Effects of Different Stretching Techniques on the Outcomes of Isokinetic Exercise in Patients with Knee Osteoarthritis

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We recruited 132 subjects with bilateral knee osteoarthritis (Altman Grade II) to compare the effects of different stretching techniques on the outcomes of isokinetic muscle strengthening exercises. Patients were randomly divided into four groups (I–IV). The patients in Group I received isokinetic muscular strengthening exercises, Group II received bilateral knee static stretching and isokinetic exercises, Group III received proprioceptive neuromuscular facilitation (PNF) stretching and isokinetic exercises, and Group IV acted as controls. Outcomes were measured by changes in Lequesne's index, range of knee motion, visual analog pain scale, and peak muscle torques during knee flexion and extension. Patients in all the treated groups experienced significant reductions in knee pain and disability, and increased peak muscle torques after treatment and at follow-up. However, only patients in Groups II and III had significant improvements in range of motion and muscle strength gain during 60°/second angular velocity peak torques. Group III demonstrated the greatest increase in muscle strength gain during 180°/second angular velocity peak torques. In conclusion, stretching therapy could increase the effectiveness of isokinetic exercise in terms of functional improvement in patients with knee osteoarthritis. PNF techniques were more effective than static stretching.

Key Words: isokinetic exercise, knee, osteoarthritis, stretching
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Osteoarthritis (OA) is the most common form of degenerative arthritis and is a widespread, slowly developing disease that increases in prevalence with increasing age [1,2]. The knee joint is the most commonly affected large weight-bearing joint, where the disease can be particularly disabling because of the consequent difficulties in rising from a chair, climbing stairs, kneeling, standing, and walking. The presence of pain, combined with muscle weakness, increased body sway, and impaired balance, put affected individuals at risk of falls and decreased activity [3].

Although many older adults with arthritis tend to avoid activity, exercise is one of the most effective, non-pharmacologic treatments for OA, particularly for knee OA [4–6]. Specifically, long-term walking [7], isokinetic quadriceps exercise [8,9], high and low intensity cycle ergometry [10], and aquatic exercise classes can improve physical function and gait, and reduce knee pain in older adults with knee OA [11]. An increasing number of studies have demonstrated the benefits of exercise for knee OA, clearly indicating that aerobics and strength training improve strength, exercise capacity, gait, functional performance and

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balance, and reduce the risk of falling [12,13]. However, compliance is an important issue, and those studies with high patient compliance produced better results. Patients' compliance depends on many elements, including consistent education, encouragement, and follow-up. Injury and complications as a direct consequence of inappropriate exercise, such as knee pain during exercise, weakness of leg muscles, and initial range of motion (ROM), are major factors resulting in poor compliance [14].

In patients with chronic knee OA, knee pain and weakness of the quadriceps result in the progressive shortening of periarticular connective tissue and flexion contracture of the arthritic knee. Connective tissue is composed of collagen fibers within a proteoglycan matrix. It may become fibrotic, contracted, and shortened when subjected to immobilization or inactivity due to arthritic joint pain, resulting in joint capsule contractures and limited ROM, and adaptive shortening may occur in the muscles as well. Slow, sustained stretching and ROM exercises should therefore be performed to treat arthritic knees. Quick, jerky stretching should be avoided as it stimulates the muscle spindle of the intrafusal muscle fibers, causing the muscle to contract reflexively. Slower sustained stretching, however, causes firing of the Golgi tendon organs, which lie in series with the extrafusal muscle fibers, resulting in muscle relaxation [15].

In a previous study [16], long-term flexibility stretch training, as well as acute single stretching maneuvers, produced significant increases in ROM but either no changes in stiffness, or only minor, short-lasting changes. Bjorklund et al [17] suggested that sensory adaptation was an important mechanistic factor in the effects of stretching on ROM changes. Therefore, the increase in ROM following appropriate stretching therapy should be taken into account in planning therapeutic exercises for patients with knee OA.

Our previous report [18] showed that isokinetic exercise combined with ultrasound treatment for periarticular soft tissue pain control could reduce joint pain during exercise and increase the therapeutic efficacy of isokinetic exercise. Nevertheless, the limited ROM of the arthritic knee joint was still the main factor resulting in muscular weakness or fatigue during isokinetic exercise. Based on the hypothesis that stretching-induced improvements in ROM of the arthritic knee would increase the peak muscle torque (MPT) from isokinetic exercise, we compared the effects of various stretching techniques on the outcomes of isokinetic exercise in patients with knee OA.

Patients and Methods

Subjects

One hundred and thirty-two patients with bilateral, moderate knee OA (Altman Grade II, as shown in Table 1) [19] were selected and randomly assigned to four groups, followed by an intention-to-treat analysis using a secure system of sequentially numbered, opaque, sealed envelopes containing treatment allocations (I–IV), randomly assigned by computer. Patients with hip joint OA or any other hip problems with ROM limitations were excluded. The doctor who assigned the patients was blinded to the treatment the patients received. Patients underwent their respective treatments three times weekly, for 8 weeks. Patients in Group I (33 patients) received isokinetic muscular strengthening exercises, those in Group II (33 patients) received bilateral knee static stretching therapy before isokinetic exercise, those in Group III (33 patients) received proprioceptive neuromuscular facilitation (PNF) stretching therapy before isokinetic exercise, and those in Group IV (33 patients) received no treatment, other than warm-up cycling, and acted as controls. All patients received hot packs for 10 minutes and passive ROM exercise on an electric stationary bike (20 cycles per minute) for 10 minutes before undergoing muscle-strengthening exercises. The therapeutic

Table 1. Stages of knee osteoarthritis*

Stage	Age (yr)	Knee pain	Osteophytes	Morning stiffness	Crepitus	Bony enlargement
I	<40	Y	Y	N	N	N
II	>40	Y	Y	<30 min	Y	N
III	>40	Y	Y	>30 min	Y	N
IV	>40	Y	Y	>30 min	Y	Y

*Modified with permission from Reference 19. Y = presence of the symptom or sign; N = absence of the symptom or sign.

effects of the exercises were evaluated by changes in ROM of both knees [20], pain measured on a visual analog scale (VAS) [21], Lequesne's index (LI) [22], and MPT during knee flexion and extension, measured with an isokinetic dynamometer (Kin-Com 505; Chattanooga Corp., Chattanooga, TN, USA) after treatment and at 1-year follow-up. All the measurements were performed by the same physiatrist who was unaware of the treatment the patients had received. The attrition rate in each group was analyzed. All participants gave informed consent for the study and the study protocol was approved by the Ethics Review Committee of Kaohsiung Medical University.

Measurement of knee ROM

Assisted, active ROM was measured using a large plastic goniometer with 25-cm movable arms, marked in 1° increments. This device has been shown to be reliable if the patient remains in the same position for all the measurements [23]. Measurements of knee flexion and extension were taken with subjects lying supine on an examination couch, at active, maximum flexion of the knee joint with the hip flexed. Concomitant hip flexion prevented premature limitation of knee motion due to possible rectus femoris shortening. The fully extended knee was considered to be the zero position, and the degrees of maximum flexion and maximum extension were recorded. A negative ROM score for extension indicated that the patient was unable to reach the zero position. The angle between maximum flexion and maximum extension was defined as the excursion range.

Measurement of pain severity

The severity of knee pain was evaluated by VAS scores after patients had been in a weight-bearing posture (walking) for 5 minutes. The instrument used consisted of horizontal lines 10 cm long, with anchor points of 0 (no pain) and 10 (pain as bad as it could possibly be). The average of three measurements was recorded, and a 10-minute interval was set between tests to produce more consistent measurement conditions.

Measurement of disability

Disability of patients with knee OA was evaluated using the LI index. The questionnaire included 11 questions concerning knee discomfort, endurance of ambulation, and difficulties in daily life. A maximum score of 26 indicated the greatest degree of dysfunction, and a score of 1–3 indicated mild dysfunction. Patients with scores of <7 points were considered to be suitable for isokinetic exercise.

Measurement of isokinetic peak torque during knee flexion and extension

The peak torque of the arthritic knee was measured using a method modified from Snow and Blacklin [24] under the following conditions: knee extension with concentric quadriceps contraction (Ex/Con); knee flexion with eccentric quadriceps contraction (Ex/Ecc); knee flexion with concentric biceps femoris contraction (Flex/Con); knee flexion with eccentric biceps femoris contraction (Flex/Ecc). The subject was seated, leaning against a backrest inclined at 16° from the vertical and with the seat inclined 6° from the horizontal. The axis of the knee was aligned with the axis of the dynamometer exercise arm. The accuracy of alignment was checked by allowing the subject to extend the leg while pushing against the shin pad, which was positioned over the lower third of the leg. If the pad did not move up or down the leg over the ROM to be tested, the knee was considered to be aligned with the axis of the exercise arm. Gravity-compensated torque values were corrected with the exercise arm positioned 15° from the horizontal.

The Kin-Com's exercise arm was used to set the test ROM. The angle at which knee flexor muscle shortening began (start angle) was set at 20° from the horizontal and the angle at which muscle lengthening began (return angle) was set at 85° from the horizontal. To calculate the torque, the distance between the point of application of the generated force and the axis of rotation of the exercise arm was measured using the scale on the arm itself, and keyed into the computer. Each subject used the same radius for all tests. Exercise-arm velocity was set to either 60°/second or 180°/second for the isokinetic peak torque measurements.

Knee stretching exercises

The quadriceps and biceps femoris are the key muscles that require strengthening to improve the stability of OA knees. The stretching exercise therefore focused on the quadriceps and biceps femoris.

Static stretch

Active-assistive stretching of bilateral knees was performed after 15 minutes of hot-packing the arthritic knee in the supine position, and holding the positions of knee flexion and extension at the end points of the ROM for 30 seconds [25]. This was repeated 10 times (10 minutes) for each treatment. The static stretching programs were performed by the same physical therapist.

PNF stretch

The PNF stretching techniques included hold-relax (HR), contract-relax (CR), contract-relax agonist contract (CRAC) and hold-relax agonist contract (HRAC) for 15 seconds for each stretching step. The program was repeated 10 times (10 minutes) for each treatment. HR: the patient was kept in a prone position with the lower leg outside the table held at full extension of the knee against the practitioner's resistance; CR: same as HR, except that the practitioner held against the patient's resistance; HRAC: same as HR, but with active contraction of the quadriceps muscles to achieve greater ROM; CRAC: contraction of biceps femoris, followed by contraction of quadriceps to achieve greater ROM [26]. The PNF stretching programs were also performed by the same physical therapist.

Isokinetic exercise

After measuring blood pressure, heart rate and the ROM of the arthritic knee, the patient underwent a 5-minute warm-up exercise on a stationary bike, without resistance. Hot packs were then applied to the knee joint before stretching the quadriceps and hamstrings muscles. The isokinetic muscle strengthening exercise program was performed for the left and right knees, three times a week for 8 weeks (24 sessions), as described in our previous study [8]. The initial amount of isokinetic exercise was selected as 60% of the average torque, and an increasing dose program was used in the initial first to fifth sessions (1–5 sets), and six sets from the sixth to 24th sessions. Each set consisted of five repetitions of concentric and eccentric (Con/Ecc) contractions at angular velocities of 30°/second and 120°/second for extensors, and five repetitions of eccentric and concentric (Ecc/Con) contractions at angular velocities of 30°/second and 120°/second for flexors. The start and stop angles for extension exercise were 40° and 70°, and the start and stop angles for flexion exercise were 70° and 40°. Patients were allowed 5 seconds of rest between sets, 10 seconds of rest between different modes of training, and 10 minutes of rest between right and left knee training.

Rate of attrition

The rate of attrition was determined by the number of participants who dropped out of the treatment course. The major reasons for dropping out were also analyzed.

Statistical analysis

Weighted kappa statistics were used to test intra-observation agreement between repeated measurements of ROM, LI and MPT. Paired t tests were used to study the changes in ROM, VAS, LI values and MPT in each group after treatment and at 1-year follow-up. One way analysis of variance with Tukey's test was used to compare the differences in ROM, VAS, LI, and MPT among the three treated groups. Dunnett's test was used to compare the differences between the treated groups and the control group at zero time, after treatment, and 1 year later. A statistically significant difference was defined as $p < 0.05$.

Results

Subjects

The 132 patients ranged in age from 46 to 78 years (mean, 64.0 ± 7.5 years), with a female:male ratio of 106:26. The duration of knee pain ranged from 4 months to 9.5 years (mean, 42.5 ± 17.6 months). There were no significant differences in initial knee pain, ROM, LI or MPT among all groups. Eight subjects withdrew from the therapeutic exercises (2 subjects in Group I, 4 in Group II, 2 in Group III). Contact with 13 subjects was lost during the follow-up period (3 subjects in Group I, 2 in Group II, 1 in Group III, and 7 in the control group).

Intra-observation repeatability

The first 45 patients received repeated measurements of ROM, LI and MPT by the same physiatrist. Intra-observation repeatability revealed good agreement for ROM, LI and MPT ($k = 0.85$, 0.86, 0.90, respectively).

Changes in ROM

The changes in average ROM of the arthritic knees for each group are shown in Table 2. The ROM scores increased gradually in all treated groups. However, significant changes found after treatment and at follow-up were only found in Groups II and III, which had received the stretching exercises.

Table 2. Range of motion, visual analog score and Lequesne's index (mean ± standard deviation) for knees in each group before and after treatment

	I	II	III	IV (Control)
ROM				
Before	97 ± 14 (n = 66)	97 ± 12 (n = 66)	98 ± 16 (n = 66)	97 ± 15 (n = 66)
After	102 ± 17 (n = 62)	107 ± 16 (n = 58)*†	115 ± 17 (n = 62)*†‡	95 ± 11 (n = 66)
Follow-up	103 ± 15 (n = 56)	110 ± 14 (n = 54)*†	126 ± 17 (n = 60)*†‡	100 ± 17 (n = 52)
VAS				
Before	4.7 ± 1.6 (n = 66)	4.7 ± 1.2 (n = 66)	4.9 ± 1.4 (n = 66)	4.5 ± 1.5 (n = 66)
After	3.6 ± 0.7 (n = 62)*†	3.1 ± 0.8 (n = 58)*†	2.7 ± 1.9 (n = 62)*†‡	4.4 ± 1.4 (n = 66)
Follow-up	3.6 ± 1.6 (n = 56)*†	2.9 ± 1.4 (n = 54)*†	2.0 ± 1.4 (n = 60)*†‡	5.0 ± 1.4 (n = 52)*
LI				
Before	7.3 ± 2.5 (n = 33)	7.1 ± 1.5 (n = 33)	7.2 ± 1.5 (n = 33)	7.1 ± 1.8 (n = 33)
After	5.6 ± 0.9 (n = 31)*†	5.0 ± 1.0 (n = 29)*†	4.2 ± 0.5 (n = 31)*†‡	6.9 ± 1.3 (n = 33)
Follow-up	6.3 ± 1.7 (n = 28)*†	4.0 ± 1.3 (n = 27)*†	2.9 ± 1.7 (n = 30)*†‡	7.3 ± 1.7 (n = 26)

*Paired t tests were used to study the changes in ROM, VAS, LI values and mean peak torques for each group after treatment and at 1-year follow-up; †one-way analysis of variance with Tukey's test was used to compare the differences in ROM, VAS, LI, and mean peak torques among the three treated groups; ‡Dunnett's test was used to compare the differences between treated groups and the control group at zero time, after treatment, and 1 year later. A statistically significant difference was defined as $p < 0.05$. ROM = range of motion; VAS = visual analog score; LI = Lequesne's index; n = number of knees in each group at various time periods.

Changes in knee pain

The changes in average scores of knee pain for each subgroup are shown in Table 2. Pain scores in Groups I–IV were initially similar. However, pain scores decreased significantly in all treated groups after treatment, and decreased further in Groups II and III at follow-up, while the score increased in the control group. Patients in Group III showed the greatest degree of pain reduction, both after treatment and at follow-up.

Changes in LI

There were no significant differences in initial LI among the treated and control groups. The changes in mean LI values for each patient group are shown in Table 2. The average LI scores decreased significantly in all treated groups after treatment and at the 1-year follow-up. Patients in Group I had the smallest reduction in LI scores after treatment, while patients in Group III had the greatest reduction in disability after treatment and at follow-up.

Changes in muscle power

The changes in mean MPT at knee flexion and extension during concentric and eccentric contraction in all patient groups are shown in Table 3 (60°/second) and Table 4 (180°/second). The average MPT at 60°/second in Ex/Con, Ex/Ecc, Flex/Ecc, and Flex/Con increased significantly in Groups II and III, both after treatment and at follow-up. Patients in Group I showed the least improvement in MPT after treatment, but the MPT in Group I was significantly improved at follow-up, compared with the control group. This demonstrated that short-term training strategies, including stretching and isokinetic muscle strengthening exercises, were more effective than isokinetic exercise alone. Table 4 shows that patients in Group III had the greatest improvement in MPT at 180°/second in all contraction modes (Ex/Con, Ex/Ecc, Flex/Con, and Flex/Ecc) after treatment and at follow-up.

Rate of attrition

The rates of attrition were 6.06% (2/33), 12.1% (4/33), 6.06% (2/33) and 0% (0/33) in Groups I, II, III and IV, respectively. The percentage of patients who withdrew from the treatment because of intolerable, isokinetic exercise-induced knee pain or leg muscle weakness was 37.5% (3/8), while 62.5% (5/8; 3 in static stretching group, 2 in PNF stretching group) withdrew due to stretching therapy-related pain.

Discussion

Older adults with OA, particularly knee OA, tend to have decreased strength and proprioception, decreased flexibility, increased body sway and impaired balance,

Table 3. Mean peak torque at knee flexion and extension during concentric and eccentric contractions at 60°/second in each group before and after treatment

	I	II	III	IV (Control)
Ex/Con				
Before	46.3±6.6 (*n*=66)	47.9±8.0 (*n*=62)	46.9±6.2 (*n*=66)	48.1±7.1 (*n*=66)
After	51.1±7.6 (*n*=62)*‡	58.1±6.9 (*n*=58)*†	59.2±9.2 (*n*=62)*†	47.7±8.4 (*n*=66)
Follow-up	54.3±3.4 (*n*=56)*†‡	64.3±2.5 (*n*=54)*†	67.6±6.1 (*n*=60)*†	44.3±5.8 (*n*=52)
Ex/Ecc				
Before	94.1±8.4 (*n*=66)	88.7±6.9 (*n*=66)	86.7±5.8 (*n*=66)	87.5±7.1 (*n*=66)
After	96.4±6.3 (*n*=62)†‡	102.3±5.9 (*n*=58)*†	115.5±6.6 (*n*=62)*†	87.9±6.7 (*n*=66)
Follow-up	97.5±7.2 (*n*=56)†‡	123.1±6.3 (*n*=54)*†	127.5±6.8 (*n*=60)*†	83.3±7.3 (*n*=52)
Flex/Con				
Before	55.7±5.9 (*n*=66)	55.1±7.1 (*n*=66)	53.6±7.7 (*n*=66)	55.5±6.3 (*n*=66)
After	57.1±6.4 (*n*=62)†‡	63.6±6.1 (*n*=58)*†	63.6±6.7 (*n*=62)*†	51.6±7.3 (*n*=66)
Follow-up	56.4±7.4 (*n*=56)†‡	66.0±6.9 (*n*=54)*†	70.0±7.2 (*n*=64)*†	47.1±7.8 (*n*=52)*
Flex/Ecc				
Before	67.1±6.6 (*n*=66)	69.0±7.3 (*n*=66)	66.7±8.0 (*n*=66)	69.8±7.2 (*n*=66)
After	74.7±5.9 (*n*=62)*†‡	79.8±7.1 (*n*=58)*†	79.2±6.7 (*n*=62)*†	67.9±8.4 (*n*=66)
Follow-up	75.9±6.9 (*n*=56)*†‡	83.0±7.8 (*n*=54)*†	84.4±8.5 (*n*=60)*†	59.8±6.7 (*n*=52)*

*Significant difference in peak torque in each group after treatment or at follow-up ($p<0.05$); †significant difference in peak torque in each group compared with control at various time periods ($p<0.05$); ‡significant difference compared with other treated groups ($p<0.05$). Ex/Con = knee extension with concentric quadriceps contraction; Ex/Ecc = knee flexion with eccentric quadriceps contraction; Flex/Con = knee flexion with concentric biceps femoris contraction; Flex/Ecc = knee flexion with eccentric biceps femoris contraction; *n* = number of knees in each group at various time periods.

Table 4. Mean peak torque at knee flexion and extension during concentric and eccentric contraction at 180°/second in each group before and after treatment

	I	II	III	IV (Control)
Ex/Con				
Before	35.9±10.3 (*n*=66)	35.3±9.7 (*n*=66)	36.1±8.8 (*n*=66)	36.5±9.5 (*n*=66)
After	40.2±9.8 (*n*=62)*†	44.0±10.4 (*n*=58)*†	50.1±10.4 (*n*=62)*†‡	36.0±8.9 (*n*=66)
Follow-up	42.1±11.2 (*n*=56)*†	46.4±12.0 (*n*=54)*†	55.5±11.4 (*n*=60)*†‡	34.7±10.2 (*n*=52)
Ex/Ecc				
Before	93.2±8.5 (*n*=66)	95.9±11.1 (*n*=66)	97.4±9.7 (*n*=66)	97.7±10.5 (*n*=66)
After	114.7±10.8 (*n*=62)*†	120.3±9.8 (*n*=58)*†	129.9±13.3 (*n*=62)*†‡	95.3±12.1 (*n*=66)
Follow-up	119.1±12.2 (*n*=56)*†	126.1±13.0 (*n*=54)*†	139.7±15.1 (*n*=60)*†‡	118.4±11.9 (*n*=52)*
Flex/Con				
Before	36.8±8.7 (*n*=66)	37.1±9.8 (*n*=66)	37.8±9.3 (*n*=66)	36.4±9.7 (*n*=66)
After	45.8±9.0 (*n*=62)*†	49.2±11.4 (*n*=58)*†	54.7±10.5 (*n*=62)*†‡	35.7±10.8 (*n*=66)
Follow-up	47.5±11.4 (*n*=56)*†	54.7±12.6 (*n*=54)*†	60.7±12.4 (*n*=60)*†‡	32.5±11.6 (*n*=52)*
Flex/Ecc				
Before	63.5±12.1 (*n*=66)	63.0±13.1 (*n*=66)	61.9±11.6 (*n*=66)	64.1±12.5 (*n*=66)
After	68.3±13.2 (*n*=62)*†	71.9±12.7 (*n*=58)*†	77.1±13.4 (*n*=62)*†‡	60.3±11.9 (*n*=66)
Follow-up	71.2±11.6 (*n*=56)*†	76.7±10.9 (*n*=54)*†	83.2±11.0 (*n*=60)*†‡	56.7±10.4 (*n*=52)*

*Significant difference in peak torque in each group after treatment or at follow-up ($p<0.05$); †significant difference in peak torque in each group compared with control at various time periods ($p<0.05$); ‡significant difference compared with other treated groups ($p<0.05$). Ex/Con = knee extension with concentric quadriceps contraction; Ex/Ecc = knee flexion with eccentric quadriceps contraction; Flex/Con = knee flexion with concentric biceps femoris contraction; Flex/Ecc = knee flexion with eccentric biceps femoris contraction; *n* = number of knees in each group at various time periods.

and resulting disability. Therapeutic exercise can help to prevent accelerated degeneration due to disuse, and so avoid further degeneration and pain as a consequence of joint deformity or incongruence. Several recent longitudinal studies have concluded that carefully controlled exercise programs, designed primarily to address OA of the knee, are indeed beneficial [12,13]. Reported benefits include increased joint mobility, increased strength, and enhanced performance in sports activities. Our previous study [8] showed that isokinetic muscle-strengthening exercises were more effective than isometric or isotonic exercises for improving disability, muscular strength and ambulation ability. However, patient compliance is an issue, and studies with higher patient compliance produced better results. Patient compliance depends on many elements, including consistent education, encouragement, and follow-up. Injury and complications as a direct consequence of inappropriate exercise [14], such as knee pain during exercise, weakness of leg muscles, and limited ROM, are the major reasons for poor compliance.

Various degrees of knee flexion are needed for mobility, for example, at least 70° for walking on level surfaces, 83° for climbing stairs, 93° for getting up from a chair, and 120° for squatting. Steultjens et al [27] established the relationships between ROM and disability and found that restricted joint mobility, especially in flexion of the knee, was an important determinant of disability in patients with knee OA. This suggested that a comprehensive exercise program should include stretching exercises to increase ROM, as well as muscle strengthening and aerobic exercises. The subjects in the present study had initial ROM of bilateral knees of $<100°$, and their disability indices were >7.0. ROM and LI indices were improved more in Groups II and III after stretching therapy and isokinetic exercise (Tables 2 and 4), suggesting that stretching therapy helped to improve ROM and patient disability.

The primary factors limiting joint movement at the ends of the range are the muscle and its fascial sheath, the capsule, and the tendon, in that order. When the role of the muscle is considered as a factor limiting ROM, the contribution of the peripheral receptors must also be taken into account. The muscle spindle and the Golgi tendon organ play an important role in the muscle's ability to lengthen adequately in response to imposed tension. The Golgi tendon organ is sensitive to tension changes within the muscle as it stretches or contracts. The resulting reflex is inhibitory and acts to inhibit its own muscle and excite the antagonist muscle. These principles form the rationale for PNF stretching techniques, which use volitional contractions to increase ROM by minimizing the resistance to stretch by the active components attributed to the spinal reflex pathway [28]. Static stretching differs from PNF stretching in that its primary goal is to address the viscoelastic components, especially the connective tissue, that may be responsible for limiting the ROM [29]. The passive components of flexibility must be dealt with differently from the active components, which exhibit time- and rate-dependent changes. Many investigators have concluded that passive components must be targeted to achieve a permanent lengthening of the musculotendinous structures [30]. Both PNF and static stretching were associated with greater improvements in ROM in Groups II and III, compared with Group I and the control group.

Four subjects withdrew from Group II and two from Group III due to knee discomfort induced by isokinetic muscle strengthening exercises. However, the weight-bearing VAS pain scores were reduced more in Groups II and III after treatment and at follow-up (Table 3). These results indicate that stretching therapy, combined with isokinetic muscle strengthening exercises, can be beneficial for long-term knee pain reduction. However, the discomfort induced by isokinetic muscle strengthening exercises is compatible with the results of a report showing that eccentric activities could induce micro-injuries, resulting in delayed-onset muscle soreness [31].

Cramer et al [32] stated that MPT, at both 60° and 240°/second, decreased immediately after static stretching. However, our present results showed that the MPT in each treated group was improved after treatment and at follow-up, and the improvements in MPT (at 60°/second) were greatest in Groups II and III, though there was no significant difference between these two groups. This demonstrated that both static and PNF stretching increased the efficacy of isokinetic strengthening exercises, and that stretching therapy caused muscle relaxation, possibly due to central nervous system inhibition [30], resulting in pain reduction following isokinetic exercises. Furthermore, the improvement in MPT (at 180°/second) in Group III was greater than in Group II, suggesting that the improvement in MPT at 180°/second is closely correlated with improvements in disability. PNF stretching was shown to be more effective for improving flexibility, and its mechanism could explain the greater improvement in functional status in Group III compared with Group II. Although some of the mechanisms underlying static stretching are the same as those for PNF stretching, there is a greater emphasis on the role of connective tissue in joint stiffness.

In conclusion, stretching therapy is recommended as an adjuvant treatment to isokinetic exercise for patients with knee OA. PNF stretching is more effective than static stretching exercise.

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References

1. Felson DT. The epidemiology of knee osteoarthritis: results from the Framingham osteoarthritis study. *Semin Arthritis Rheum* 1990;20:42–50.
2. Badley E, Tennant A. Impact of disablement due to rheumatic disorders in a British population: estimates of severity and prevalence from the Calderdale Rheumatic Disablement Survey. *Ann Rheum Dis* 1993;52: 6–13.
3. McAlindon TE, Cooper C, Kirwan JR. Knee pain and disability in the community. *Br J Rheumatol* 1992;31: 189–92.
4. Thompson RC, Oegema TR, Wallace L, et al. Osteoarthritic changes after acute transarticular load: an animal model. *J Bone Surg Am* 1991;73:990–1001.
5. Van Baar ME, Assendelft WJ, Dekker J. Effectiveness of exercise therapy in patients with osteoarthritis of hip or knee: a systematic review of randomized clinical trials. *Arthritis Rheum* 1999;42:1361–9.
6. Deyle GD, Henderson NE, Allison SC, et al. Effectiveness of manual physical therapy and exercise in osteoarthritis of knee. *Ann Intern Med* 2000;132:173–81.
7. Messier SP, Thompson CD, Ettinger WH Jr. Effects of long-term aerobic or weight training regimens on gait in an older, osteoarthritis population. *J Appl Biomechanics* 1997;13:205–25.
8. Huang MH, Lin YS, Lee CL, et al. A comparison of various therapeutic exercises on the functional status of patients with knee osteoarthritis. *Semin Arthritis Rheum* 2003;32:398–406.
9. Hueley MV, Scott DL. Improvements in quadriceps sensorimotor function and disability of patients with knee osteoarthritis following a clinically practicable exercise regimen. *Br J Rheum* 1998;37:1181–7.
10. Mangione KK, McCully K, Craik R, et al. The effects of high-intensity and low-intensity cycle ergometry in older adults with knee osteoarthritis. *J Gerontol* 1999; 54:184–90.
11. Spencer AC, Kinne S, Patrick DL, et al. Recruiting adults with osteoarthritis into an aquatic exercise class: strategies for a statewide intervention. *Arthritis Care Res* 1998;11:455–62.
12. Røgind H, Bibow-Nielsen B, Bliddal H, et al. The effects of physical training program on patients with osteoarthritis of the knee. *Arch Phys Med Rehabil* 1998; 79:1421–7.
13. Fransen M, McConnell S. Exercise for osteoarthritis of the hip or knee. *Cochrane Database Syst Rev* 2003;3: CD004286.
14. Ettinger WH, Burns R, Morgan T, et al. A randomized trial comparing aerobic exercise and resistance exercise with a health education program in older adults with knee osteoarthritis. The Fitness Arthritis and Seniors Trial (FAST). *JAMA* 1997;277:25–31.
15. Proske U, Morgan DL, Gregory JE. Thixotropy in skeletal muscle and in muscle spindle: a review. *Prog Neurobiol* 1993;41:705–21.
16. Magnusson SP, Simonsen EB, Kjaer M, et al. Mechanical and physiological responses to stretching with and without preisometric contraction in human skeletal muscle. *Arch Phys Med Rehabil* 1996;77:373–8.
17. Bjorklund M, Hamberg J, Crenshaw AG. Sensory adaptation after a 2-week stretching regimen of the rectus femoris muscle. *Arch Phys Med Rehabil* 2001;82:1245–50.
18. Huang MH, Lin YS, Yang RC, et al. Use of ultrasound to increase effectiveness of isokinetic exercise for knee osteoarthritis. *Arch Phys Med Rehabil* 2005;86:1545–51.
19. Altman RD. Criteria for classification of clinical osteoarthritis. *J Rheumatol* 1991;18(Suppl 27):10–2.
20. Ersoz M, Ergun S. Relationship between knee range of motion and Kellgren-Lawrence radiographic scores in knee osteoarthritis. *Am J Phys Med Rehabil* 2003;82: 110–5.
21. Dalton JA, McNaull F. A call for standardizing the clinical rating of pain intensity using a 0 to 10 rating scale. *Cancer Nursing* 1998;21:46–9.
22. Lequesne M. Clinical features, diagnostic criteria, functional assessments and radiological classifications of osteoarthritis. *Rheumatology* 1982;7:1–10.
23. Rothstein JM, Miller PJ, Roettger RF. Goniometric reliability in a clinical setting: elbow and knee measurement. *Phys Ther* 1983;63:1611–5.
24. Snow CJ, Blacklin K. Reliability of knee flexor peak torque measurement from a standardized test protocol on a Kin/Com Dynamometer. *Arch Phys Med Rehabil* 1992;73:15–21.
25. Bandy WD, Irion JM. The effect of time on static stretch on the flexibility of the hamstring muscles. *Phys Ther* 1994;74:845–50.
26. Webright WG, Randolph BJ, Perrin DH. Comparison of non-ballistic active knee extension in neural slump position and static stretch techniques on hamstring flexibility. *J Orthop Sports Phys Ther* 1997;26:7–12.
27. Steultjens MPM, Dekker J, Van Baar ME. Range of motion and disability in patients with osteoarthritis of the knee or hip. *Rheumatology* 2000;39:955–61.
28. Voss DE, Ionta MK, Myers BJ. *Proprioceptive Neuromuscular Facilitation*, 3rd edition. Philadelphia: Harper & Row, 1985:1–8.

29. Condon SM, Hutton RS. Soleus muscle electromyographic activity and ankle dorsiflexion range of motion during four stretching procedures. *Phys Ther* 1987;67:24–30.
30. Bandy WD, Irion JM. The effect of time on static stretch on the flexibility of the hamstring muscles. *Phys Ther* 1994;74:845–52.
31. Cheung JT, Huang P, Maxwell L. Delayed onset muscle soreness: treatment strategies and performance factors. *Sport Med* 2003;33:145–64.
32. Cramer JT, Housh TJ, Beck TW, et al. The acute effects of static stretching on peak torque, mean power output, electromyography, and mechanomyography. *Eur J Appl Physiol* 2005;93:530–9.

不同型態的伸展運動對膝關節炎病人等速肌力運動的影響

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對於膝退化性關節炎的患者，除了藥物治療以外，還有許多非藥物的治療選擇。其中相關肌力強化的運動，是一種很重要的復健處方。對於慢性膝蓋退化性關節炎的患者，常見股四頭肌無力及因為膝蓋疼痛，而導致病人活動力下降，進一步關節活動度減少，甚至攣縮。因此，如何給予適當的活動，來強化股四頭肌以及維持關節活動度，對於病人的生活品質是格外的重要。本研究的目的，在於比較給予病人等速肌力運動前，施以兩種不同的伸展運動，包括靜態的伸展運動以及本體感覺神經肌肉誘發式伸展運動，對於病人的肌力訓練、關節活動度、失能的狀態以及膝蓋的疼痛等之改善程度加以評估。結果發現，有接受等速肌力運動病患，其疼痛的改善、肌力的強化及失能的狀態，皆得到改善。其中有接受伸展運動的兩組受測者，其肌力及關節活動度有顯著的改善。而且接受本體感覺神經肌肉誘發式伸展運動這組的效果，又比接受靜態的伸展運動的受測者為佳。由此可知，對於膝退化性關節炎的患者，給予適當的等速肌力運動，並且在運動前指導伸展運動，是一種較為適合的運動處方。

關鍵詞：等速肌力運動，膝蓋，退化性關節炎，伸展運動

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