ORIGINAL ARTICLE

Effect of static stretching of muscles surrounding the knee on knee joint position sense

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Background: Muscle stretching is widely used in sport training and in rehabilitation. Considering the important contribution of joint position sense (JPS) to knee joint stability and function, it is legitimate to question if stretching might alter the knee JPS.
Objective: To evaluate if a stretch regimen consisting of three 30 s stretches alters the knee JPS.
Design and setting: A blinded, randomised design with a washout time of 24 h was used.
Subjects: 39 healthy students (21 women, 18 men) volunteered to participate in this study.
Methods and main outcome measures: JPS was estimated by the ability to reproduce the two target positions (20° and 45° of flexion) in the dominant knee. The absolute angular error (AAE) was defined as the absolute difference between the target angle and the subject perceived angle of knee flexion. AAE values were measured before and immediately after the static stretch. Measurements were repeated three times. The static stretch comprised a 30 s stretch followed by a 30 s pause, three times for each muscle.
Results: The AAE decreased significantly after the stretching protocols for quadriceps (3.5 (1.3) vs 0.7 (2.4); $p<0.001$), hamstring (3.6 (2.2) vs 1.6 (3.1); $p=0.016$) and adductors (3.7 (2.8) vs 1.7 (2.4); $p=0.016$) in 45° of flexion, but no differences were found for values of the gastrocnemius and popliteus muscles in this angle and for the values of all muscles in 20° of flexion ($p>0.05$).
Conclusion: The accuracy of the knee JPS in 45° of flexion is improved subsequent to a static stretch regimen of quadriceps, hamstring and adductors in healthy subjects.

Joint position sense (JPS) is generally defined as the ability to assess a limb's position without the assistance of vision.[1] Position sense at the knee joint is governed by central and peripheral mechanisms, mainly muscular receptors and also tendinous, articulate, cutaneous and anterior cruciate ligament (ACL) receptors.[2 3] The respective roles of these various sources of afferent information have been debated, but it is now generally accepted that the greatest contribution to position sense is from muscular receptors.[3–6] This role of muscular receptors indicates that modifying the functional state of the muscles can affect the precision of position sense.[1]

Muscle stretching is widely used in sport training and in rehabilitation of patients with musculoskeletal disorders.[7 8] It is assumed that stretching may increase range of motion (ROM),[7] improve performance,[9 10] and diminish muscle fatigue and delayed onset muscle soreness after unaccustomed exercise.[10 11] Static stretching is one of the safest and most commonly performed stretching methods used to increase muscle length. This type of stretch is applied slowly and gradually at a relatively constant force to avoid eliciting a stretch reflex.[12]

Several studies have reported that static stretching reduces passive stiffness of the muscle.[13–15] However, more recent studies showed a significant increase in ROM but found either no change in stiffness, or only minor short-lasting changes.[16–18] Halbertsma *et al*[17] and Magnusson *et al*[18] reported that static stretching may alter stretch tolerance. The subjective sensation of stretching is significantly lower after 2 weeks of a stretching protocol, indicating that stretch tolerance is altered.[19] This may be due to alteration in the muscle spindle or Golgi tendon organ firing rate.[20] This assumption is supported by the observation that the muscle spindles are affected by a previous history of muscle stretching.[21] Several studies indicate that 15–30 s of stretching are needed to achieve an increased ROM and the static stretch must last for 30 s.[22 23]

Considering the important contribution of JPS for knee joint stability and function, it is legitimate to question if stretching might alter the knee JPS. Thus, the purpose of this study was to evaluate if a regimen consisting of three 30 s stretches would alter the knee JPS.

SUBJECTS AND METHODS

Subjects

Thirty-nine university students (21 women, 18 men) volunteered. Their mean (SD) age was 25.6 (1.2) years, mean height 175.2 (7.5) cm and mean weight 72.9 (9.6) kg. They were healthy, and performed moderate or greater intensity exercise at least three times a week. Excluded were subjects who had a history of trauma to the lower extremity, rheumatological, orthopaedic or neuromuscular disorders. All subjects gave written informed consent to participate in the study. The study was approved by the Medical University of Shiraz for Health Sciences Research involving Human Subjects.

Procedure

All subjects were tested to assess their sense of knee joint position, and the data recorded. Each subject then performed standardised stretching of quadriceps, gastrocnemius, popliteus, hamstring and adductors. The stretching position is held for 30 s and then released. The sense of knee joint position was then re-evaluated. To avoid interference, the stretching periods were separated by a washout period of 1 day. Each muscle was tested on each day, for a total of 5 days of testing. Only the dominant (right) leg was tested.

Abbreviations: AAE, absolute angular error; ACL, anterior cruciate ligament; JPS, joint position sense; ROM, range of movement

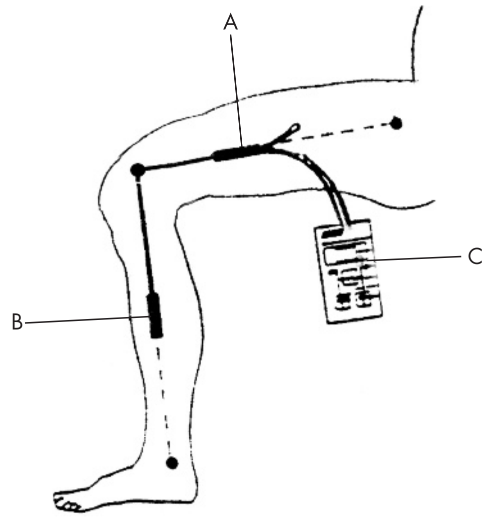

Figure 1 Apparatus for testing knee joint position sense. (A) coincides with the axis of the thigh and (B) coincides with the axis of the lower limb. An angle display unit (C) records the knee angle.

Measurement of knee joint position sense

Knee JPS was assessed by the subject's ability to reproduce passive positioning of the leg, using an electrogoniometer at the lateral aspect of knee joint (fig 1). This device was modified from Penny and Giles[24] and consists of two end blocks connected by a protective spring, with a composite wire housing a series of strain gauges mounted around its circumference. When the angle is produced between the two end blocks, a change in strain along the length of the wire is measured and this is equated to an angle. An angle display unit was connected to the electrogoniometer to record the subject's knee angle in degrees. The electrogoniometer measures angular joint motion, regardless of linear movements due to skin stretches or poor alignment with the joint axis of rotation. So, it is possible to measure knee joint angles, without problems of axis location or land marking.[24] The test–retest reliability for the electrogoniometer was high ($r = 0.96$).

Subjects were comfortably seated on a high armchair, with their foot hanging off the ground and blindfolded to ensure elimination of visual clues. Subjects had their knees moved passively (by an electronic device, with constant speed) from 90° of flexion to predetermined target positions (20° and 45° of flexion) and held there for 5 s. The leg was then returned to the starting position (90° flexion) and the subject asked to actively reproduce the required angles. The difference between the actual and the reproduced angle was the absolute angular error (AAE). Measurement of JPS was blinded in relation to muscle group stretched and repeated three times.

Stretching regimen

After oral and written instruction, stretching was carried out three times, as a passive static stretching of 30 s with 30 s rest, in a randomised manner.

Quadriceps stretching was applied in a prone position. The examiner stabilised contralateral pelvis and flexed the knee joint, until the heel touched the buttock.[25]

Hamstring stretching was applied in a supine position. The examiner flexed the hip joint up to 90°, and pushed the knee joint into extension.[25]

Adductor stretching was applied in a supine position. The examiner stood between the patient's abducted thigh, supporting the weight of his/her leg and moved the straight leg into abduction.[25]

Gastrocnemius stretching was applied in a supine position. The examiner placed one hand across the superior aspect of the subject's knee, to stabilise the joint and the other hand, pushed the foot into dorsiflexion.[25]

Popliteus stretching was applied in a prone position. The examiner flexed the knee joint, up to 20°, with one hand and lateral rotated the lower leg, with the other.[25]

Statistical analysis

The statistical package for the social sciences (SPSS) for windows (version 11.0; SPSS Inc, Chicago, IL, USA) was used for statistical analysis. To determine test–retest reliability, a paired t test and Pearson's correlation coefficient were calculated from the measurements obtained from tests. Pre- and post-stretching AAE mean values for each of the five muscles were analysed individually using an analysis of variance to evaluate the effects of stretching of each muscle on a subject's ability to reproduce the knee joint angles. For all analyses, the level of significance was set at $p<0.05$.

RESULTS

There was no systemic variation of the ratings of JPS from test occasions ($p = 0.21$) and the data between occasions correlated well ($r = 0.71$, $p<0.001$). Table 1 shows AAE values for knee JPS of two target positions (20° and 45° of flexion) before the stretching. The means of AAE values in 45° of flexion were significantly greater than the values in 20° of flexion ($p<0.05$). Table 2 shows the AAE difference values for knee JPS of 20° flexion before and after the stretching protocols. There were no differences in AAE values in 20° of flexion after the stretching protocols for all five muscles ($p>0.05$). Table 3 shows the AAE difference values for knee JPS of 45° flexion before and after the stretching protocols. In 45° of flexion, there was significant decrease in AAE, after the stretching protocols for quadriceps ($p<0.001$), hamstring ($p = 0.016$) and adductors ($p = 0.016$), but there were no significant differences for values of the gastrocnemius and popliteus ($p>0.05$).

Table 1 Absolute angular error (AAE) values for knee joint position sense of two target positions (20° and 45° of flexion) before the stretching protocols

	AAE (degree)		
Muscle	Values in 20° flex	Values in 45° flex	p Value
Quadriceps	1.1 (1.2)	3.5 (1.3)	<0.001
Hamstring	1.3 (2.1)	3.6 (2.2)	<0.001
Adductors	1.2 (2.2)	3.7 (2.8)	<0.001
Gastrocnemius	0.4 (1.8)	1.4 (1.3)	<0.001
Popliteus	0.5 (1.4)	1.4 (1.4)	<0.001

Values are means (SD).

Table 2 Absolute angular error (AAE) and p values for knee joint position sense of 20° flexion before and after the stretching protocols

	AAE (degree)		
Muscle	Pre-stretching values	Post-stretching values	p Value
Quadriceps	1.1 (1.2)	1.1 (2.1)	0.11
Hamstring	1.3 (2.1)	1.7 (2.6)	0.87
Adductors	1.2 (2.2)	1.9 (2.3)	0.97
Gastrocnemius	0.4 (1.8)	1.6 (2.9)	0.16
Popliteus	0.5 (1.4)	1.2 (2.4)	0.75

Values are means (SD).

Table 3 Absolute angular error (AAE) and p values for knee joint position sense of 45° flexion before and after the stretching protocols

Muscle	AAE (degree) Pre-stretching values	Post-stretching values	p Value
Quadriceps	3.5 (1.3)	0.7 (2.4)	
Hamstring	3.6 (2.2)	1.6 (3.1)	0.016*
Adductors	3.7 (2.8)	1.7 (2.4)	0.016*
Gastrocnemius	1.4 (1.3)	1.2 (2.8)	0.114
Popliteus	1.4 (1.4)	1.3 (1.2)	0.75

Values are means (SD).
*Significant value.

DISCUSSION

This study showed a significant effect of static stretching of quadriceps, hamstring and adductors on knee JPS in 45° of flexion. This supports the view that stretching may influence the mechanoreceptors in the muscles around the knee joint.[19 21]

Bjorklund *et al* showed that after a 2-week stretching regimen of the rectus femoris, stretch sensation was decreased in an experimental group and suggested that receptors were responsible for reduced stretch sensation.[19] Proske *et al* showed that as the muscle spindles have a thixotropic property, stretching may improve proprioceptive input of muscular receptors.[21] It has been suggested that static stretching may adjust the positional sensitivity of the muscular receptors by affecting the series elastic component of the muscles. This adjustment may begin early after stretching and involve recoil of the stretched elastic component of the tendon to a new equilibrium state.[22 23] Our results support these suppositions.

There is not extensive documentation about the effects of muscle stretching on knee JPS. Larsen *et al* evaluated the effect of static stretching of quadriceps and hamstring muscles on knee JPS.[20] Their stretching regimen was similar to ours, but they found no significant difference in constant error between the stretching and control groups. Our finding of an effect of stretching on knee JPS in this study is not in agreement with the study of Larsen *et al*. There is a possible explanation for this inconsistency. Their study subjects showed a small difference between estimate and target positions, which made it difficult to demonstrate any improvement after stretching, but in our study this difference was greater.

Because the muscular receptors have an important role in the elaboration of limb position sense,[3 4] it seems that stretching may improve sensory and motor capabilities of perception of JPS. It has been reported that the accuracy of JPS would improve as the muscles stretched and that this increase in accuracy might be responsible for the increase in motor capabilities after stretching.[9 10] Such an increase may be due to a better proprioceptive feedback, but may also act indirectly by leading to a better sensory imagery.[9 10] Anecdotal experience indicates relief by stretching after relatively tough physical activity. It has been suggested that stretching augments the sensibility of the intrafusal fibres of the muscle spindles and improves the performance of subsequent physical activity/exercise. Accordingly, stretching may diminish the amount of error observed when measuring the JPS.[20 21]

It has been clearly established that among the muscular receptors, the spindles discharge rate is greater during lengthening,[26–28] so we suggested that the role of spindles in improving the knee JPS after stretching is more important than other proprioceptive receptors.

Our results showed that the acuity of knee JPS in 20° of flexion was significantly greater than the values in 45° of flexion ($p<0.05$). This may be explained by an increase in afferent input from the ACL in early ranges of knee flexion, which was reported by MacDonald *et al*.[29]

We found no difference in AAE values in 20° of flexion, after the intervention. As mentioned earlier, MacDonald *et al*[29] reported that in early ranges of knee flexion, afferent input from the ACL is most likely to be detected, but in the intermediate ranges, muscle receptors are primarily responsible for knee JPS[30] and stretching may affect these receptors. Therefore it seems that because of afferent input of the ACL in early ranges of knee flexion, the muscle stretching regimen minimally influences the knee JPS, but in 45° of flexion the stretching may improve the awareness of joint position. No differences in AAE results were found in 45° of flexion after the stretching of gastrocnemius and popliteus muscles. This might be a problem of low study power owing to the relatively small sizes of the groups, so these two muscles might show similar improvement in a larger study.

Further studies are necessary to detect the exact mechanism of the difference in the results of stretching of these two kinds of muscles. The results would probably have been more accurate if the values of ankle JPS had been detected. Further studies will not have this limitation. Our study showed that stretching may improve knee JPS and this effect of stretching empirically defends its widespread use in conjunction with sports activities.

What is already known about this topic

- Muscle stretching is widely used in sport training and in rehabilitation of patients with musculoskeletal disorders.
- It is assumed that stretching may increase range of movement, improve performance, diminish muscle fatigue and delayed onset muscle soreness after unaccustomed exercise.
- Considering the important contribution of joint position sense (JPS) for knee joint stability and function, it is legitimate to question if stretching might alter the knee JPS.

What this study adds

A regimen consisting of three 30 s stretches alters the knee joint position sense.

CONCLUSION

The accuracy of the knee JPS in 45° of flexion is increased subsequent to a static stretch regimen of quadriceps, hamstring and adductors in healthy subjects.

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