Research Report

The Effect of Time on Static Stretch on the Flexibility of the Hamstring Muscles

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Background and Purpose. *To date, there are no reports comparing duration of static stretch in humans on joint range of motion (ROM) and hamstring muscle flexibility. The purpose of this study was to examine the length of time the hamstring muscles should be placed in a sustained stretched position to maximally increase ROM.* ***Subjects.*** *Fifty-seven subjects (40 men, 17 women), ranging in age from 21 to 37 years and with limited hamstring muscle flexibility (ie, 30° loss of knee extension measured with femur held at 90° of hip flexion), were randomly assigned to one of four groups. Three groups stretched 5 days per week for 15, 30, and 60 seconds, respectively. The fourth group, which served as a control group, did not stretch.* ***Methods.*** *Before and after 6 weeks of stretching, flexibility of the hamstring muscles was determined by measuring knee extension ROM with the femur maintained in 90 degrees of hip flexion. Data were analyzed with a 4×2 analysis of variance (group×test) for repeated measures on one variable.* ***Results.*** *The data analysis revealed a significant group×test interaction, indicating that the change in flexibility was dependent on the duration of stretching. Further post hoc analysis revealed that 30 and 60 seconds of stretching were more effective at increasing flexibility of the hamstring muscles (as determined by increased ROM of knee extension) than stretching for 15 seconds or no stretching. In addition, no significant difference existed between stretching for 30 seconds and for 1 minute, indicating that 30 seconds of stretching the hamstring muscles was as effective as the longer duration of 1 minute.* ***Conclusion and Discussion.*** *The results of this study suggest that a duration of 30 seconds is an effective time of stretching for enhancing the flexibility of the hamstring muscles. Given the information that no increase in flexibility of the hamstring muscles occurred by increasing the duration of stretching from 30 to 60 seconds, the use of the longer duration of stretching for an acute effect must be questioned. [Bandy WD, Irion JM. The effect of time on static stretch on the flexibility of the hamstring muscles. Phys Ther. 1994;74:845–852.]*

Key Words: *Kinesiology/biomechanics, lower extremity; Muscle; Muscle performance, lower extremity.*

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Anderson and Burke defined *flexibility* as "the range of motion available in a joint or a group of joints that is influenced by muscles, tendons, ligaments, and bones."[1(p63)] Flexibility of muscle has long been a concern of physical therapists and rehabilitation specialists, as well as physical educators and coaches. Claims have been made that increased flexibility resulting from stretching activities may decrease the incidence of musculotendinous injuries, minimize and alleviate muscle soreness, and improve athletic performance.[1–7]

Three types of stretching exercises are used in an attempt to gain an increase in flexibility: static stretching, ballistic stretching, and proprioceptive neuromuscular facilitation (PNF) techniques.[1,6,8] The ballistic stretch uses bouncing or jerking movements imposed on the muscles to be stretched.[1,8] The quick, jerking motion that occurs during the ballistic stretch can theoretically exceed the extensibility limits of the muscle in an uncontrolled manner and cause injury. The use of this technique, therefore, has not been widely supported in the literature.[1,3] The static stretch is a method in which the muscle is slowly elongated to tolerance (comfortable stretch, short of pain) and the position held with the muscle in this greatest tolerated length. Static stretching offers advantages over the ballistic stretching method. Exceeding the extensibility limits of the tissue involved is unlikely, and the technique requires less energy to perform and alleviates muscle soreness.[1,3] The PNF techniques of contract-relax and hold-relax involve the use of a brief isometric contraction of the muscle to be stretched prior to a static stretch.[9–11] The PNF techniques presumably not only require the most expertise of the three techniques described, but an experienced therapist is required to administer the PNF techniques.[9–11]

Each of these three types of stretching techniques (static, ballistic, and PNF) appears to increase the flexibility of a muscle immediately after the stretching.[1,2,6,8,10,11] Given that the ballistic stretch may pose the greatest potential for trauma and that PNF requires the assistance of an experienced practitioner, the most common method of stretching used to increase the flexibility of the muscle is the static stretch.[1–3,6,8]

Only limited studies exist concerning the optimal time the stretch should be sustained, and no comparative studies evaluating the optimal time of stretch have been performed. Investigators[3,8,10–13] demonstrating that static stretching is an effective means of increasing flexibility have used stretch durations ranging from 15 to 60 seconds, but no justification was given for the stretch duration used. In addition, studies comparing the effectiveness of static stretch and PNF have used varying lengths of static stretch (10,[3,10,11] 30,[14] and 60[15] seconds), as have investigations evaluating the effectiveness of combining various modalities (eg, massage, heat, cold) with static stretch (3,[13] 10,[16,17] 30,[18] and 45[19] seconds). No rationale was given for the duration of stretch in any of these studies.

In only one study were changes in flexibility in humans as a result of different durations of static stretch investigated. Comparing the effects of one session of 15, 45, and 120 seconds of stretching on hip abduction passive range of motion (ROM), Madding et al[20] reported that sustaining a stretch for 15 seconds was as effective as sustaining a stretch for 120 seconds. These results reflect only one session of stretching, and the effect of these varying durations of stretch over time are not known.

In summary, the literature supports the fact that static stretch will increase the flexibility of muscle. A great deal of variability exists, however, concerning the length of time a static stretch should be sustained. To date, no multiple-day study with the specific purpose of comparing duration of static stretch and the effect on muscle length in humans has been reported.

The purpose of our study was to examine the length of time a muscle should be sustained in a stretched position to maximally increase flexibility. More specifically, this study compared the effects of daily stretches of the hamstring muscles of 15, 30, and 60 seconds in duration on knee joint ROM.

Method

Subjects

Seventy-five subjects (44 men, 31 women) between the ages of 20 and 40 years ($\bar{X}$=26.53, SD=5.33) and without any significant history of pathology of the hip, knee, thigh, or low back were recruited for this study. 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 measured with the femur held at 90 degrees of hip flexion (refer to "Procedure" section for details). In addition, subjects who were not involved in any exercise activity at the start of the study had to agree to avoid lower-extremity exercise 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.

Fourteen (2 men, 12 women) of the original 75 volunteers were excluded from the study because their hamstring muscles were considered too flexible by the established criteria, and 4 subjects (2 men, 2 women) were eliminated from the study as a result of noncompliance with the training program. Therefore, 57 subjects (40 men, 17 women), with a mean age of 26.11 years (SD=5.26, range=21–37), met the established criteria and completed the study.

Equipment

Flexibility of the hamstring muscles was measured with a goniometer* that was a double-armed, full-circle

*Cleo Inc, 3957 Mayfield Rd, Cleveland, OH 44121.

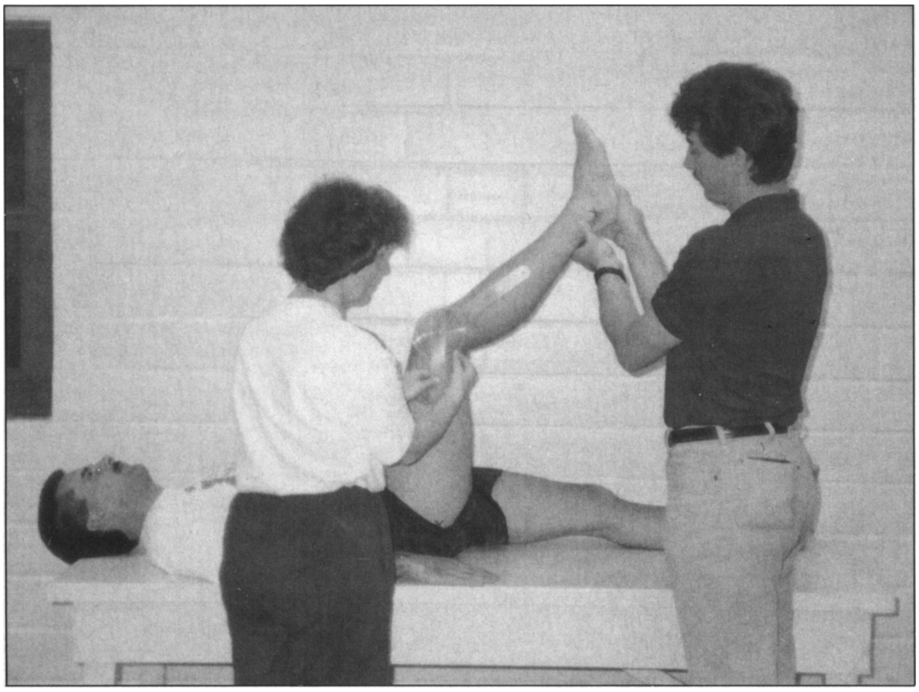

Figure 1. *Measurement of hamstring muscle flexibility.*

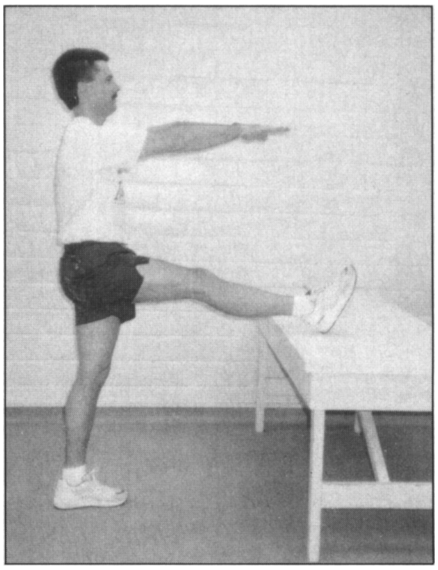

Figure 2. *Stretching procedure for hamstring muscles.*

protractor made of transparent plastic. The arms of the goniometer were 30.48 cm (12 in) long and marked off in 1-degree increments.

Procedure

All subjects who met the criteria for inclusion in the study were measured for flexibility of the right (arbitrarily chosen) hamstring muscles prior to assignment to groups. Each subject was positioned supine with the right hip and knee flexed to 90 degrees. The lateral malleolus, lateral epicondyle of the femur, and greater trochanter of the right lower extremity were then marked with a felt-tipped pen for later goniometric measurement. Ninety degrees of hip flexion was maintained by one researcher (MB), while the tibia of the knee was passively moved to the terminal position of knee extension by the second researcher (JMI) (Fig. 1). The terminal position of knee extension was defined as the point at which the subject complained of a feeling of discomfort or tightness in the hamstring muscles or the experimenter perceived resistance to stretch. Once the terminal position of knee extension was reached, the second examiner measured the amount of knee extension with the goniometer using methods described by Norkin and White.[21] Zero degrees of knee extension was considered full hamstring muscle flexibility. No warm-up period was allowed prior to data collection.

The same examiners made all goniometric measurements throughout the study. In addition, the second examiner (measuring the amount of knee extension) was not informed which subjects were doing stretching.

Prior to data collection, intratester reliability of the measurement of hamstring muscle flexibility using the procedure described was evaluated in these researchers using a test-retest (1-week apart) design on 10 different subjects. The intraclass correlation coefficient (ICC[1,1])[22] was .98, which was considered appropriate for proceeding with this study.

Following pretesting, the subjects were randomly assigned to four groups. Group 1 (10 men, 4 women; $\bar{X}$ age=26.50 years, SD=4.69, range=22–36) was assigned to participate in passive, static stretching activities sustained for 15 seconds; group 2 (10 men, 4 women; $\bar{X}$ age=24.64 years, SD=2.31, range=22–28) was assigned to participate in static stretching sustained for 30 seconds; and group 3 (9 men, 5 women; $\bar{X}$ age=26.36 years, SD=6.66, range=21–37) was assigned to receive static stretching for a 60-second duration. Group 4 (11 men, 4 women; $\bar{X}$ age=26.87 years, SD=6.42, range=22–36) served as a control group. No stretching was performed by the control group.

Subjects in groups 1 through 3 stretched five times a week for 6 weeks. The subjects performed stretching of the hamstring muscles by standing erect with the left foot planted on the floor and placed directly forward without hip medial (internal) or lateral (external) rotation. The posterior calcaneal aspect of the contralateral (right) foot was placed on a plinth or chair with the toes of the foot directed toward the ceiling, again without hip medial or lateral rotation (Fig. 2). The knee remained fully extended. The arms were flexed to shoulder height with the elbows fully extended. The subject then flexed forward from the hip, maintaining the spine in a neutral position, while reaching the arms forward. The subject moved forward in this position 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 to approximate the type of static stretch procedure commonly taught in a clinical setting.[3,6]

Performance of each stretching session by each subject was supervised and recorded by one researcher (MB) on an attendance sheet to document compliance with the program. If a subject missed a scheduled session, he or she made up the session on another day during the same week or during the next week (requiring an exercise frequency of six times per week during the week following the missed session). Any subject missing more than 4 days without performing the stretching was eliminated from the study.

After the 6 weeks of training, all subjects were retested using the same procedures described for the pretest. Two days of rest was provided prior to the posttest.

Data Analysis

Reliability of the knee extension measurements were determined using an ICC (formula 1,1) on the pretest and posttest measurements of the control group.[22] Means and standard deviations for the pretest and posttest measurements were calculated for each group, as well as the mean differences between the pretest and posttest data (gain scores), for the dependent variable, knee extension ROM (in degrees).

To determine whether significant differences existed between the values of the four groups, a 4×2 (group×test) two-way analysis of variance (ANOVA) for repeated measures on one variable (test) was performed. Significance for all statistical tests was accepted at the .05 level of probability.

Results

The mean values for the pooled pretest measurements and the pooled posttest measurements of the control group for degrees of knee extension were 45.47 degrees (SD=7.29) and 45.20 degrees (SD=6.68), respectively. The ICC value calculated for the pretest-posttest knee extension data of the control group was .91.

The means for pretest and posttest measurements and gain scores for each group are presented in Table 1. The two-way ANOVA indicated a significant interaction between the groups (control and 15-, 30-, and 60-second stretches) and test (pretest and posttest) in degrees of knee extension (Tab. 2). Further evaluation of the data indicated that the change in degrees of knee extension for the subjects in both groups 2 and 3, who stretched for 30 and 60 seconds, respectively, were much greater than for the subjects in both groups 1 and 4, who stretched for 15 and 0 (control) seconds, respectively. The differences observed between groups 2 and 3 and between groups 1 and 4 were minimal (Fig. 3).

Table 1. *Mean (±Standard Deviation) Values for Pretest, Posttest, and Gain Scores (in Degrees) of Knee Flexion for Each Level of Group*

	Group[a]			
	1 (n=14)	2 (n=14)	3 (n=14)	Control (n=15)
Pretest	50.14 (6.09)	51.64 (9.74)	50.07 (4.92)	45.47 (7.29)
Posttest	46.36 (7.92)	39.14 (9.54)	39.21 (9.59)	45.20 (6.68)
Gain (difference between pretest and posttest)	3.78	12.50	10.86	0.27

[a]Group 1 stretched for 15 seconds, group 2 stretched for 30 seconds, and group 3 stretched for 1 minute; the control group did not stretch.

Discussion

To ensure that appropriate reliability occurred in the study, we used ICC (formula 1,1), which Shrout and Fleiss[22] suggest is the most conservative form of ICC and almost always underestimates the reliability. The conservative estimate of .91 for the reliability of the pretest-posttest measurements of knee extension ROM for the 15 control group subjects, therefore, appears quite acceptable for the purposes of this study.

Based on the results of the two-way ANOVA (Tab. 2), the null hypothesis that no difference would be obtained in knee extension ROM if the hamstring muscles were stretched at durations of 15, 30, and 60 seconds for 6 weeks must be rejected. Stretching the hamstring muscles for 30 and 60 seconds showed greater gains in ROM than stretching for 15 seconds or no stretching (control).

Because 15 seconds of stretching was no more effective than no stretching, we must question the use of stretching of 15 seconds or less. Based on our results, individuals performing 15-second stretches may be wasting their time, as only a minimal increase in flexibility is likely to occur.

Our study is the first to investigate the effect of static stretching on ROM over a period of time (eg, 6 weeks). In the only other investigation of the effect of time on stretching, only one session of stretching was used. Although previous research on humans using one session of stretching exercise indicated that 15 seconds' duration was as effective as 2 minutes,[20] the results of our study contradict these findings and indicate that longer periods of time (eg, 30 and 60 seconds)

Table 2. *Two-Way (Four Groups×Two Tests) Analysis-of-Variance Results*

Source	*df*	SS	MS	*F*
Group[a]	3	215.71	0.68	0.68
Test[b]	1	1337.03	1337.03	72.29[c]
Group×test	3	726.27	242.09	13.09[c]

[a]Control (no stretching) and 15-, 30-, and 60-second static stretching groups.

[b]Test-retest.

[c]$P<.05$.

are more effective for increasing muscle flexibility. We believe evaluating one session of stretching[22] did not provide a true indication of what actually occurs. Measuring the change in ROM across 6 weeks, as was performed in our research, we believe is a more clinically relevant investigation.

Only a minimal increase in flexibility of the hamstring muscles (as indicated by increased ROM) occurred by increasing the duration of stretching from 30 to 60 seconds. The use of the longer duration of stretching, therefore, must be questioned. The results of our study suggest that the most effective duration of stretching is 30 seconds.

Our study was limited to the effects of one session of static stretching performed once a day. Future research is needed to evaluate the effects of different durations of stretching performed at various times throughout the day and to determine how long lasting are increases in flexibility. Instructions for individuals who lack appropriate flexibility include stretching frequently during the day, such as three to five times in 1 day, irrespective of the duration of the stretch.

We examined the time of stretch of up to 1 minute in duration. Future research could evaluate whether durations of 90 to 120 seconds or longer will provide increased muscle flexibility. We believe, however, that compliance may be decreased if durations of stretching are too long, particularly in people with muscle tightness. In future research, durations of stretching that are clinically appropriate and acceptable need to be studied and the effect of multiple stretches per day need to be investigated. Future research would also be appropriate to evaluate the effect of duration of stretching on other muscles. Although 30 seconds of stretching the hamstring muscles was found to be as effective as 60 seconds of stretching in increasing ROM at the knee, 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.

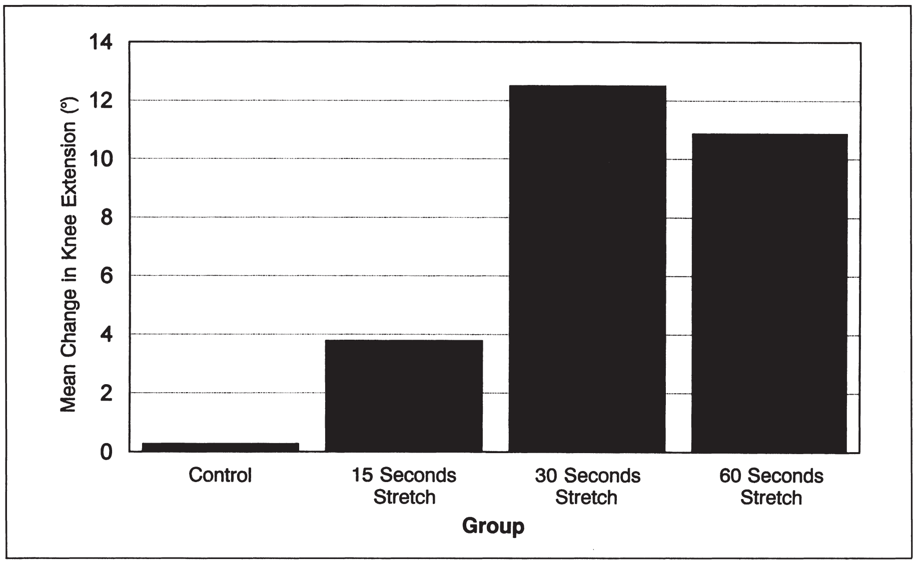

Figure 3. *Mean change (difference between pretest and posttest measurements, in degrees) in knee extension by group.*

Conclusion

Our study demonstrated that 30 and 60 seconds of static stretching of the hamstring muscles for 5 days per week for 6 weeks was more effective for increasing muscle flexibility (as determined by increased knee extension ROM) than stretching for 15 seconds or no stretching. In addition, no significant difference existed between 30 and 60 seconds of stretching. Enhanced understanding of the effect of duration of stretching on the hamstring muscles as a result of the findings of our study will hopefully enable clinicians to provide more effective and scientifically based treatment when incorporating stretching activities into rehabilitation programs.

Acknowledgment

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Invited Commentary

The authors are to be commended for investigating the effect of time, stretching over a 6-week period, on the flexibility of the hamstring muscles. Both amateur and professional sport persons, as well as many ordinary people who daily walk, jog, or run, do flexibility exercises as part of their warm-up routine. As the authors note, there have been a number of investigations into different combinations of heat and cold with stretching, but no longitudinal studies have been reported that have examined static stretches on flexibility.

Although many, including the authors, tend to relate flexibility solely to a muscle group, it is, in healthy subjects, more likely that biochemical alterations in collagen and elastin structure account for variation among individuals in laxity ... flexibility, and for interethnic differences. The unit of concern is the muscle-tendon unit and specifically the passive elements of that unit, connective tissues predominantly composed of collagen. Maintenance of stretch after the limit of joint range of motion (ROM) has been achieved influences the creep response of connective tissues.[1] Although it is often stated that this stretch should be of "long duration," the ideal duration has not been established.

The authors state that subjects had a *loss* of greater than 30 degrees of knee extension when in a position of 90 degrees of hip flexion. Subjects used, however, were healthy, and no evidence was given to support a "loss" of ROM; rather, this was their normal ROM in that position. The measure of muscle flexibility used, ROM, is a variable that appears to be a graded trait, with a normal distribution in the population, so that some veer toward hypermobility (double-jointed), others to hypomobility, as their "normal" ROM. It would be useful to know whether subjects were screened for symptomless abnormalities such as sacralization of lumbar vertebra, which is a factor in reduced ROM in the position tested. It would be useful to repeat the study using a clinical sample in whom a real loss of ROM due to muscle pathology has occurred to determine whether similar results in terms of time are obtained.

Reproducibility of the study is impeded by the authors' lack of a clear definition of what exactly was done. They state that subjects stretched "five times a week for 6 weeks" and that subjects had "one session of static stretching performed once a day." I am unclear on what a "session" is, whether subjects stretched once, 3, 5, or 10 times *per* session.

Acceptable intersession reliability was reported, but to reproduce the study it is necessary to also know how the length of the stretch was controlled. Was a stopwatch used? Additionally, the end-of-range limit of a "gentle stretch sensation" is likely to be interpreted differently dependent on an individual's perception of stretch. Was this defined in a standardized manner to all subjects? Individuals who regularly stretch as part of a warm-up routine may have a higher threshold than inactive individuals. Although the sample consisted of individuals who regularly exercise and some who did not, the authors did not report whether the randomized placement into groups gave about equal numbers of exercisers and nonexercisers in each group, or whether the change in ROM differed between these two "groups."

The authors concluded that their results suggest that "the most effective duration of stretching is 30 seconds." Their results, however, showed that 30- and 60-second stretches were equally effective. Although it may be reasonable to suggest that healthy individuals may restrict their stretch period to 30 seconds, this study only on healthy subjects cannot be extrapolated to a clinical population as response may vary in presence of inflammation and repair. Further, because outcome was assessed only after 6 weeks of stretching, not serially, it cannot be established whether the ROM gain occurred before the 6-week limit, such as at 3 weeks, and then was maintained by continued stretching.

There is a widely held view that flexibility exercises assist in decreasing injuries of the muscle-tendon unit and therefore reduce activity-induced inflammatory response.[2] No hard evidence, however, exists to support the view that flexibility training specifically prevents injury, although clinical data do support usage to prevent muscle soreness and potential trauma to the myotendinous junction. Because heat and warm-up exercises are demonstrated to enhance flexibility, it would be interesting to know whether the researchers controlled or adjusted for activity prior to testing. It is stated that no warm-up was allowed, but were subjects' activity (walked, cycled to test site?) prior to testing recorded? Given the benefits of warm-up activity on circulation and intramuscular temperature and in conditioning connective tissues to enhance tolerance of stretch without further injury, it is unclear why a standardized warm-up period was not included, as this is common practice.

The authors have made a useful contribution to the literature in testing static stretches of 15, 30, and 60 seconds' duration over a 6-week period. Their results can justify healthy individuals using a stretch of 30 seconds. Further longitudinal studies are needed to determine the relationship between time and ROM gain in a clinical sample, as well as the influence, if any, of modalities such as heat.

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Author Response

As indicated in our article, a lack of research exists evaluating the optimal duration of static stretch for increasing range of motion. In the only study published in a refereed journal, Madding et al[1] used a single bout of stretching, *one time only.* In a popular text, Zachazewski has recently supported the results of Madding et al[1] by suggesting that "holding a stretch for 15 seconds is as effective as two minutes for increasing muscle flexibility."[2] Based on our combined 20+ years of clinical experience, we were surprised that 15 seconds could possibly be the optimal time of stretch to a muscle in order to enhance range of motion. Therefore, we essentially set out to support or reject the study by Madding et al[1] by examining the effects of one stretch per day, over a 6-week period of time—a simple concept, yet one that had never been addressed in a controlled design.

We appreciate the opportunity to clarify concerns about the study that were not clearly understood and that were raised in the commentary by Dr Walker. "One bout of static stretch once a day" referred to each subject performing the assigned duration of static stretching activity (15, 30, or 60 seconds) *one time per day.* Additionally, the duration of static stretch was directly supervised and timed via a stopwatch. No attempt was made to specifically standardize "gentle stretch sensation."

Dr Walker's commentary raises several ideas for continued research in the area of static stretch of muscle including the effect of previous training activity, serial measurement, use of a clinical sample, and the effect of warm-up and modalities. Given that, to date, no previous study has evaluated the effect of various durations of stretch using a longitudinal design (as was used in our investigation), we believe that a "base" has been established justifying 30 seconds as an appropriate time of stretch in healthy individuals. Researchers and clinicians are encouraged to continue investigations in static stretch of muscle using the ideas from the commentary in order to build on this research study. Such continued research will assist in further defining the appropriate and effective use of the static stretch.

Finally, we appreciate Dr Walker's final comment that "the authors have made a useful contribution to the literature." In our clinical judgment, the results of this research offer some important information that will be helpful for those clinicians who use flexibility exercises in their rehabilitation programs.

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