Journal of Strength and Conditioning Research, 2005, 19(1), 27–32

The Effectiveness of 3 Stretching Techniques on Hamstring Flexibility Using Consistent Stretching Parameters

D. Scott Davis, Paul E. Ashby, Kristi L. McCale, Jerry A. McQuain, and Jaime M. Wine

Department of Human Performance and Exercise Science, Division of Physical Therapy, West Virginia University, Morgantown, West Virginia 26505.

Abstract. Davis, D.S., P.E. Ashby, K.L. McCale, J.A. McQuain, and J.M. Wine. The effectiveness of 3 stretching techniques on hamstring flexibility using consistent stretching parameters. *J. Strength Cond. Res. 19(1):27–32. 2005.*—This study compares the effects of 3 common stretching techniques on the length of the hamstring muscle group during a 4-week training program. Subjects were 19 young adults between the ages of 21 and 35. The criterion for subject inclusion was tight hamstrings as defined by a knee extension angle greater than 20° while supine with the hip flexed 90°. The participants were randomly assigned to 1 of 4 groups. Group 1 ($n = 5$) was self-stretching, group 2 ($n = 5$) was static stretching, group 3 ($n = 5$) was proprioceptive neuromuscular facilitation incorporating the theory of reciprocal inhibition (PNF-R), and group 4 ($n = 4$) was control. Each group received the same stretching dose of a single 30-second stretch 3 days per week for 4 weeks. Knee extension angle was measured before the start of the stretching program, at 2 weeks, and at 4 weeks. Statistical analysis ($p \leq 0.05$) revealed a significant interaction of stretching technique and duration of stretch. Post hoc analysis showed that all 3 stretching techniques increase hamstring length from the baseline value during a 4-week training program; however, only group 2 (static stretching) was found to be significantly greater than the control at 4 weeks. These data indicate that static stretching 1 repetition for 30 seconds 3 days per week increased hamstring length in young healthy subjects. These data also suggest that active self-stretching and PNF-R stretching 1 repetition for 30 seconds 3 days per week is not sufficient to significantly increase hamstring length in this population.

Key Words. proprioceptive, muscle length, daily dose

Introduction

Muscular flexibility is an important aspect of normal human function. Limited flexibility has been shown to predispose a person to several musculoskeletal overuse injuries and significantly affect a person's level of function (4, 8–11, 16, 19–21, 25). Musculoskeletal overuse injuries resulting from decreased lower-extremity flexibility range from stress fractures and shin splints to patellofemoral pain syndrome and muscle strains (10). Muscle strains are particularly common in multijoint muscles, which have a greater functional excursion and tend to have a higher concentration of fast-twitch muscle fibers (20). The hamstring muscles are reported to be the most commonly injured multijoint muscle group in the body (20).

Maintaining normal muscle length requires regular stretching to prevent muscle stiffness and benefit from the decreased risk of musculoskeletal injuries and enhanced physical performance (3, 4, 6, 8, 10, 16, 19–21, 24). Despite the importance of regular stretching, much controversy exists as to which stretching technique and parameters are the most effective for increasing muscle flexibility.

Several stretching techniques have been described in the literature. Three common stretching techniques include static stretching, active self-stretching, and proprioceptive neuromuscular facilitation (PNF) (3, 4, 12–14, 21, 23).

Static stretching is a common technique used by strength and conditioning specialists and athletes to increase muscle length. This type of stretching takes the muscle to its end range and maintains this position for a specified duration (4, 12, 14, 21). One of the advantages of static stretching may be the facilitation of the Golgi tendon organ (GTO). Static tension placed on the muscle-tendon unit has been shown to activate the GTO, which may produce autogenic inhibition of the muscle that is stretched (4). Static stretching has been shown to be very effective at increasing hamstring length (1, 2, 5, 9, 14, 15, 19, 21, 23).

Several studies have attempted to determine the most appropriate parameters for static stretching. Duration, frequency, number of repetitions, daily dose, and length of program are important parameters to consider. Suggested effective durations range from 5 to 60 seconds. Roberts and Wilson (17) compared nine 5-second static stretches and three 15-second static stretches with a control group by using an active static stretch for 5 weeks. They concluded that both durations increased hamstring flexibility when compared with a control, but the 15-second stretch was more effective than the 5-second stretch. Bandy and Irion (1) compared the effectiveness of 3 durations of static hamstring stretch (15, 30, 60 seconds) 5 days per week for 6 weeks. They found that 30- and 60-second stretches were both superior to a 15-second stretch; however, no difference was found between a 30- and a 60-second stretch. Cipriani and colleagues (6) compared six 10-second static stretches with two 30-second static stretches during a 6-week program. They found no statistical difference between the 2 stretching protocols when the total daily dose of the stretch remained the same for both groups.

Researchers have proposed frequencies ranging from 1 to 3 times per day and up to 5 days per week (1, 5, 17, 18, 23). Bandy and colleagues (2) attempted to determine the effect of frequency of static stretch by comparing a control with three 60-second static stretches, three 30-second static stretches, one 60-second static stretch, and one 30-second static stretch. They reported that all the groups increased hamstring length compared with the control, but no difference was found among the different frequencies or stretching durations. They concluded that one 30-second stretch was just as effective as a 60-second stretch performed 3 times per day (2).

The length of the stretching program is also of great concern. Studies have recommended 1 day to 8 weeks (1, 2, 5, 9, 17–19, 23). Six weeks has been consistently shown to be an effective length of a stretching program and has been used by many investigators (1–3, 19, 23). Chan and colleagues (5) compared a 4-week and an 8-week static stretching program with a control and found that both groups were equally effective at increasing hamstring length. It remains unclear if shorter stretching programs are effective at increasing hamstring muscle length.

Proprioceptive neuromuscular facilitation is another common stretching technique. Theoretically, PNF stretching uses muscle inhibition techniques before the stretch to enhance the effectiveness of the stretch (12). This type of stretching uses the theories of autogenic and reciprocal inhibition to “relax” the muscle before the stretch (12). However, some researchers have questioned the ability of these techniques to actually inhibit muscle activity (14, 15). Lack of standardized parameters and consistent terminology has created confusion when attempting to compare the effectiveness of PNF stretching techniques (4, 7, 12, 13, 15, 21).

Only 1 type of PNF stretching will be discussed here to both avoid confusion and confine the discussion to the techniques used in this investigation. Concentric contraction of the opposing muscle is theorized to result in reciprocal inhibition of the muscle that is stretched. The technique is sometimes referred to as *agonist contraction* (12); however, to avoid confusion, this form of PNF stretching will be operationally defined as PNF-R.

On the basis of the electromyogram (EMG) results of Moore and Hutton (14) and Osternig and colleagues (15), the theory by which PNF stretching works has been called into question. Both investigations found an increase in EMG activity during the stretching phase of the PNF techniques. Despite the apparent lack of muscle inhibition associated with these techniques, PNF stretching has been shown to be an effective method of increasing hamstring flexibility (14, 19).

It is extremely difficult to determine the most efficacious hamstring stretching program in the current literature. Inconsistent parameters resulting in different stretching doses and a lack of direct comparison with a control make determination impossible. Therefore, controversy remains regarding which stretching technique is the most effective and what the frequency, length of program, speed of stretch, and the intensity of stretch for these various techniques should be.

Research conducted by Bandy and Irion (1) and Bandy et al. (2, 3) has provided a gold standard for duration and frequency of static stretching. Unfortunately, the same is not available for PNF techniques. Therefore, no study has compared the 3 PNF inhibition techniques with one another and with static stretching by using consistent parameters. On the basis of the literature, it is clear that further research is needed to compare PNF techniques with static stretching in a randomized controlled trial with consistent parameters. It is also clear that further investigation is needed to better understand how hamstring flexibility changes during the course of a 4-week program.

The primary purpose of this investigation was to compare static stretching, PNF-R stretching, and active self-stretching in a randomized controlled trial by using the same stretching parameters during a 2- and 4-week training program.

Methods

Experimental Approach to the Problem

A repeated-measures design was used to determine the effectiveness of 3 common stretching techniques during a 4-week training program. The design allowed for the investigation of possible interaction effects of technique and duration of training. The dependent variable was hamstring length as measured by the knee extension angle (KEA), and the 2 independent variables included stretching technique and duration of the stretching program. Before recruiting the subjects, the investigation was approved by the West Virginia University Institutional Review Board for Human Subjects. The subjects were randomly assigned to 1 of 3 treatment groups or a control. The primary investigator was blinded to subject assignment throughout the investigation.

Subjects

Nineteen individuals (age = 23.1 ± 1.5 years) volunteered to participate in this study. To be included in the investigation, participants were required to have tight hamstring as defined by a 20° KEA with the hip in 90° of hip flexion. Participants were also required to be between 18 and 40 years of age. Subjects were excluded from the investigation if they had previous history of lower-extremity pathology, which may adversely affect hamstring flexibility length. Each participant signed a consent form approved by the West Virginia University Institutional Review Board for Human Subjects, and the rights of human subjects were protected.

Knee Extension Angle

Measurements were performed throughout the study by the same examiner (D.S.D.), who had 13 years of clinical experience as a physical therapist. The examiner was blinded to group assignment throughout the investigation. Measurements were taken with subjects in the supine position on a treatment plinth. Bilateral KEA measurements were obtained in sequence (Figure 1). The tested extremity was placed in a 90° hip and 90° knee position with the contralateral lower extremity placed flat on the table. Two Velcro straps were placed on the distal leg above the malleoli and 2 were placed on the distal thigh above the patella to hold gravity inclinometers. The inclinometers were consistently placed at the level of the medial malleoli and the superior pole of the patella. The examiner used the inclinometer on the thigh to maintain 90° of hip flexion. Pelvic position was monitored by palpation of the anterior superior iliac spine and lumbar spinous processes to maintain a neutral pelvic position. Next, the examiner passively extended the knee to the point of a “strong, but tolerable stretch”, as reported by the subject. The primary examiner read the angle of the inclinometer while a second investigator recorded the value. Measurements were repeated on the opposite limb by the same procedure. The angle that was used for statis-

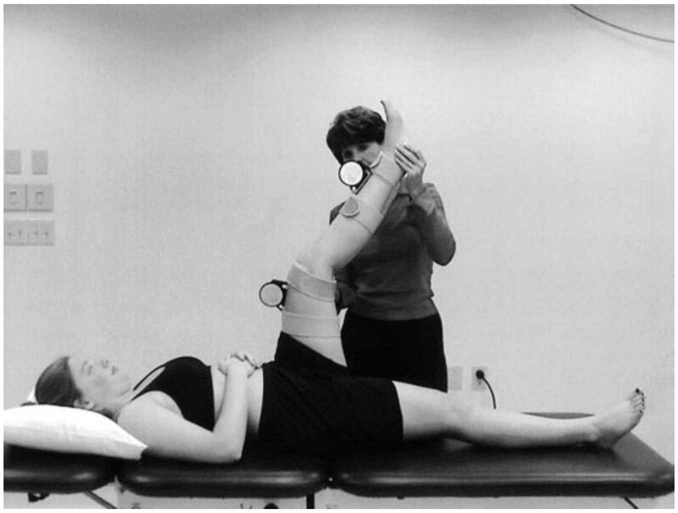

FIGURE 1. Measurement of hamstring flexibility with knee extension test.

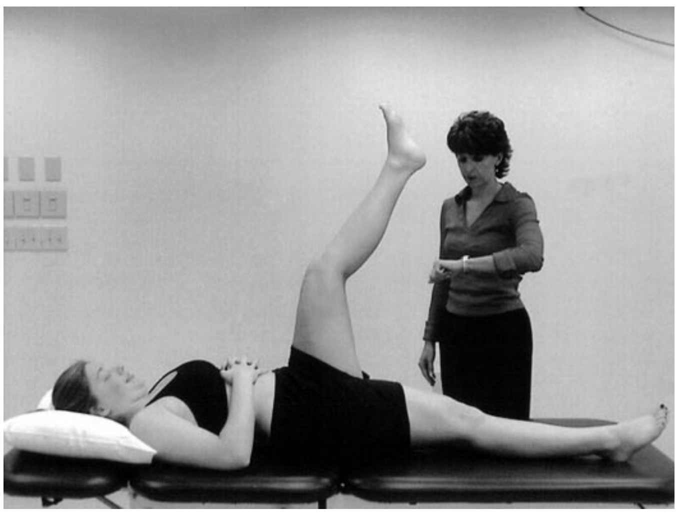

FIGURE 2. Self-stretching of the hamstring muscles.

tical analysis was 90°–θ, where θ is the actual knee angle from terminal extension.

The knee extension test has been shown to be a reliable measure of hamstring flexibility. Sullivan and colleagues (22) found the intratester reliability of the knee extension test to be 0.99 by using the inclinometer method. Webright and colleagues (23) also found high intratester (0.98) and intertester (0.98) reliability with the knee extension test by using a universal goniometer.

Stretching Protocols

Subjects who met the inclusion criteria were randomly assigned to 1 of 4 groups. Group 1 (3 men, 2 women) performed an active self-stretch under the supervision of an investigator (Figure 2). Subjects in this group were positioned supine on a treatment plinth and instructed when to begin and end the stretch, which was timed by the examiner. To stretch the right hamstrings, the right hip was actively flexed to 90° and the knee actively extended. The opposite lower extremity remained flat on the treatment plinth. The active self-stretch was maintained for 30 seconds. The same procedure was then performed with the opposite lower extremity. This procedure was chosen because it uses active quadriceps contraction as the stretching force, thus theoretically allowing reciprocal inhibition of the hamstring muscles.

Group 2 (3 men, 2 women) received a manual static stretch. Subjects in this group were positioned supine on a treatment plinth and instructed to relax as the examiner performed the stretch. To stretch the right hamstrings, the right hip was passively flexed to 90° and the knee passively extended until the subject reported a strong but tolerable stretch. The contralateral extremity remained flat on the plinth. The static stretch was maintained for 30 seconds. The same procedure was then performed with the opposite lower extremity.

Group 3 (3 men, 2 women) participated in a PNF-R stretch. Subjects in this group were positioned supine on a treatment plinth. To stretch the right hamstrings, the right hip was passively flexed to 90° and the knee passively extended until the subject reported a strong but tolerable stretch. Subjects were instructed to straighten their knee concentrically against the examiner's resistance (contracting the quadriceps) for 10 seconds. The investigator held the new position at a point of strong but tolerable stretch, as reported by the subject. The static stretch was maintained for 30 seconds. The same procedure was then performed with the opposite lower extremity.

Group 4 (2 men, 2 women) served as the control. Subjects in this group performed no stretching. Subjects in groups 1–3 met with an examiner 3 times per week for 4 weeks to participate in their respective stretching programs as described above. Each subject in each group performed one 30-second stretch per treatment session. Knee extension range of motion was measured before starting the stretching program, at 2 weeks, and at 4 weeks with the procedure described above.

Statistical Analyses

The data were analyzed with a 3 × 4 repeated-measures analysis of variance (ANOVA) with treatments nested within subjects. Before the investigation, the significance level was established at $p \leq 0.05$. Post hoc analysis with Tukey Honestly Significant Difference was performed to determine differences between the interaction of technique and time. A power analysis was also conducted for the interaction of technique and time. The data analysis was performed with the aid of a statistical consultant and JMP Version 4.04 (SAS Institute, Cary, NC).

RESULTS

Data analysis revealed a significant interaction ($p < 0.0016$) between the technique and the length of the stretching program. This suggests that the effectiveness of the stretching techniques depended upon the length of the stretching program. Power analysis revealed that power (1-β) equaled 0.96 for the interaction of technique and time. Table 1 shows the results of the repeated-measures ANOVA, and Table 2 lists the means for each technique by the length of the stretching program. Figure 3 shows an interaction plot between technique and time. Post hoc analysis revealed statistical differences among several combinations of technique and time.

A careful examination of Table 3 shows that at baseline there was no difference in hamstring length among the 3 stretching techniques and the control. At 2 weeks

Table 1. Repeated-measures analysis of variance.

Source	*df*	*F* ratio	Probability > *F*
Technique	3	2.76	0.708
Time	2	37.61	<0.0001*
Technique × time	6	3.93	0.0016*
Subject (technique)	15	13.8	<0.0001

* Significant variables ($p \leq 0.05$).

Table 2. Mean knee extension angle for each technique by time.*

	Control	PNF-R	Self-stretch	Static stretch
Baseline	51.4	57.1	54.6	61.5
2 wk	56.1	65.9	62.0	73.0
4 wk	54.6	70.2	66.1	85.2

* PNF-R = proprioceptive neuromuscular facilitation incorporating the theory of reciprocal inhibition.

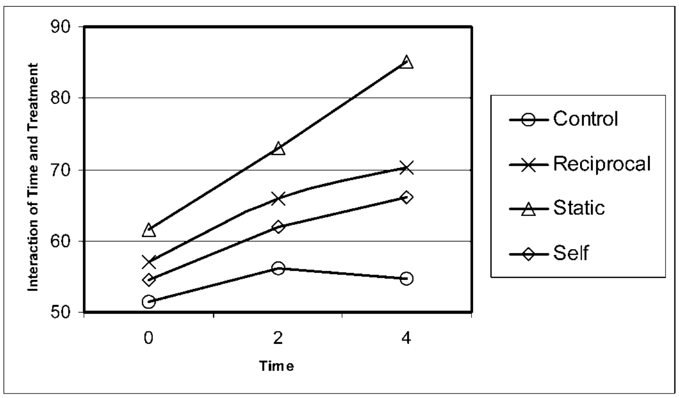

Figure 3. Interaction plot of technique and time.

Table 3. Tukey post hoc analysis.†

	C,0	C,2	C,4	R,0	R,2	R,4	Se,0	Se,2	Se,4	St,0	St,2	St,4
C,0	—											*
C,2		—										*
C,4			—									*
R,0				—		*						*
R,2					—							
R,4				*		—						
Se,0							—		*			*
Se,2								—				*
Se,4							*		—			
St,0										—	*	*
St,2										*	—	*
St,4	*	*	*	*			*	*		*	*	—

* Significant comparisons ($p \leq 0.05$).
† C = control; 0 = baseline; 2 = 2-week treatment duration; 4 = 4-week treatment duration; R = proprioceptive neuromuscular facilitation incorporating the theory of reciprocal inhibition; Se = self-stretch; St = static stretch.

of stretching, the only significant increase in hamstring flexibility over baseline occurred in the static stretching group. At 2 weeks, there was no difference in the effectiveness among any of the stretching techniques compared with the control. By 4 weeks, all 3 stretching techniques (static, PNF-R, and self-stretching) produced statistically significant improvements in flexibility from their own baseline. However, at 4 weeks, static stretching was the only technique found to be statistically greater than the control. Additionally, the only significant increase between weeks 2 and 4 occurred in the static stretching group. Despite the increase in hamstring length of the static stretching group over the control, no difference was found between static stretching and the other 2 stretching groups. Therefore, static stretching was the only stretching technique that increased hamstring flexibility over a control during a 4-week stretching program. On the basis of the results of this investigation, static stretching for 30 seconds 3 times per week for 4 weeks is an effective method of increasing hamstring length in young healthy adults. Stretching 30 seconds 3 times per week with self-stretching and PNF-R stretching did not show a significant increase in hamstring length over a control when performed during a 4-week stretching program.

Discussion

The results of this investigation provide evidence to help answer 2 main questions: (a) Is there a difference in the effectiveness of 3 common stretching techniques when the stretching parameters are consistent among the stretching techniques, and (b) can improvements in hamstring length be seen with stretching programs that are less than 4 weeks in length? The results of this investigation suggest that static stretching was the only effective technique for increasing hamstring length in this population when using one 30-second stretch 3 days per week for 4 weeks. Despite increases over the baseline value, active self-stretching and PNF-R stretching did not demonstrate a significant increase in hamstring flexibility with a stretching dose of 30 seconds performed 3 days per week for 4 weeks. As discussed previously, several investigations that have compared stretching techniques have used an inconsistent stretching dose or durations less than 30 seconds, as suggested by Bandy and Irion (1), which make direct comparison based on technique impossible.

The results of this investigation suggest that significant improvements in hamstring length cannot be achieved with a 2-week stretching program that incorporates a 30-second stretching dose. This investigation contradicts the findings of Ross (18), which showed significant improvement in hamstring length during a 2-week stretching program. This difference is most likely because Ross (18) used five 30-second stretches for a total daily dose of 150 seconds 5 days per week during the 2-week training program.

The results of this investigation support the findings of Bandy and Irion (1) and Bandy and colleagues (2), who concluded one 30-second static stretch is an effective dose for increasing hamstring length. However, Bandy and colleagues (2) used a frequency of 5 days per week for 6 weeks.

This investigation does not supports the findings of researchers who reported that active self-stretching and PNF-R stretching are capable of significantly increased hamstring flexibility compared with a control (3, 23). However, it is important to keep in mind that Bandy and colleagues (3) again used a frequency of 5 days per week for 6 weeks and that Webright and colleagues (23) used thirty 1-second stretches twice daily during a 6-week stretching program.

This investigation contradicts the findings of previous investigators (14, 15, 19) who found PNF inhibition techniques to be more effective than static stretching. One of the most likely reasons for the difference in findings was that this investigation used a 30-second static stretch, as suggested by Bandy and Irion (1), as compared with a 6-second static stretch used by Sady and colleagues (19) and a 9-second static stretch used by Moore and Hutton (14).

When reviewing the results of this investigation, it is conceivable to ask why static stretching was the only stretching technique effective at increasing hamstring length. It has been theorized that a slow static stretch facilitates the GTO, which may produce inhibition of the muscle that is stretched. Self-stretching and PNF-R require an active contraction of the opposing muscle (quadriceps), which, according to Moore and Hutton (14) and Osternig et al. (15), actually facilitates the hamstring muscles. Therefore, the mechanism by which PNF functions may not be related to the long-held theory of neural inhibition associated with prestretch contractions. The authors speculate that other mechanisms such as mechanical elongation or creep of the connective-tissue components of the muscle while in the presence of inhibition of the GTO during passive static stretching may be the overriding difference.

This investigation clearly outlines the parameters and procedures used with each stretching technique. Previous investigations have been inconsistent with terminology, used inconsistent stretching parameters, and failed to adequately describe the stretching procedures for the PNF stretching techniques (4, 12, 14, 15, 21, 22).

One of the limitations of this investigation is the sample size. Despite the limited sample size, the response to stretching was great enough in the static stretching group to identify a statistically significant difference between the interaction of stretching technique and time at the level of significance ($p < 0.05$). Power analysis revealed ample power ($1-\beta = 0.96$) for the interaction of stretching technique and time. It is also important to keep in mind that the sample included only healthy young adults, and the results of this investigation should not be generalized to persons outside the sample population. Additionally, because the hamstring muscles were the only muscles tested, it would be inappropriate to generalize the results of this investigation to other muscles or muscle groups. Further investigation in this area is needed to compare other forms of PNF stretching with static stretching by using consistent parameters and to determine the most effective parameters for PNF stretching.

PRACTICAL APPLICATIONS

The purpose of this study was to compare 3 common stretching techniques by using the same stretching parameters on the hamstring muscle group in healthy young subjects and to determine if a stretching program of 2 and 4 weeks is capable of producing significant gains in hamstring flexibility. The results of this investigation revealed that static stretching of the hamstrings is more efficacious than self-stretching and PNF stretching that incorporates the theory of reciprocal inhibition when using a 30-second stretching dose applied 3 days per week for 4 weeks. On the basis of the results of this investigation, strength and conditioning specialists are encouraged to use one 30-second static stretch 3 days per week for at least 4 weeks with their athletes and clients who have tight hamstrings. Also, strength and conditioning specialists should recognize that intensity, dose, frequency, and program duration are just as important with muscle stretching as with strength training.

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Acknowledgments

This study was approved by the Institutional Review Board for the Protection of Human Subjects, Office of Sponsored Programs, West Virginia University, Morgantown, WV.

Address correspondence to D. Scott Davis, dsdavis@hsc.wvu.edu.