ORIGINAL ARTICLE

Effect of static stretching of quadriceps and hamstring muscles on knee joint position sense

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Objectives: To evaluate if a stretch regimen consisting of three 30 second stretches would alter joint position sense (JPS).
Methods: A blinded, randomised, cross over design with a washout time of 24 hours was used with 20 healthy volunteers. JPS was estimated from the ability to reproduce the same position in one knee (target versus estimated angle) expressed as the difference between target and estimated angle (constant error, CE). Measurements were repeated three times in a sitting and a prone position on the dominant leg measured before and immediately after the static stretch. The static stretch consisted of a 30 second stretch followed by a 30 second pause, repeated three times.
Results: At baseline, the mean (SD) CE was −2.71 (3.57)° in the sitting position. No difference ($p = 0.99$) in CE between stretching and control was observed (0.00; 95% confidence interval −0.98 to 0.99). At baseline, the CE was −3.28 (4.81)° in the prone position. No difference ($p = 0.89$) in CE between stretching and control was observed (0.12; 95% confidence interval −1.52 to 1.76).
Conclusion: A static stretch regimen had no effect on JPS in healthy volunteers.

Stretching is commonly used in relation to physical activity and rehabilitation of patients with musculoskeletal disorders.[1 2] Different reasons for using stretching have been proposed, such as improved performance,[3] diminished delayed onset muscle soreness after unaccustomed exercise,[4] and increased range of motion.[1] More recent studies indicate that stretching does not, as previously thought,[5 6] alter muscle stiffness,[7 8] but it may alter stretch tolerance.[7 8] The subjective sensation of stretching is significantly lower after two weeks of a stretching protocol, indicating that stretch tolerance is altered.[9] This may be due to alterations in the muscle spindle or tendon organ firing rate. This assumption is supported by the observation that the muscle spindles are affected by the foregoing history of muscle contraction and/or stretching (thixotropic property of the muscle spindles).[10]

Joint position sense (JPS) is predominantly determined by muscle receptors, and the sensations from joint receptors play a secondary role.[11–14] Whether stretching affects the mechanoreceptors, such as the muscle spindles, can be tested by measuring the JPS immediately before and after a static stretch programme. Stretching is often applied over the knee and/or hip joint, as both hamstrings and rectus femoris are two-joint muscles and thus susceptible to tightness.[15]

Several studies indicate that 15–30 seconds of stretching is needed to achieve an increased range of motion, and the static stretch must last 30 seconds.[16–19]

A reliable method for the estimation of JPS is measurement of the reproduction of a specific target position, the difference between the target and the estimate position being used.[20] With this method, JPS is expressed as the absolute error (AE) between target and estimate position. A sitting position is preferred to a prone position,[21] the ipsilateral measurement is preferred to the counter lateral measurement,[22] and the test angle should be in the middle (40–80° of flexion is suggested) of the knee joint's range of motion. To minimise the AE, an active/active protocol should be applied—that is, both the target and estimate positions are found with active involvement of the subject.[23] Although AE gives a general expression of the amount of error between the target position and the estimate position, it is also important to know if the subject overestimates or underestimates the target position. In this study, the constant error (CE) was measured in both a sitting and a prone position, the actual differences being used.

The purpose of this study was to evaluate if a regimen consisting of three 30 second stretches would alter the JPS.

METHODS

Subjects for the study were students recruited from the department. Twenty (14 women, six men) volunteered. The median age was 25 years (range 21–31), median height 175.25 cm (range 160.5–192.5), and median weight 72.95 kg (range 55.5–90.5). They were considered to be in at least normal physical condition according to their age and were healthy, without known neurological, rheumatic, or orthopaedic diseases. Six were participating in elite sports (organised), and the rest were physically active on a regular basis (self administered). All subjects gave written informed consent to participate in the study, which was approved by the scientific ethical committee of the County of Copenhagen (KA 97177g).

Study design

The study was an experimental, observer blinded, cross over design comprising two treatments and two control periods. The subjects were randomly allocated to either group A or group B. The treatment periods were separated by a washout period of one day. In the first period, group A received active treatment, and group B acted as control, and vice versa in the second period. Only the dominant leg was tested.

Procedures

The JPS was measured using two electrogoniometers (Ergotest Technology, Langesund, Norway; range 15–320°) connected to an analogue/digital converter (MuscleLab; Ergotest Technology), with a sampling frequency of 100 Hz.[24] The equipment was calibrated before every session using a carpenter's level.

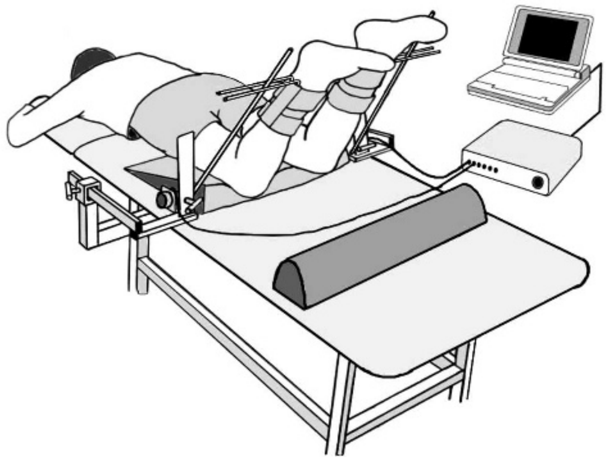

Figure 1 Measurement of joint position sense in the prone position. The subject was asked to actively flex or extend the knee until the target position was achieved. The subject was instructed to hold the position for 5 seconds, and then to return the leg to the resting position (15° of flexion of the knee). The subject was then asked to voluntarily place the lower leg in the same position and notify the project leader when he/she believed the position (estimated angle) was obtained.

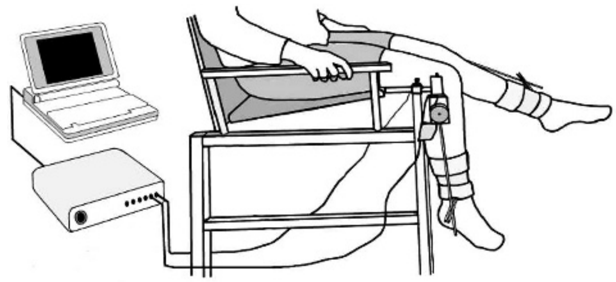

Figure 2 Measurement of joint position sense in the sitting position. The subject was asked to actively flex or extend the knee until the target position was achieved. The subject was instructed to hold the position for five seconds, and then return the leg to the resting position (80° of flexion of the knee). The subject was then asked to voluntarily place the lower leg in the same position and notify the project leader when he/she believed the position (estimated angle) was obtained.

Participants were barefoot and dressed in shorts and shirt during all tests. They were blindfolded and placed sitting in a special adjusted chair or prone on a massage bench. In the sitting position, they were seated with back support and the hip at an angle of 80° of flexion. To avoid cutaneous sensation, a small rubber mat (1 cm thick) with cotton cover was placed under the subject's thighs, and the knee joint and the distal part of the hamstrings were free from the chair. The lower legs were relaxed, which gave a resting position of 80° of flexion in the knees.

In the prone position, a wedge shaped foam rubber pillow was placed under the subject's thighs, to give the patella free movement during knee flexion/extension. The lower legs were placed on a cylinder shaped cushion, which gave a resting position of 15° of flexion in the knees.

After correct positioning, the subject was fixed with straps around the waist and back and secured to the chair or bench (figs 1 and 2).

An electrogoniometer was placed at the lateral aspect of each knee joint (without touching the knee) resulting in a match between the electrogoniometer axis and the flexion/extension axis of the knee joint. This was controlled before each session. To avoid skin contact at knee level, the electrogoniometer was extended by a light aluminium leveller arm to a 10 cm "fork" placed on a soft Velcro cuff on each ankle. The fork allowed some sideways movements due to hip rotation (prone position) without affecting the knee joint angle. The forks of the ankle cuffs were placed to match the lateral malleolus on each leg. To match the axis of the electrogoniometer with the flexion/extension axis of the knee, a sticker was placed on the leveller arm at fork level with the lower leg in the resting position. The position of the subject and/or the electrogoniometer was adjusted until the sticker and fork were aligned during flexion of the knee, by which the axes were defined as matching. After positioning of the subject and electrogoniometers, the entire set up was calibrated in the resting position, setting the knee joint angle to 80° in the sitting position and 15° in the prone position. The position of the electrogoniometer was visualised on a monitor as a numerical angle and a figure. Angle measurements were sampled for five seconds at 100 Hz, and all data were converted from analogue into digital signals and recorded by MuscleLab. After each session, the data were transferred to and saved in a database. The two electrogoniometers in each setting were calibrated daily before every session using a carpenter's level.

Only dominant legs were tested. Each subject underwent two identical test sessions in either the sitting or prone position scheduled with two sessions on day one and two sessions on day two, with either stretch or control in between, according to the randomisation (as described previously). To avoid distractions, all testing was conducted in a quiet room, by the same investigator, using the same commands.

The investigator verbally guided the participant to the desired position of the experimental leg in 50° of flexion for the sitting position or 70° of flexion for the prone position and to hold the position. The position was recorded for five seconds and called the target angle. The subject was then asked to return the leg to the resting position. After a few seconds, he/she was asked voluntarily to place the same leg in the same position and notify the project coworker when he/she believed the position was obtained. The position was then recorded for five seconds and called the estimated angle.

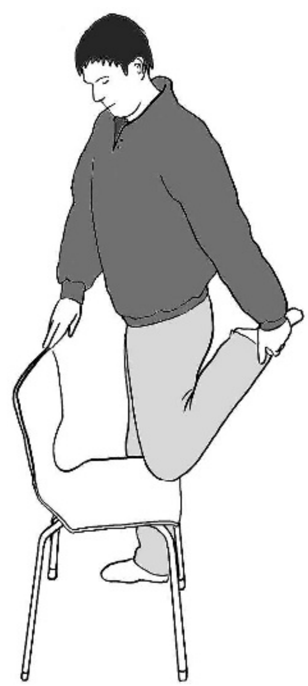

Figure 3 Stretching of the quadriceps muscle. After oral and written instruction, stretching was carried out three times as self applied, active static stretching of 30 seconds with 30 seconds rest.

Figure 4 Stretching of hamstrings. After oral and written instruction, stretching was carried out three times as self applied, active static stretching of 30 seconds with 30 seconds rest.

A recording was performed again if the leveller arm fell out of work or if the leg and leveller arm touched one another.

Determination of leg dominance

Because of a possible difference in JPS in the dominant and non-dominant limbs, only the dominant leg was chosen. Kicking a ball was chosen as the test of leg dominance.[25]

Stretching regimen

After oral and written instruction, stretching was carried out three times as a self applied active static stretching of 30 seconds with 30 seconds rest. Hamstrings and quadriceps were stretched, and the subject was then asked to illustrate the stretch sensation on a specially designed diagram.

Full instructions were given on how the stretch should be performed. The written material and the randomising letter were in an envelope, which the subject opened after receiving the instructions. After the stretching or non-stretching had been performed, the written material was replaced in the envelope and returned to the tester, so the tester was blinded. This procedure was carried out on both day 1 and day 2.

After receiving the instructions, the subject started with active static stretching of the quadriceps in a standing position with the knee resting on a chair covered with soft material and with a back to provide stability for the stretch. One hand grabbed around the ankle of the experimental leg and the other hand grabbed the chair back. The subject was instructed to press the lower leg in the direction of the gluteal region and at the same time press the pelvis forward to obtain hip extension (fig 3).

After the quadriceps, the hamstrings were stretched in the standing position with the heel resting on a chair. The subject was instructed to lean the trunk forward with spine upright and pelvis pressed backwards to obtain a stretch over both the knee and the hip. The spine was kept upright and the pelvis pressed backwards all the time to avoid compensation (fig 4).

The written material contained an illustration of the position, the instructions, a timetable, and the figure of a person from the front and from behind on which the subject was told to indicate where the stretch was felt. In addition, a watch with a second hand was placed in front of the subject so that the stretch could be performed with an interval of 30 seconds.

Statistical analysis

With a 5% level of significance, a power of 80%, a minimal relevant difference of 0.5°, and an estimated standard deviation of results of 1.06° (calculated from earlier measurements), the sample size in each group was calculated to be at least 18.[26]

To test the hypothesis that there was no difference in CE after the two treatments, we used a two factor analysis of covariance, with a factor for subject (n = 20) and a factor for treatment ("stretch" or "control"). CE at baseline was used as a covariate with the aim of reducing the random variation.[27] All statistical analysis was carried out using the SAS general linear model procedure (version 8.2; SAS Institute Inc, Cary, North Carolina, USA).

RESULTS

Stretching

All subjects correctly stretched both hamstring and quadriceps muscles. The stretch for each muscle group lasted about three minutes. At baseline, the mean (SD) CE was −2.71 (3.57)° (n = 120), ranging from −11.66 to 7.83° in the sitting position. As indicated in fig 5A, there was no difference ($p = 0.99$) in CE after the two interventions (0.00; 95% confidence interval −0.98 to 0.99). At baseline, the mean CE was −3.28 (4.81)° (n = 120), ranging from −10.21 to 15.65° in the prone position. As indicated in fig 5B, there was no difference ($p = 0.89$) in CE after the two interventions (0.12; 95% confidence interval −1.52 to 1.76).

DISCUSSION

This study found no significant effect of static stretching on knee JPS measured in either a sitting or a prone position. This is in contrast with previous indications that stretching may influence the mechanoreceptors in the muscles around the knee or the knee joint.[9] It has been suggested that, as the muscle spindle has a thixotropic property, stretching may alter the proprioceptive input. However, thixotropic behaviour of contraction or stretching will only be present for a very short period especially when the muscle is lengthened.[10] With our schedule for measurements, with a delay of 6–7 minutes after stretching, this effect cannot be expected to influence the results.

Anecdotal experience indicates relief by stretching after relatively tough physical activity. It has been suggested that stretching augments the sensibility of the mechanoreceptors of the muscle spindles and improves the subsequent physical activity/exercise session. Accordingly, stretching may

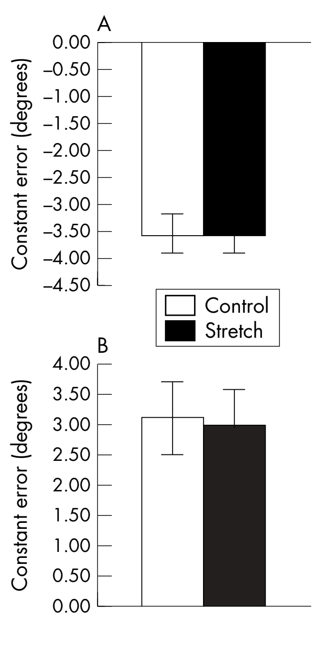

Figure 5 Illustration of the results for the sitting position (A) and prone position (B), where one group performed stretching in between measurements of joint position sense and the other group rested as the control. No significant difference was found. Values shown in the figure are mean (SE) after the interventions. All analyses were performed using a two factor analysis of covariance, using the baseline value as a covariate. (A) Sitting position. At baseline, the mean (SD) CE was −2.71 (3.57)° (n = 120), ranging from −11.66 to 7.83°. There was no difference ($p = 0.99$) in CE after the two interventions (0.00; 95% confidence interval −0.98 to 0.99). (B) Prone position. At baseline, the CE was −3.28 (4.81)° (n = 120), ranging from −10.21 to 15.65°. There was no difference ($p = 0.89$) in CE after the two interventions (0.12; 95% confidence interval −1.52 to 1.76).

diminish the amount of error observed when measuring the JPS. We found no evidence in support of this hypothesis.

Normal subjects were used in our study, and the negative results may have been due to the function of the mechanoreceptors being as good as it could be before stretching. Indeed, the subjects in our study showed a small difference between estimate and target position in the control condition,[28] which makes it difficult to demonstrate any improvement after stretching.

Another explanation for the lack of effect of stretching on JPS may be the stretching procedure itself. The duration of the stretch used in this study (30 seconds) seems to be adequate to gain an increase in range of motion[16 17] and is in line with a practical programme for both athletes and ordinary subjects.

We conclude that static stretching has no significant effect on JPS of the knee in healthy subjects.

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