>3 times/week) and were regularly competing in running distances of 1,500 m or more. The UT participants were age-matched adults who volunteered for the study. These participants had not undergone regular musculoskeletal training and had never entered a competitive track-and-field or other musculoskeletally demanding athletic event. The UT participants, however, were active older adults partaking in low-intensity health-maintenance activities such as golf, walking, and gardening. All participants gave their consent in accordance with the University of Oregon's policy on research using human participants.

TESTING

The study was designed to assess knee-extension ROM after three PNF stretch techniques. The method of stretch application was similar to methodology reported in two earlier investigations (Osternig et al., 1988, 1990). Participants were positioned supine on a padded table with the nondominant thigh fixed by straps at 0° of hip flexion (Figure 1[a]). Knee-extension ROM was tested using the dominant thigh, which was fixed by straps at maximal hip flexion according to the procedure of Evjenth and Hamberg (1984).

Three PNF stretches were used as the treatment, with order of stretches counterbalanced among participants. The PNF stretches were static stretch (SS), contract-relax (CR), and agonist contract-relax (ACR). For the SS, participants were asked to concentrate on relaxing their leg muscles as much as possible while the examiner passively extended the knee joint to the point of muscle restriction. This position was held by the examiner and gradually increased for 80 s, during which time ROM data were recorded (Figure 1[b]). It has been postulated that a gentle, sustained stretch will result in a mechanical viscoelastic stress relaxation-induced response and increase joint ROM (Sullivan, Markos, & Minor, 1982).

As with the SS condition, the CR-stretch application began with the examiner passively extending the participant's knee to a point of muscle restriction. When this position was attained, the participant was instructed to flex the knee with maximal force (isometric knee-flexor contraction) against examiner resistance for 5 s. The participant was then instructed to completely relax the knee muscles while the examiner passively extended the knee for 5 s to the newly attained point of muscle restriction (Phase 1). This procedure was then immediately repeated (Phase 2). A trial consisted of two contractions, each followed by a 5-s interval of muscle stretch (Phases 1 and 2). Four 2-phase trials (20 s each) were performed, with ROM data collected throughout each trial (Figure 1[c]). It has been postulated that muscle inhibition is greater after intense muscle contraction because of Golgi-tendon-organ recruitment (Granit, 1975; Prentice, 1983; Sullivan et al., 1982).

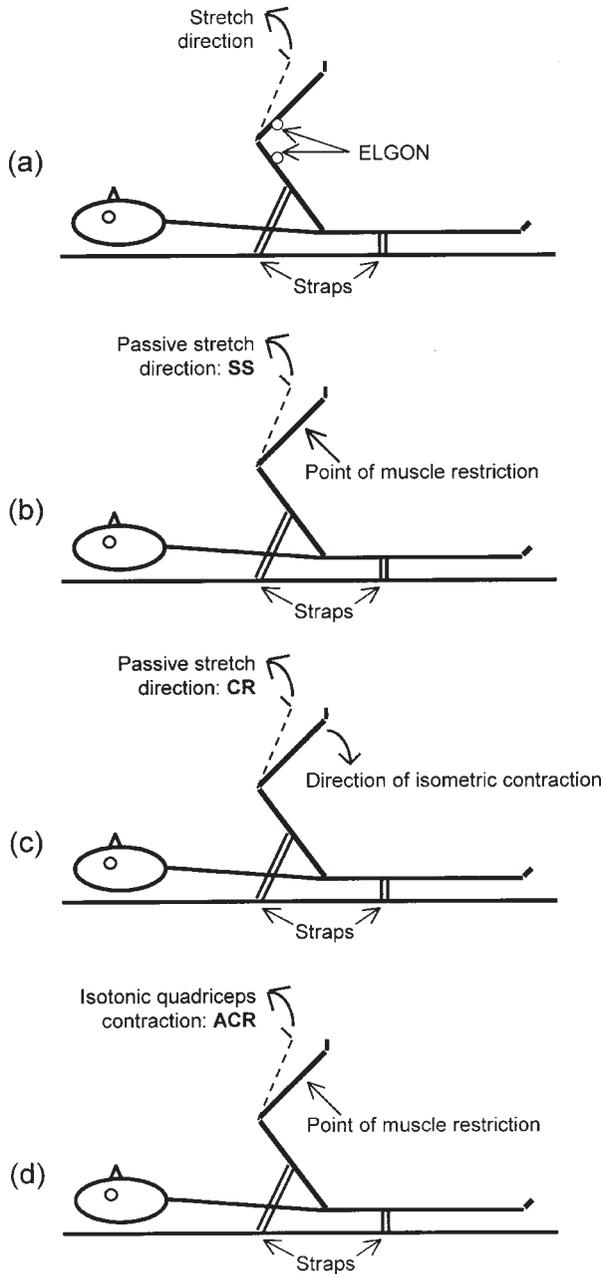


Figure 1. (a) Participant position during proprioceptive neuromuscular facilitation (PNF) stretch application. (b) Application of static-stretch (SS) stretch procedure. (c) Application of contract-relax (CR) PNF stretch procedure. (d) Application of agonist contract-relax (ACR) PNF stretch procedure.

The ACR procedure began with the examiner passively extending the participant's knee to the point of muscle restriction. When this position was attained, the participant was instructed to actively extend the knee with maximal force (concentric quadriceps contraction) for a 5-s period, thereby actively stretching the knee-flexor muscles while the examiner manually assisted in knee extension. The participant was then instructed to relax the thigh muscles while the examiner maintained the knee at the obtained stretched position for 5 s (Phase 1), after which the procedure was repeated a second time (Phase 2). A trial consisted of two contractions (active knee-flexor stretch), each followed by a 5-s interval of muscle relaxation (Phases 1 and 2). Four 2-phase trials (20 s each) were performed, with ROM data collected throughout each trial (Figure 1[d]). It is believed that intense quadriceps contraction will cause reciprocal inhibition of the knee-flexor muscles, resulting in decreased resistance to increasing knee-extension ROM (Morin & Pierrot-Desceilligny, 1977; Prentice, 1983; Tanaka, 1974).

Before data collection, participants were allowed unlimited warm-up time but were instructed not to include any stretching as part of the warm-up. Examples of preferred warm-up techniques included brief bouts of submaximal running and cycling. During testing, 5 min of rest between trials and conditions were given in order to limit fatigue.

INSTRUMENTATION

In order to measure changes in knee-joint ROM, an electrogoniometer (ELGON, Penny and Giles, Kistler, UK) was aligned to the lateral bisection of the leg and thigh with the center of the ELGON coil positioned coincident with the center of the knee-joint coronal axis (Figure 1). The ROM achieved for each stretching procedure was calculated as the actual pre- to post- difference in knee-extension ROM for each stretch condition and reported as degrees of ROM. Data were collected at 500 Hz using the Ariel Performance Analysis System (APAS, San Diego, CA) with an analog-to-digital sampling module interfaced with a computer.

STATISTICAL METHODS

The effects of three independent variables on knee-extension ROM were examined in this study: age, training status, and PNF stretch condition. A $2 \times 2 \times 3$ (Age \times Training Status \times Stretch Condition) general factorial ANOVA was computed to identify significant differences ($p < .05$), if any, in knee-extension ROM. When the omnibus F ratio indicated significant differences, planned comparisons were conducted via Scheffé's post hoc analysis (Keppel, 1982). Each possible combination of stretch conditions was assigned a number from 1 to 6, and one additional general linear ANOVA was performed to detect any changes in total ROM achieved as a result of the order of stretch application.

Results

A significant three-way (Age \times Training Status \times Stretch Condition) interaction was observed, $F(2,11) = 3.997$, $p < .05$. Planned post hoc testing indicated an age effect in the UT group across all stretch conditions (Figure 2). The results revealed

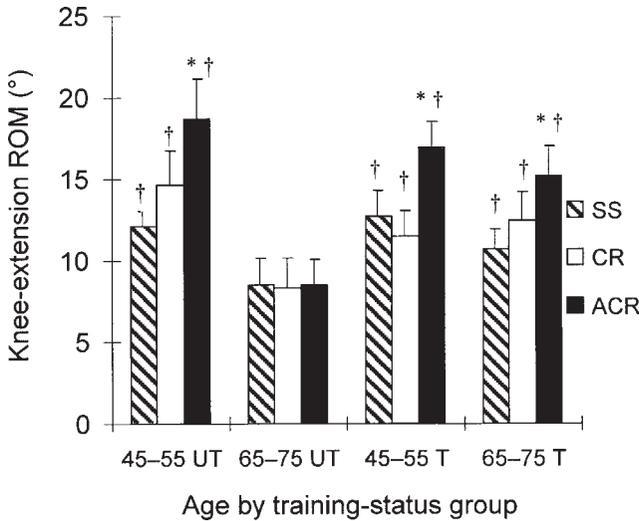


Figure 2. Mean age by training status ROM for each proprioceptive neuromuscular facilitation stretch condition. *Significantly greater ($p < .05$) than corresponding group's contract-relax (CR) and static stretch (SS). †Significantly greater ($p < .05$) than 65-75 untrained (UT). Note. T = trained.

that the 45-55 UT group achieved greater knee extension in all three stretch conditions (SS, $12.13 \pm 1.0^\circ$; CR, $14.67 \pm 2.2^\circ$; ACR, $21.34 \pm 2.6^\circ$) compared with the 65-75 UT group (SS, $8.34 \pm 1.4^\circ$; CR, $8.58 \pm 1.6^\circ$; ACR, $8.52 \pm 1.7^\circ$). An effect of training in the 65- to 75-year-old age group was also observed (Figure 2); the 65-75 T group achieved greater knee-extension ROM in all three stretch conditions (SS, $10.31 \pm 1.4^\circ$; CR, $12.42 \pm 2.3^\circ$; ACR, $15.15 \pm 2.4^\circ$) than did the 65-75 UT group (SS, $8.34 \pm 1.4^\circ$; CR, $8.58 \pm 1.6^\circ$; ACR, $8.52 \pm 1.7^\circ$). No differences in knee-extension ROM for any stretch condition were observed between the 45-55 T and 65-75 T groups ($p > .05$; Figure 2). An effect of condition was also observed in that the ACR-PNF stretch condition ($15.66 \pm 1.44^\circ$) achieved significantly greater knee-extension ROM than did SS ($10.99 \pm 0.92^\circ$) and CR ($11.83 \pm 2.3^\circ$) in the 45-55 T, 45-55 UT, and 65-75 T groups but not in the 65-75 UT group (Figure 2). No significant effects, $F(5,10) = 1.979$, $p > .05$, of the order of stretch application were found.

Discussion

The focus of this study was to determine the effect of different PNF stretch techniques on knee-joint ROM between two age groups consisting of either trained (T) or untrained (UT) older adults. Knee-joint ROM was tested in participants age 45-55 and 65-75 years who were either trained (T) or untrained (UT) using three PNF stretch techniques: static stretch (SS), contract-relax (CR), and agonist contract-relax (ACR).

In the present study, the 45–55 year UT group achieved greater knee-joint-extension ROM across all stretch conditions than did the 65–75 UT group (Figure 2). These findings are consistent with other studies showing a reduction in ROM beginning at or near the fourth decade of life and progressing thereafter (Boone & Azen, 1979; Dummer et al., 1985; Gajdosik, Vander Linden, & Williams, 1999; James & Parker, 1989; Misner et al., 1992; Smith & Walker, 1983). This difference in joint ROM between the two UT age groups could possibly be attributed to a shift in the ratio between Type III and Type I collagen in skeletal muscle (Kovanen & Suominen, 1989). Type I collagen is the primary component of intramuscular connective tissue, adding a high degree of tensile strength and elastic stiffness. Type III collagen is especially characteristic in young tissues and is a secondary component in intramuscular connective tissue, adding a high degree of elastic compliance to the tissue. An overall increase in Type I collagen and a decrease in Type III collagen occurs with aging, which might add stiffness to the musculotendinous unit, thereby creating increased resistance to stretch, reduced elastic compliance, and diminished functional performance, especially in Type I slow oxidative muscle tissue, which is predominant in individuals past the fourth decade of life (Kovanen & Suominen).

Results of this investigation also demonstrated that the 65–75 T group achieved significantly greater knee-extension ROM across all stretch conditions than did the 65–75 UT group (Figure 2). This suggests that such training might serve to counteract the age-related decline in joint ROM. It has been suggested that chronic training might serve to counteract the age-related decline in joint ROM observed in individuals past the fourth decade of life (Coggan et al., 1993; Suominen, Heikkinen, Liesen, Michel, & Hollmann, 1977). Furthermore, studies have investigated the effects of short-term training on increases in joint ROM and reported significant improvements in ROM for various joints (Hubble-Kozey, Wall, & Hogan, 1995; Leslie & Frekany, 1975; Lesser, 1978). Older adults engaged in a 6-week strengthening exercise program demonstrated reduced elastic stiffness in the ankle plantar-flexor muscle group compared with pretraining values (Blanpied & Smidt, 1993). It was postulated that a short-term training program possibly altered the elastic properties of specific muscle-fiber types or changed the passive elastic component of the musculotendinous unit, resulting in increases in joint ROM.

Few investigations have been conducted to determine alterations in joint ROM in master-level athletes. Dummer and colleagues (1985) assessed shoulder- and knee-joint ROM in 2 female master swimmers age 70 and 71. The results were compared with normative data presented in the American Academy of Orthopaedic Surgeons handbook (1965), which reported an age-related decline in joint ROM. The study showed that the 2 master swimmers had no decline in joint ROM and muscle strength compared with data from same-age women. Dummer suggested that lifetime physical activity might help delay the decline in muscle strength that is associated with inactivity during aging and might also offset the age-related decline in flexibility.

In the present study, all three stretch techniques were found to be effective in increasing knee-extension ROM for all groups. The active ACR-PNF stretch condition, however, generated greater knee-joint-extension ROM than did the passive CR and SS stretch conditions (Figure 2). Other investigations have

demonstrated that active PNF stretch techniques achieve a greater gain in ROM than do passive stretch techniques (Condon & Hutton, 1987; Hardy, 1985; Lucas & Koslow, 1984; Lustig, Ball, & Looney, 1992; Markos, 1979; Medeiros, Smidt, Burmeister, & Sodoerberg, 1977; Moore & Hutton, 1980; Osternig et al., 1988, 1990; Prentice, 1983; Sady, Wortman, & Blanke, 1982; Tanigawa, 1972; Wallin, Ekblom, Grahn, & Nordenborg, 1985). In the present study, however, the ACR > CR/SS effect was not exhibited in the 65–75 UT group (Figure 2).

It has been shown previously (Condon & Hutton, 1987; Moore & Hutton, 1980; Osternig et al., 1988, 1990) that substantial hamstring activation accompanies the application of PNF stretch techniques, particularly during the active ACR-PNF stretch technique. Previous research indicates that an age-related decline in muscle strength and alterations in the motor unit occur in individuals past the fourth decade of life, becoming more predominant after the sixth decade (Boone & Azen, 1979; Campbell, McComas, & Petito, 1973; Doherty et al., 1993; Frontera, Meredith, O'Reilly, Knuttgen, & Evans, 1988; Grimby, 1995; Guttman, & Hanzlikova, 1966; Hortobagyi et al., 1995; Ishihara, Naitoh, & Katsuta, 1987; Kovanen & Suominen, 1989; Larsson, 1995; Lewis & Brown, 1994; Nelson, Soderberg, & Urbscheit, 1984; Vandervoort & McComas, 1986). The 65–75 UT group possibly lacked the muscle strength or neuromuscular coordination necessary to produce a sustained concentric knee-extensor torque while undergoing the active ACR antagonist stretch. It has been demonstrated, however, that given adequate training stimulus, elderly individuals undergo muscle ultrastructural adaptations similar to those observed in younger populations (Coggan et al., 1993). It is possible that the 65–75 T group, as a result of chronic training, were better able to generate knee-extensor torque to overcome the antagonist resistance during the ACR-PNF stretch condition and thus achieve greater knee-joint ROM than were their UT counterparts.

In summary, the findings of the present study indicate that PNF stretch techniques can be used to produce increases in knee-joint extension ROM in older adults. Active PNF stretch techniques achieved a greater gain in ROM than did passive stretch techniques, although this was not observed in the 65–75 UT group. The 45–55 UT group achieved significantly more ROM than did the 65–75 UT group, suggesting an age-related decline in ROM. The 65–75 T group achieved significantly greater knee-extension ROM than did the 65–75 UT group, suggesting that decreased ROM observed in individuals past the sixth decade of life might be counteracted through lifetime training.

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