Research Report

The Effect of Time and Frequency of Static Stretching on Flexibility of the Hamstring Muscles

Background and Purpose. Frequency and duration of static stretching have not been extensively examined. Additionally, the effect of multiple stretches per day has not been evaluated. The purpose of this study was to determine the optimal time and frequency of static stretching to increase flexibility of the hamstring muscles, as measured by knee extension range of motion (ROM). Subjects. Ninety-three subjects (61 men, 32 women) ranging in age from 21 to 39 years and who had limited hamstring muscle flexibility were randomly assigned to one of five groups. The four stretching groups stretched 5 days per week for 6 weeks. The fifth group, which served as a control, did not stretch. Methods. Data were analyzed with a 5 × 2 (group × test) two-way analysis of variance for repeated measures on one variable (test). Results. The change in flexibility appeared to be dependent on the duration and frequency of stretching. Further statistical analysis of the data indicated that the groups that stretched had more ROM than did the control group, but no differences were found among the stretching groups. Conclusion and Discussion. The results of this study suggest that a 30-second duration is an effective amount of time to sustain a hamstring muscle stretch in order to increase ROM. No increase in flexibility occurred when the duration of stretching was increased from 30 to 60 seconds or when the frequency of stretching was increased from one to three times per day. [Bandy WD, Irion JM, Briggler M. The effect of time and frequency of static stretching on flexibility of the hamstring muscles. *Phys Ther.* 1997;77:1090–1096.]

Key Words: *Flexibility, Lower extremity, Muscle, Muscle performance.*

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Zachezeweski[1] has defined *muscle flexibility* as "the ability of a muscle to lengthen, allowing one joint (or more than one joint in a series) to move through a range of motion [ROM]" and a loss of muscle flexibility as "a decrease in the ability of the muscle to deform," resulting in decreased ROM about a joint. Much has been written on the importance of flexibility in normal muscle function and the prevention of injury.[1–11] Advocates believe that stretching can prevent injury,[1–10] enhance athletic performance,[2,3,11] and assist in rehabilitation following musculoskeletal injury.[2,3,6,11]

Among the methods of stretching are ballistic stretching, static stretching, and variations of proprioceptive neuromuscular facilitation (PNF) techniques.[1–3,7,12,13] Ballistic (bouncing) stretching is a rapid, jerky movement in which a body part is put into motion and momentum carries the body part through the ROM until the muscles are stretched to their physiological limits.[3,7,12] Static stretching is performed by placing muscles at their greatest possible length and holding that position for a period of time.[2,3] Voss et al have defined *proprioceptive neuromuscular facilitation* as a method "of promoting or hastening the response of a neuromuscular mechanism through stimulation of the proprioceptors."[13(pxvii)] Frequently, PNF techniques involve isometric contractions of a lengthened muscle, followed by further lengthening, either actively or passively.

Although documentation exists that static, ballistic, and PNF techniques will increase the flexibility of muscle,[12,14–16] we believe that the most common method is the static stretch.[1–3,12,16] Therefore, it is surprising that there is little literature concerning how to optimize the stretch with this technique.

Several authors[3,9–11] have made suggestions as to the appropriate time a stretch should be maintained in order to be effective, but give no objective data to support their opinions. Beaulieu,[3] for example, developed a stretching program that included slow, gentle stretches until tightness, not pain, was felt in the muscle. Once the subject felt tightness, the stretch was sustained for 30 to 60 seconds. In the opinion of Beaulieu,[3] positions held less than 30 seconds would not result in relaxation of the muscle being stretched and thus the maximum benefits would not be attained.

Attempting to evaluate the appropriate method for increasing muscle flexibility, other authors have apparently chosen random times for sustaining the static stretch and have not provided evidence for the most effective duration. Hardy and Jones,[17] for example,

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compared three different stretching techniques (dynamic, static, and PNF) and selected 6 seconds as the time of stretching for each technique. Etnyre and Lee[18] compared ROM changes in the hip and knee, using three different stretching techniques. One technique, the static stretch, when held for 9 seconds, resulted in increased ROM. Gajdosik[19] suggested using a slow, static stretch of the hamstring muscles for 15 seconds and reported that holding the stretch for 15 seconds caused increases in ROM of the hamstring muscles, as measured by straight leg raising. Raab et al[20] reported that active and passive stretches held for at least 20 seconds, in combination with an exercise program, increased ROM in a group of elderly women.

Two studies have investigated changes in flexibility of muscle in humans as a result of different durations of static stretching.[16,21] Madding et al[21] compared the effects of 15, 45, and 120 seconds of stretching on passive ROM in hip abduction. They reported that sustaining a stretch for 15 seconds was as effective as sustaining a stretch for 120 seconds, following one repetition of stretching. Only one repetition of stretching and not the effect of varying these durations of stretching over time, however, was investigated.

Bandy and Irion[16] examined the effects of hamstring muscle stretching in three groups (stretching for 15, 30, and 60 seconds) as compared with a control group that did not stretch. Subjects in the stretching groups stretched 5 days per week for 6 weeks. The results indicated that 30 and 60 seconds of static stretching were more effective at increasing hamstring muscle flexibility than stretching for 15 seconds or not stretching. No difference was found between 30 and 60 seconds of stretching, indicating that 30 seconds of stretching the hamstring muscles was as effective as the 1-minute duration.

Under certain conditions, static stretching appears to increase the flexibility of muscles. A great deal of variability, however, exists in the literature concerning the length of time a static stretch should be sustained. To date, there has been only one longitudinal study examining the duration of static stretching.[16] Additionally, the one study comparing different durations of static stretching used only one stretch per day, and the effect of multiple stretches per day has not been evaluated.

The purpose of our study was to determine the time and frequency of static stretching that most effectively increase flexibility of the hamstring muscles, as measured by knee extension ROM. We compared the effects of five daily frequencies and durations of static stretching on hamstring muscle flexibility: (1) three 1-minute stretches, (2) three 30-second stretches, (3) one 1-minute stretch, (4) one 30-second stretch, and (5) a control (no stretching activity).

Method

Subjects

One hundred subjects between the ages of 20 and 40 years with no history of pathology of the hip, knee, thigh, or low back were recruited. Subjects were volunteers and signed an institutionally approved informed consent statement.

To participate in the study, subjects must have exhibited tight hamstring muscles, operationally defined as having greater than 30 degrees' loss of knee extension as measured with the femur held at 90 degrees of hip flexion.[16] In addition, subjects who were not involved in any exercise activity at the start of the study had to agree to avoid lower-extremity exercises and activities other than those prescribed by the research protocol. Subjects who were involved in exercise activity at the start of the study agreed not to increase the intensity or frequency of the activity during the 6 weeks of training. Ninety-three subjects (61 men, 32 women), with a mean age of 26.24 years (SD=5.13), met the established criteria and completed the study.

Equipment

A goniometer with a double-armed, full-circle protractor made of transparent plastic was used for all measurements. The protractor was marked off in 1-degree increments. To ensure appropriate reliability, extensions were added by taping a 30.48-cm (12-in) ruler to each plastic goniometer arm, increasing the length of the arms to 43.18 cm (17 in). The rationale for adding the extensions was that, in doing so, the distance between the goniometer arm and the marked bony landmarks was decreased, thereby allowing greater ease and speed of measurement in comparison with the technique used in an earlier study.[16] Comparison of the reliability of the measurements obtained for the control group in this study (r=.97) with the reliability of data collected in the same laboratory by the same investigators in a previous study (r=.91)[16] suggests that the extensions added to the goniometer arms allowed the maintenance of accurate measurement of hamstring muscle flexibility while decreasing measurement time (in the opinion of the researchers).

Procedure

Hamstring muscle flexibility of the right (arbitrarily chosen) lower extremity of each subject was measured prior to assignment to groups. Landmarks used to measure hip and knee flexion were the greater trochanter, the lateral condyle of the femur, and the lateral malleolus. With each subject positioned supine with the right hip and knee flexed to 90 degrees, the landmarks were marked with a felt-tipped pen for goniometric measurement.

With each subject positioned supine, one researcher (JMI) positioned the right hip in 90 degrees of hip flexion. A second researcher (MB) passively moved the tibia to the terminal position of knee extension, defined as the point at which the subject complained of a feeling of discomfort or tightness in the hamstring muscle or the experimenter perceived resistance to stretching. Once the terminal position of knee extension was reached, the first examiner measured the amount of knee extension with the goniometer using methods described by Norkin and White.[22] Zero degrees was considered to be full knee extension. No warm-up period was allowed prior to data collection.

Prior to data collection, intratester reliability of the measurements of the hamstring muscles using the procedures described was evaluated in these researchers (JMI, MB) using a test-retest design. Ten subjects (7 male, 3 female), with a mean age of 25.76 years (SD=4.34), who were not participating in the time and frequency of stretching study agreed to participate in this assessment of reliability. One week separated the first and second measurements, and the testers did not have information about the first measurement when performing the second measurement. Mean values were 47.35 degrees (SD=8.17) for the pretest measurements and 47.19 degrees (SD=7.58) for the posttest measurements. The intraclass correlation coefficient (ICC[1,1]) as .98 for the measurements taken 1 week apart, which we deemed to be appropriate for proceeding with this study.

Following the initial measurement, subjects were randomly assigned to one of five groups. Subjects assigned to group 1 (12 men, 6 women; mean age=24.44 years, SD=3.35, range=21–31) did three 1-minute static stretches (10 seconds between stretches) of the hamstring muscles. Group 2 (12 men, 7 women; mean age=27.32 years, SD=5.60, range=21–31) did three 30-second static stretches, with a 10-second rest between stretches. Group 3 (12 men, 6 women; mean age=27.33 years, SD=7.60, range=21–39) did one static stretch for 1 minute. Group 4 (12 men, 6 women; mean age=24.78 years, SD=2.37, range=22–29) did one static stretch for 30 seconds. The fifth group (13 men, 7 women; mean age=27.20 years, SD=4.79, range=22–36) served as a control group and did no stretching activities.

Subjects in groups 1 through 4 stretched 5 days a week for 6 weeks. To stretch the hamstring muscles, each subject stood erect with the left foot on the floor and pointing straight ahead with no rotation of the hip. The subjects stretched the right hamstring muscle by placing the calcaneal aspect of the right foot on an elevated surface with the knee fully extended, toes pointing to the ceiling, no rotation of the hip, and arms flexed to shoulder level. The elevated surface was high enough to cause a gentle stretching sensation in the posterior thigh. Each subject was instructed to flex forward from the hip, maintaining the spine in a neutral position, while reaching the arms forward until a gentle stretch was felt in the posterior thigh. Once the subject achieved this position, the stretch was sustained the assigned amount of time. This stretching technique was used because we believe that it approximates the type of static stretching procedure commonly used in clinical practice.[2,16] During the 10 seconds of rest between stretches, the subject removed the right limb from the elevated surface.

Each stretching session was supervised, and an attendance sheet was used to document adherence. If a subject was not able to stretch on a particular day, the subject did one set of stretches the following morning and one set of stretches the following afternoon. Any subject missing more than 4 days of stretching was dropped from the study (two subjects were dropped from group 1, one subject was dropped from group 2, one subject was dropped from group 3, and two subjects were dropped from group 4).

All subjects were retested after the 6 weeks using the same procedures described for the pretest. Two days of rest separated the last day of stretching and the posttest.

Data Analysis

Reliability of the measurements was assessed by using ICC (3,1) on the pretest and posttest scores of the control group. Means and standard deviations were calculated for the pretest and posttest measurements for each group, as well as the mean differences between pretest and posttest scores (gain scores), for the dependent variable knee extension ROM (in degrees).

A 5 × 2 (group × test) two-way analysis of variance (ANOVA) for repeated measures on one variable (pretest and posttest values) was initially performed to determine whether there were differences between values of the five groups. Because a significant interaction was found, three follow-up analyses were done to determine which group differed from the others.

First, one dependent t test was calculated on the pretest to posttest change for each group (a total of five t tests were performed). To prevent an inflation of the Type I error rate, the alpha level (.05) was adjusted with the Bonferroni method by dividing .05 by the number of t tests performed (five). Therefore, in all analyses using

Table.
Pretest, Posttest, and Gain Scores (in Degrees) of Knee Flexion for Each Group

	Group[a]									
	1 (n=18)		2 (n=19)		3 (n=18)		4 (n=18)		Control (n=20)	
	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Pretest	43.33	8.31	42.31	10.13	43.78	6.91	42.78	10.28	41.20	8.09
Posttest	32.83	7.40	32.26	9.68	33.33	8.32	31.28	9.05	40.60	8.71
Gain (difference between pretest and posttest)	10.50		10.05		10.45		11.50		00.60	

[a] Group 1 stretched for 1 minute, three times; group 2 stretched for 30 seconds, three times; group 3 stretched for 1 minute, one time; group 4 stretched for 30 seconds, one time; the control group did not stretch.

the *t* test, the rejection region was $P<.01$. These *t* tests were used to assess which group(s) increased hamstring muscle flexibility (ROM) after stretching.

Second, a repeated-measures one-way ANOVA was calculated to assess whether any differences existed in the pretest scores across the five groups. This analysis was performed to assess whether differences existed among the five groups prior to the initiation of the study.

Finally, to assess whether any difference existed in the posttest scores, a repeated-measures one-way ANOVA was calculated across the posttest scores of the five groups. This analysis was performed to assess whether differences existed among the five groups after each group stretched the assigned duration and frequency (including control group). For all statistical tests and all follow-up tests, the .05 level of probability was used.

Results

In the control group, the mean values for knee extension were 41.20 degrees (SD=8.09) for the pretest measurement and 40.60 degrees (SD=8.71) for the posttest measurement. The ICC (3,1) value calculated for the control group's pretest and posttest knee extension data was .97. The means for pretest and posttest measurements and gain scores for each group are presented in the Table. The two-way ANOVA demonstrated a statistically significant difference between pretest and posttest stretching scores ($F=192.36$; $df=1,88$; $P<.05$) and for the group × test interaction ($F=11.13$; $df=4,88$; $P<.05$), but no statistically significant difference was found among groups ($F=1.61$; $df=4,88$; $P>.05$) (Figure).

Three follow-up statistical analyses were used to interpret the significant group × test interaction. First, the five *t* tests calculated (using Bonferroni correction to avoid inflation of the alpha level) on the pretest to posttest change for each group indicated statistically significant increases in hamstring muscle flexibility in the stretching groups (group 1: $df=17$, $t=6.79$, $P<.01$; group 2: $df=18$, $t=6.70$, $P<.01$; group 3: $df=17$, $t=6.43$, $P<.01$; group 4: $df=17$, $t=7.23$, $P<.01$), but no statistically significant change in hamstring muscle flexibility in the control group ($df=19$, $t=1.39$, $P>.01$).

Second, the repeated-measures one-way ANOVA calculated to assess whether any differences existed in the pretest scores across the five groups indicated no statistically significant difference ($F=1.51$; $df=4,88$; $P>.05$). Finally, the repeated-measures one-way ANOVA calculated to assess whether differences existed in the posttest scores across the five groups indicated a statistically significant difference ($F=3.99$; $df=4,88$; $P<.05$). Tukey *post hoc* analyses indicated statistically significant differences between the stretching groups and the control group, but no statistically significant differences were found among the stretching groups (ie, all the stretching groups appeared to increase hamstring muscle flexibility to the same extent).

Discussion

As indicated by the *post hoc* analyses, increasing the duration and frequency beyond one 30-second stretch performed one time per day did not increase flexibility. The results of this study are similar to the results of our previous longitudinal study investigating the effects of duration of stretch,[16] in which 30 seconds of static stretching was reported to be as effective as 60 seconds of static stretching in increasing flexibility of the hamstring muscles and more effective than not stretching. The use of longer duration and more frequent daily stretching, therefore, must be questioned. The results of our study, in conjunction with our previous research, indicate that 30 seconds is an effective length of time to sustain a hamstring muscle stretch in order to increase ROM. In neither of our studies, however, did we examine how long the increased flexibility was maintained.

Limitations of the Study

Our study was limited to the effects of stretching the hamstring muscles on knee flexion ROM. Although one 30-second bout of stretching the hamstring muscles was

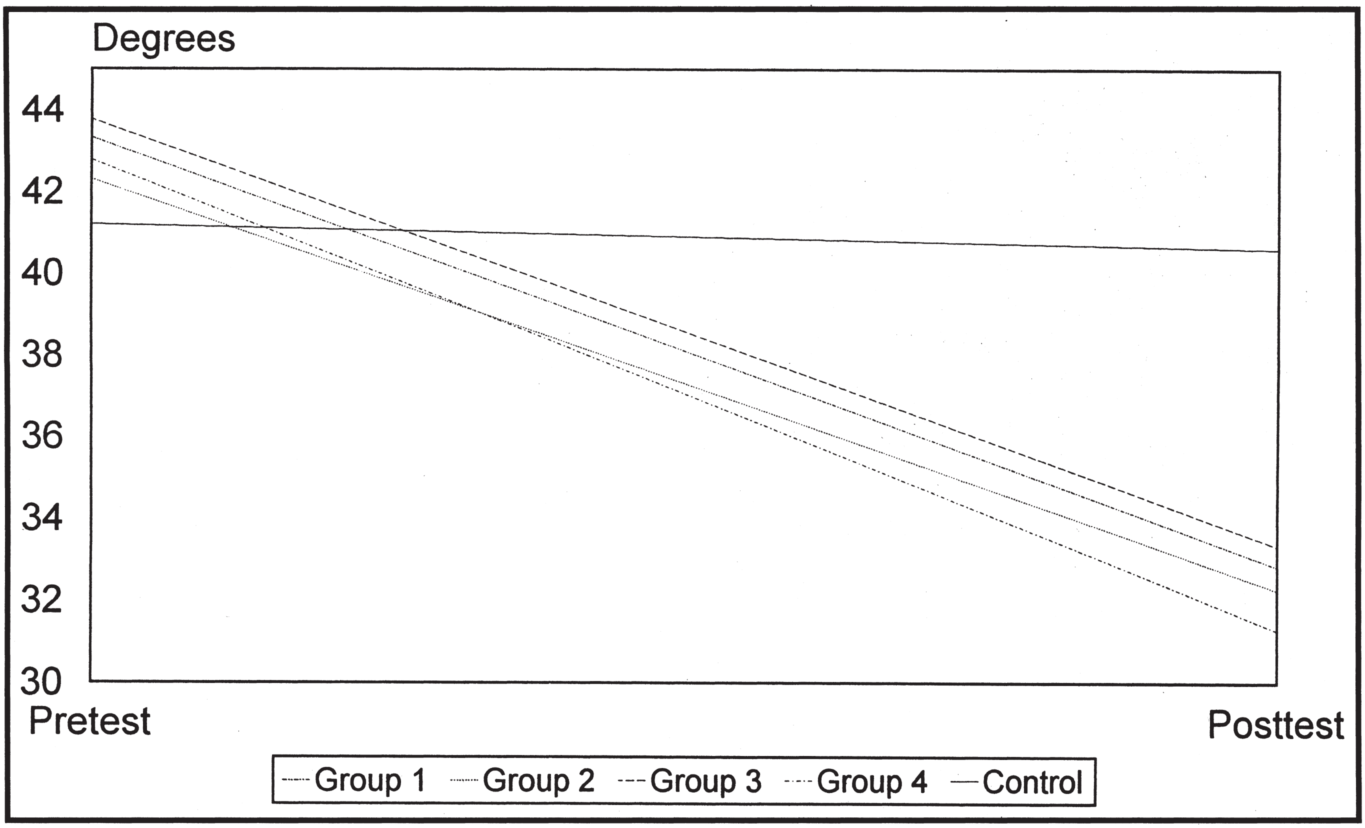

Figure.
Mean scores for pretest and posttest measurements of knee flexion for each group. Group 1 stretched for 1 minute, three times; group 2 stretched for 30 seconds, three times; group 3 stretched for 1 minute, one time; group 4 stretched for 30 seconds, one time; the control group did not stretch.

found to be as effective as more frequent stretching at longer durations, similar studies are needed to evaluate the effects of various durations of stretching on other muscles such as the gastrocnemius, soleus, and quadriceps femoris muscles.

We only examined stretching of up to 60 seconds in duration. Additional research is needed to evaluate whether durations of 90 to 120 seconds or longer will provide more flexibility.

Finally, the sample under study was relatively young, with a mean age of 26 years and a small standard deviation. Conclusions from this study should only be applied to similar age groups, and future research is needed on subjects in other age groups, particularly older individuals.

Conclusion

We demonstrated that although stretching for 30 and 60 seconds one or three times per day for 5 days per week for 6 weeks was more effective for increasing muscle flexibility (as determined by increased knee extension ROM) than no stretching, there was no difference between stretching one or three times per day using either a 30- or 60-second duration of stretching. Therefore, a 30-second duration is an effective amount of time to sustain a hamstring muscle stretch in order to increase ROM. The results from this study will be helpful for individuals who desire to increase their flexibility in an attempt to decrease injury and enhance performance, as well as for those clinicians who incorporate static stretching activities as part of their rehabilitation programs.

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