The Effect of Duration of Stretching of the Hamstring Muscle Group for Increasing Range of Motion in People Aged 65 Years or Older

**Background and Purpose.** Stretching protocols for elderly people (≥65 years of age) have not been studied to determine the effectiveness of increasing range of motion (ROM). The purpose of this study was to determine which of 3 durations of stretches would produce and maintain the greatest gains in knee extension ROM with the femur held at 90 degrees of hip flexion in a group of elderly individuals.

**Subjects.** Sixty-two subjects (mean age = 84.7 years, SD = 5.6, range = 65–97) with tight hamstring muscles (defined as the inability to extend the knee to less than 20° of knee flexion) participated. Subjects were recruited from a retirement housing complex and were independent in activities of daily living.

**Methods.** Subjects were randomly assigned to 1 of 4 groups and completed a physical activity questionnaire. The subjects in group 1 (n = 13, mean age = 85.1 years, SD = 6.4, range = 70–97), a control group, performed no stretching. The randomly selected right or left limb of subjects in group 2 (n = 17, mean age = 85.5 years, SD = 4.5, range = 80–93), group 3 (n = 15, mean age = 85.2 years, SD = 6.5, range = 65–92), and group 4 (n = 17, mean age = 83.2 years, SD = 4.6, range = 68–90) was stretched 5 times per week for 6 weeks for 15, 30, and 60 seconds, respectively. Range of motion was measured once a week for 10 weeks to determine the treatment and residual effects. Data were analyzed using a growth curve model.

**Results.** A 60-second stretch produced a greater rate of gains in ROM (60-second stretch = 2.4° per week, 30-second stretch = 1.3° per week, 15-second stretch = 0.6° per week), which persisted longer than the gains in any other group (group 4 still had 5.4° more ROM 4 weeks after treatment than at pretest as compared with 0.7° and 0.8° for groups 2 and 3, respectively). Discussion and Conclusion. Longer hold times during stretching of the hamstring muscles resulted in a greater rate of gains in ROM and a more sustained increase in ROM in elderly subjects. These results may differ from those of studies performed with younger populations because of age-related physiologic changes. [Feland JB, Myrer JW, Schulthies SS, et al. The effect of duration of stretching of the hamstring muscle group for increasing range of motion in people aged 65 years or older. *Phys Ther.* 2001;81:1100–1117.]

**Key Words:** Age, Elderly, Flexibility, Hamstring muscles, Lower extremity.

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Numerous researchers have compared various stretching techniques to determine which technique is most effective for increasing joint range of motion (ROM). Stretching is important because it is believed to provide many physical benefits, including improved flexibility, improved muscle or athletic performance, improved running economy (decreased energy expenditure at a given speed), injury prevention, promotion of healing, and possibly decreased delayed-onset muscle soreness. Although evidence to support these beliefs is limited, stretching appears to us to be in widespread use.

Researchers have looked at the effect of different variables associated with stretching, including force or intensity, position, frequency and duration, and repetition. In the majority of these studies, younger people, usually between the ages of 18 and 39 years, were the subjects. The results of these studies, therefore, may not be applicable to all age groups, particularly elderly people because of age-related physiological changes.

Physiologic changes that are said to occur with age include muscle atrophy; reduced capacity for healing, diminished capillary blood supply, and reduced amounts of mesenchymal stem cells, and loss of strength and elasticity in soft-tissue matrices. Increased muscle and joint stiffness with increased amounts of fibrous connective tissue has also been reported.

It is our opinion, based on the review of the literature, that connective tissue compliance appears to be a major factor in musculoskeletal flexibility. Plastic rather than elastic deformation, theoretically, can result in more permanent lengthening of the tissues. Plastic changes to connective tissue are thought to be brought about by slow, low-intensity, and long-duration stretches that do not injure the muscle. Some authors have suggested stretch durations of 15 to 30 seconds using either proprioceptive neuromuscular facilitation (PNF) techniques or other stretching methods, whereas Smith, based on a review of the literature, suggested that the stretch should be held for 15 to 20 seconds.

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This study was approved by the Institutional Review Board at Brigham Young University.

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For our study, a “long-duration” stretch was defined as a stretch of greater than 30 seconds’ duration for one repetition, and a “low-intensity” stretch was defined as a stretch based on each subject’s perception of the onset of discomfort in the back of the thigh. Low-intensity and long-duration stretching approaches may optimize increases in ROM among elderly people due to the amount of connective tissue, increased stiffness, and decreased elasticity that can occur with the aging process.

Although various researchers have investigated the effects of exercise on ROM and joint stiffness in elderly people, the optimal duration of a stretch of the hamstring muscles to improve knee extension ROM has not been determined.

Therefore, the purpose of our study was to compare the effects of 6 weeks of repeated stretching of the hamstring muscle group for 15, 30, or 60 seconds to determine whether a longer stretch duration enhances ROM gains among elderly people.

Method

Subjects

Subjects recruited for this study were independently living in a retirement housing complex and were informed of the purpose of the study and the need for volunteers through a community meeting at the retirement facility. Of the 78 subjects who volunteered for the study, 62 subjects (mean age = 84.7 years, SD = 5.6, range = 65–97) qualified by not having any hip or knee replacements or any history of pathology in the low back, hips, or knees for the 3 months prior to the study. Subjects voluntarily participated and signed an informed consent form approved by Brigham Young University, Provo, Utah.

To further qualify for the study, subjects had to demonstrate “tight” hamstring muscles, defined as inability to extend the knee to less than 20 degrees of knee flexion with the femur held at 90 degrees of hip flexion while the person was positioned supine. Subjects were also screened to rule out knee joint flexion contractures by checking knee extension ROM, as described by Norkin and White, while they were lying in a prone position. A questionnaire was administered to all qualified subjects in order to quantify physical activity levels. This physical activity questionnaire has been shown to generate valid and reliable classification scores for activity in a group of elderly subjects who were similar, but not identical, to ours. Subjects were asked to maintain their level of activity throughout the study. Sixty subjects (14 male, 46 female) completed the treatment portion of the study (2 subjects did not complete the stretching phase of the study because 1 subject voluntarily withdrew and the other subject moved away). Fifty-six subjects (12 male, 44 female) continued through the 4-week recovery period (out of the 4 subjects who dropped out during the recovery period, 3 subjects developed other health problems and 1 subject moved to another residence).

Instrumentation

A double-arm (30.5-cm [12-in]) clear plastic goniometer was used to measure knee extension ROM. Prior to data collection, we performed a pilot study to establish intratester reliability of measurements of knee extension ROM. A test-retest design was used on 14 subjects of similar age (≥65 years), with measurements taken 1 week apart by the research assistant who would perform all measurements throughout the study. Reliability was determined using an intraclass correlation coefficient (ICC [3,1]). An ICC of .96 was considered appropriate for continuing the study.

Experimental Procedure

Measurement protocol. Choice of which lower extremity to use for the stretching protocols was determined by the toss of a coin for each subject; tails represented the left lower extremity, and heads represented the right lower extremity. Each subject was then measured for knee extension ROM on both lower extremities. Measurement of knee extension ROM was made with the subject lying supine with the opposite lower extremity extended and the lower extremity being measured positioned at 90 degrees of hip flexion. The greater trochanter and the lateral epicondyle of the femur and lateral malleolus were palpated and served as landmarks during measurement, as outlined by Norkin and White. We attempted to maintain hip flexion at 90 degrees while the research assistant moved the tibia into the terminal position of knee extension, which was defined as the point at which the subject reported feeling discomfort. The goniometric value was then recorded. The measurement recorded was the angle between the leg position and full knee extension (considered to be 0°) (Fig. 1). Because knee joint contractures were ruled out, the measurement of knee extension ROM was considered to be an indirect measure of hamstring muscle flexibility, with hamstring muscle tightness being the purported cause of a lack of knee extension ROM.

All subjects were measured on the same day and at the same time each week, before they had stretching for that day. Measurements were taken on the stretched lower extremity once a week for 6 weeks during the treatment period and for 4 weeks posttreatment (recovery) to determine the residual effect of the stretching. The research assistant who performed the measurements was unaware of group assignment.
Group assignment. After the initial measurements, the subjects were randomly assigned to 1 of 4 groups. Subjects assigned to group 1 (3 men, 10 women; mean age=85.1 years, SD=6.4, range=70–97) served as the control and received no stretching. Group 2 (3 men, 14 women; mean age=85.5 years, SD=4.5, range=80–93) received a passive static stretch that was sustained for 15 seconds. Group 3 (4 men, 11 women; mean age=85.2 years, SD=6.5, range=65–92) received a passive static stretch that was sustained for 30 seconds. Group 4 (5 men, 12 women; mean age=83.2 years, SD=4.6, range=68–90) received a passive static stretch that was sustained for 60 seconds.

Stretching procedure. Stretching of the hamstring muscles was performed by the primary researcher and 5 other research assistants (seniors in sports medicine and exercise science). A straight-leg-raising technique was used for this stretch because we believe that it is commonly used in the clinical setting for elderly people. All subjects were supine lying as flat as possible. Due to age-related changes in the upper thoracic and cervical spine, we used a pillow to help maintain a comfortable position for subjects who complained of neck pain when trying to lie flat. Subjects who required a pillow (ie, for both stretching and measurement) always used a pillow. Based on the primary researcher’s observations, each subject’s knee was maintained in extension with the ankle at 90 degrees without medial (internal) or lateral (external) rotation of the lower extremity, and the extremity was raised until the subject reported discomfort (Fig. 2). The subject was asked to relax the lower extremity in an effort to prevent contracting muscles from affecting the stretch and to allow for a slow stretch. No warm-up was allowed prior to stretching.

Subjects in groups 2 through 4 received 4 stretches for their designated time period, with a 10-second rest between stretches. During the 10-second rest, each subject was asked to move the lower extremity back and forth from knee to chest to lower-extremity extension in order to prevent what has been called “thixotropic stiffening.”

Subjects in groups 2 through 4 had stretching 5 days per week for 6 weeks. All subjects whose lower extremity was stretched were retested for knee extension ROM every week. A ROM measurement was also made at the end of the 6-week treatment on the uninvolved lower extremity to determine whether a stretching program indirectly affected contralateral flexibility.

All research assistants were trained in administering the stretching protocol by practicing on a similar-aged volunteer who was not participating in the study due to time constraints. Instructions included the use of the same verbal cues to minimize variation in administration. All stretching sessions were documented to record whether the subjects received stretching, and assistants were randomly assigned each day to subjects in order to reduce the risk of interaction between treatment and assistant.

If a subject missed a scheduled session, he or she made up the session on another day during the same week; this occurred a total of 16 times throughout the stretching period of 6 weeks (once for 10 subjects and twice for 3 subjects). Prior to treatment, the researchers decided that if any subject missed more than 4 days without stretching, the subject would be eliminated from the study. No subject missed more than 2 “stretch days” throughout the 6-week treatment program.

Data Analysis
Because we were primarily interested in changes occurring over time, it seemed reasonable to analyze the data using linear growth curves. The slope of a line represents a rate of change, and different slopes in different treatment conditions (treatment and recovery) would
indicate different rates of impact of the various treatments. To implement such an analysis, the SAS (version 6.12) MIXED Procedure was used to analyze the data from treatment and recovery period times. With multiple measures per subject, it is important to appropriately account for the within-subject covariance structure. An autoregressive lag 1 (AR[1]) structure was found to most closely fit the data, not unusual when measurements are taken at equally spaced time points. The problems with the more traditional repeated-measures analysis of variance in this setting have been well documented.

The SAS General Linear Models Procedure was used for analysis of contralateral lower-extremity values and for comparison of pretest and 4-week posttest values for all groups. A post hoc Student-Newman-Keuls test was used to compare the pretest values with the 4-week posttest values to determine whether a difference existed between groups when both the treatment and recovery periods were included.

### Results
A comparison of intercepts and slopes among all groups for the treatment period is shown in Table 1. Plots of response functions for all 4 groups in both treatment and recovery conditions are shown in Figure 3. The intercepts are model-adjusted estimates of initial ROM means for each group. There was no difference in the starting intercept (pretest) among group 1 (41°), group 2 (45°), and group 3 (46°), but there was a

### Table 1. Intercepts and Slopes for 6-Week Stretching Period

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Value</th>
<th>Standard Error</th>
<th>Comparison*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept Control</td>
<td>40.98710</td>
<td>2.95079</td>
<td>m (t=2.72, df=21)</td>
</tr>
<tr>
<td>Intercept 15-s</td>
<td>45.43737</td>
<td>2.72627</td>
<td></td>
</tr>
<tr>
<td>Intercept 30-s</td>
<td>46.11647</td>
<td>3.03633</td>
<td></td>
</tr>
<tr>
<td>Intercept 60-s</td>
<td>48.55765</td>
<td>2.80192</td>
<td>j (t=2.72, df=21)</td>
</tr>
<tr>
<td>Slope Control</td>
<td>0.40292</td>
<td>0.32234</td>
<td></td>
</tr>
<tr>
<td>Slope 15-s</td>
<td>-0.61078</td>
<td>0.27082</td>
<td>a (t=2.26, df=390)</td>
</tr>
<tr>
<td>Slope 30-s</td>
<td>-1.28831</td>
<td>0.29843</td>
<td>a (t=4.32, df=390), j (t=3.85, df=390), m (t=2.68, df=390)</td>
</tr>
<tr>
<td>Slope 60-s</td>
<td>-2.36798</td>
<td>0.27082</td>
<td>a (t=8.74, df=390) x (60-s stretch vs control; t=-6.58, df=390), (60-s stretch vs 15-s stretch; t=4.59, df=390), (60-s stretch vs 30-s stretch; t=-2.68, df=390)</td>
</tr>
</tbody>
</table>

*a = significantly different from 0 (P<.05), j = significantly different from control (P<.05), m = significantly different from 60-second treatment (P<.05), x = significantly different from all other groups (P<.05).
difference between groups 1 and 4 (49°). We attributed this difference to random error.

The slopes represent the rate of change in knee extension ROM during the 6-week stretching period. A comparison of the slopes (Tab. 1 and Fig. 3) for all 4 groups revealed that after treatment, the ROM measurements obtained for the treatment groups were different from ROM measurements obtained for the control group. The slope for group 1 was not different from 0, which indicates there was no change in ROM over the treatment period for that group. All 3 treatment groups had slopes different from 0, indicating changes in ROM. Comparison of slopes for the 3 treatment groups showed that the slope for group 4 was greater than the slopes for groups 2 and 3 and that the slopes for groups 2 and 3 were not different from each other (α=.05). Therefore, group 4 had greater improvements in ROM compared with groups 1 through 3. Groups 2 and 3 had greater improvements in ROM than group 1 (no stretching).

Activity level was related to knee extension ROM. For each unit increase in activity score, there was a 1.04-degree increase in ROM. However, there was no association of activity index with treatment slope, meaning that a higher activity score indicated that the subject had increased ROM that stayed higher throughout the treatment and recovery phases of the study.

The longer the stretch duration, the steeper the slope (the greater the rate of change in ROM) (Fig. 3) for both the treatment and recovery periods. After the 6-week stretching protocol, model estimates of ROM were highest for group 1 and lowest for group 4 (Tab. 2). Slopes for the recovery period were positive, indicating a regression toward pretest values. The slope for group 1 was again not different from 0.

Comparison of the treatment groups’ slopes with the control group’s slope (during the recovery period) revealed that the slopes for groups 3 and 4 were different from the slope for group 1 (Tab. 2), but the slope for group 2 was not different from the slope for group 1 (α=.05). A comparison of recovery slopes revealed that the only difference between recovery slopes existed between groups 2 and 4 (Tab. 2). Analysis of the pretest and posttest measurements of the contralateral lower extremity using the SAS General Linear Models Procedure did not show a difference in ROM in any group (P=.2851).

To determine whether treatment effects incurred during the treatment period were still evident at 4 weeks posttreatment, an analysis of 4-week posttreatment scores minus pretreatment scores was undertaken. An analysis of variance on this change score showed differences among treatment groups (P<.0001). A post hoc Student-Newman-Keuls test revealed that only group 4 still maintained incurred ROM. Group 4 still had 5.4 degrees greater ROM than at pretest.

### Discussion

The results indicated that a 60-second stretch was more effective in increasing knee extension ROM than a 15- or 30-second stretch within this elderly group. These results differ from those of Bandy and Irion,17 who reported that a 30-second stretch was as effective as a 60-second static stretch of the hamstring muscles. More recently, Bandy et al16 reported that there was no difference between stretching once or repeating the stretch 3 times

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### Table 2.
Intercepts and Slopes During 4-Week Recovery Period

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Value</th>
<th>Standard Error</th>
<th>Comparison*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>43.78760</td>
<td>3.25640</td>
<td>m (t=−2.71, df=21)</td>
</tr>
<tr>
<td>Intercept 15-s stretch</td>
<td>42.37451</td>
<td>3.02019</td>
<td>m (t=−2.46, df=21)</td>
</tr>
<tr>
<td>Intercept 30-s stretch</td>
<td>39.30303</td>
<td>3.36433</td>
<td></td>
</tr>
<tr>
<td>Intercept 60-s stretch</td>
<td>35.63790</td>
<td>3.10655</td>
<td>j (t=−2.71, df=21)</td>
</tr>
<tr>
<td>Slope</td>
<td>0.40253</td>
<td>0.43348</td>
<td>k (t=−2.46, df=21)</td>
</tr>
<tr>
<td>Slope 15-s stretch</td>
<td>1.10402</td>
<td>0.38803</td>
<td>l (t=2.98, df=259)</td>
</tr>
<tr>
<td>Slope 30-s stretch</td>
<td>1.81556</td>
<td>0.40873</td>
<td>m (t=3.80, df=259)</td>
</tr>
<tr>
<td>Slope 60-s stretch</td>
<td>2.19122</td>
<td>0.36419</td>
<td>n (t=4.44, df=259)</td>
</tr>
</tbody>
</table>

*α=significantly different from 0 (P<.05), j=significantly different from control (P<.05), k=significantly different from 15-second treatment (P<.05), l=significantly different from 30-second treatment (P<.05), m=significantly different from 60-second treatment (P<.05).
using either a 30- or 60-second static stretch. In both studies by Bandy and colleagues, treatments were given for 6 weeks, as in our study, and the researchers acknowledged that the results should be applied only to a similar age group (mean age = 26 years).

Understanding that a longer-duration stretch will improve ROM in elderly people is particularly important, in our opinion, because joint mobility declines with increasing age.35 Research has shown a decline in both active and passive ROM of lower-limb joints from 70 to 92 years of age, with a more pronounced decline during the ninth decade.35

In our study, all stretches were repeated 4 times with a 10-second rest between stretches. We used repeated stretches because Taylor et al18 suggested that maximal muscle-tendon unit elongation occurs after approximately 4 stretches, and additional stretches (ie, up to 10 stretches) resulted in little further improvement. We believe that this cyclic stretching technique may be even more beneficial for elderly people due to the physiological changes of increased muscle stiffness and collagen deposition that occur with aging.

We used a passive straight-leg-raise method of stretching because we believe that this method promotes relaxation of the hamstring muscles, and the static method was chosen over a PNF-based approach because it has been reported to be more comfortable36 and, in our opinion, is simple to perform. Older muscles are more susceptible to contraction-induced injury, especially when the muscle is lengthened during the contraction,19 and have a diminished ability to recover from acute or repetitive musculoskeletal trauma.11,20 This reduced capacity for healing, combined with a higher predisposition for injury, is why we believed that the static stretching technique may be more suitable than PNF techniques for elderly people.

The 60-second duration may have been more beneficial than the 15- or 30-second durations in overcoming the increased muscle stiffness and collagen deposition that also accompany the aging process. We showed that the more physically active a person was, the more ROM he or she had initially and throughout all treatments. Even though we did not measure the effect of ROM on function, we believe this observation is important because it suggests the importance of physical activity in maintaining a level of flexibility.

We also attempted to determine whether stretching one lower extremity resulted in any changes of the contralateral (nonstretched) lower extremity. No differences in ROM were found in the contralateral extremity in any treatment group. Stretching one lower extremity did not result in knee extension ROM improvements of the opposite (nonstretched) lower extremity. Weekly measurements of ROM were taken in hopes of seeing a trend (when the greatest improvements occurred). We were unable to show a pattern of when the majority of ROM changes occurred. This finding may have been due to our small sample size and the large standard deviation in each group.

Our post hoc comparison showed that there was a difference between the initial measurements and the measurements taken after 4 weeks without stretching in group 4, but there was no difference within the other 3 groups. Thus, groups 2 and 3 returned to their pretreatment ROM measurement values after just 4 weeks of not stretching, but group 4 still had more ROM than when the study began. This finding may have been due to the fact that the 60-second treatment resulted in greater changes in ROM due to its greater rate of change and the subjects in this group, therefore, had farther to regress in order to return to pretest values. The slope for the 60-second stretch was steeper for both the treatment and recovery periods (Fig. 3). Thus, even though the subjects in group 4 exhibited quicker improvements in ROM, they also lost ROM during the 4-week recovery period at a faster rate than the other groups. This finding emphasizes the importance of continuing a stretching regimen in order to maintain ROM gains.

Although it appears that longer-duration stretching enhances ROM increases in elderly people, many questions remain unanswered with regard to stretching protocols in this population. Groups 2 through 4 stretched for a daily total stretch time of 1 minute, 2 minutes, and 4 minutes, respectively. Further investigation is needed to determine whether the improvement made by the group that received the 60-second stretch was due to the longer duration of stretching or due to the overall time for stretching. Whether or not a single 60-second stretch is as effective as repeated stretching in elderly people also warrants further investigation. Future studies should also compare 60-second stretches with longer periods of stretching (ie, up to 2 minutes or longer) to determine whether prolonged stretches further improve ROM or enhance the residual effect.

Limitations of the Study
We examined the effects of repeated stretches of 15, 30, and 60 seconds’ duration in the hamstring muscle group on knee extension ROM in a group of elderly subjects. Our subjects were predominantly Caucasian, and the results may not be representative of other races. In addition, the subjects were living in a retirement facility, but they were independent in their activities of daily living and thus may not be representative of people with other characteristics. As 95% of our subjects were between the ages of 75 and 95 years, further studies are
needed to determine whether the results of this study can be generalized to middle-aged adults or to a younger elderly population (65–75 years of age).

**Conclusion**

We demonstrated that 60-second stretching, repeated 4 times, once per day, 5 times per week for 6 weeks, can yield a greater rate of improvement in knee extension ROM than similar regimens of 15- or 30-second stretches in elderly people. However, the groups that received 15- and 30-second stretches had improvements in ROM when compared with the group that had no stretching. In order for ROM gains to be maintained, stretching must be continued. The more active a person is, the better his or her ROM will be prior to and after treatment, regardless of treatment method. Stretching one lower extremity will not necessarily improve the ROM of the opposite lower extremity.

**References**