Effects of a 3-Minute Standing Stretch on Ankle-Dorsiflexion Range of Motion

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Context: Stretching exercise regimens are routinely prescribed to increase range of motion (ROM) and diminish injuries. Objective: To examine the effect of a 3-minute passive stretch on ankle-dorsiflexion ROM in a nonpathological population. Setting: University laboratory. Design: Prospective, randomized, controlled study. Participants: 24 apparently healthy volunteers. Interventions: Subjects stood with their heels suspended from the edge of a platform. The experimental subjects stretched for 3 minutes on 3 consecutive days. Main Outcome Measures: Passive ankle-dorsiflexion ROM. Results: Ankle-dorsiflexion ROM increased significantly (P < .0005) over the course of each day’s stretch. No significant gains in ankle-dorsiflexion ROM were realized over 3 days. Conclusions: These findings suggest the need for further research to determine the stretching frequency and duration that will result in lasting increases in ankle-dorsiflexion ROM. Key Words: exercise, stretching, creep, measurement, stretch frequency and duration

An adequate excursion of joint range of motion (ROM) is required if functional activities are to be accomplished in a normal fashion. At the ankle, the excursion required varies considerably depending on the activity. During the stance phase of gait, ankle dorsiflexion typically reaches approximately 10°.1 During sit-to-stand, stair negotiation, and certain athletic and sports activities in which the lower limb is loaded and the knee is flexed, ankle-dorsiflexion ROM (ADROM) can surpass 25°.2-5 Sufficient ROM might also be important in preventing injuries.6-9 Pope et al reported that limited “ankle dorsiflexion range of motion was a strong predictor of injury.”9,p165

The literature supports the idea that stretching regimens can increase ROM.10-18 Consequently, stretching exercise regimens are routinely prescribed for that purpose.4,13-16,19,20 The effectiveness of regimens that differ in regard to frequency, intensity, duration, speed, or type of stretch (ie, static, passive, ballistic, or proprioceptive neuromuscular facilitation)13,14,19,20 has been studied extensively; however, an agreement on the best approach has not yet been reached by researchers.10-20 Studies conducted to identify regimens that are successful in increasing ADROM are summarized in Table 1.

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Table 1  Summary of Related Studies on the Effects of Stretching on Ankle-Dorsiflexion Range of Motion (ADROM)

<table>
<thead>
<tr>
<th>Author</th>
<th>Treatment regimen/ Number of days</th>
<th>Method of stretch</th>
<th>Method of measurement</th>
<th>Subjects</th>
<th>ADROM increase (°)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zito et al(^{17})</td>
<td>15 seconds × 2/1 day</td>
<td>Standing with heel suspended off platform</td>
<td>Protractor on slides projected onto paper</td>
<td>19</td>
<td>1.1 poststretch, immediate; 2.8 poststretch, 10 minutes; (mean changes)</td>
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<tr>
<td>Bohannon et al(^{13})</td>
<td>5-minute passive stretch/1 day</td>
<td>Wall stretch</td>
<td>Protractor on slides projected onto paper</td>
<td>36</td>
<td>1.4–2.3 in experimental group (mean changes)</td>
</tr>
<tr>
<td>Worrell et al(^{22})</td>
<td>20 seconds for 6 repetitions/1 day; practice session: 10 sessions over 14 days</td>
<td>Wall stretch</td>
<td>Goniometry</td>
<td>19</td>
<td>Knee flexion, 4.0; knee extension, 5.7 (mean changes)</td>
</tr>
<tr>
<td>Grady et al(^{15})</td>
<td>0.5-minute stretch/1 day, 2.0-minute stretch/1 day, 5.0-minute stretch/1 day</td>
<td>Wall stretch</td>
<td>Tractograph (with and without knee extended)</td>
<td>25</td>
<td>0.5, 2.0, 5.0 minutes; knee flexion, 2.6, –0.2, 2.2; knee extension, 2.2, 2.3, 2.7</td>
</tr>
<tr>
<td>Moller et al(^{16})</td>
<td>Bicycle ergometer 50 W for 15 min, 8-second stretch for 6 muscle groups repeated 5 ×/1 day</td>
<td>Wall stretch</td>
<td>Goniometry (with and without knee extended)</td>
<td>8</td>
<td>30, 60, 90 minutes; knee flexion, 6.0, 4.0, 3.0; knee extension, 4.0, 4.0, 2.0</td>
</tr>
<tr>
<td>Kirsh et al(^{19})</td>
<td>60 seconds × 2 trials/1 day</td>
<td>Controlled actuator displacement-passive stretch in supine</td>
<td>Electrohydraulic rotary actuator-potentiometer</td>
<td>12</td>
<td>Torque (not °): trial 1, 0.89–1.0; trial 2, 0.85–0.95</td>
</tr>
</tbody>
</table>
These studies are similar in that they all examined the effects of stretching on a single day.\textsuperscript{13,15-17,19,21} The duration of stretch differed between the studies (from 15 seconds to 5 minutes), but the findings support gains in ROM with both shorter and longer durations of stretching.\textsuperscript{13,15-17,19,21} Given the differences in the parameters of the stretching regimens summarized, it is difficult to determine the most appropriate stretching exercise regimen to increase ADROM. Further research is necessary to direct clinicians in how to best go about increasing ADROM. We wanted to examine the effects of stretching on ADROM over successive days.

The purpose of this study was to evaluate the effect of a 3-minute passive-stretching regimen, applied over 3 consecutive days, on ADROM. Our hypothesis was that standing subjects who underwent passive stretching for 3 minutes on each of 3 consecutive days would demonstrate significantly greater gains in ADROM than would subjects who did not participate in the stretching regimen.

**Methods**

This was a randomized, controlled trial of short duration. It involved an experimental group that participated daily in a 3-minute stretching regimen and a control group that did not. The project was approved by the human subjects’ review committee at the University of Connecticut.

**Subjects**

Twenty-four volunteers (12 women and 12 men) participated in this study after providing written informed consent. Stratified random assignment was used to place the male and female subjects in the control or experimental groups. According to self-report, all subjects were free of injury, not currently stretching, and did not change their activity during the study. The subjects were informed of the need to maintain their current activity level, because a change could potentially affect the measurement of ADROM. The subjects’ mean age was $24.7 \pm 4.5$ years, and their mean mass was $69.0 \pm 11.4$ kg.

**Instrumentation**

Two low-profile BORG digital scales (BORG Electronic Scale, Newell Group, Rockford, Ill) were used to test subjects’ ability to distribute their weight symmetrically through the lower extremities. A 35-mm digital camera (Digital Mavica, MVC-FD7, Sony Corp, Japan) was used to save the digital images of ADROM on multiple disks. Stretching took place while subjects stood on a $50 \times 50 \times 25.5$-cm platform that included a 0.5-cm-thick dense foam pad on one side to diminish discomfort under the metatarsal heads during the stretch. A second platform, $91.5 \times 61 \times 12.5$ cm, was positioned
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under the first one to raise it to the level of the camera. A stopwatch was used for relevant timing. A Borg rate of perceived discomfort scale (range 0–10) was used by subjects after each stretching session to quantify the degree of stretch they perceived.22 The imaging software ACD View (ACD Systems, Ltd, Westborough, Mass) was used to save the digital images on a computer hard drive.

**Procedures**

To expedite the measurements, each subject first sat on a plinth while one of the researchers gently dorsiflexed the subject’s ankle. The same investigator used a permanent marker to mark x’s on 4 bony landmarks on the lateral side of the right lower extremity (chosen on the basis of laboratory constraints) of each subject. The fibula head and the lateral malleolus served as the proximal landmarks. The base of the fifth metatarsal and the lateral side of the heel served as distal landmarks, as shown in Figure 1. The subjects were fitted with a single posterior upright brace to maintain the knee in full extension during the stretch (Figure 1).

The subjects were asked to step onto the 2 low-profile BORG digital scales and attempt (without looking at the scales) to distribute their weight equally across the lower extremities. All demonstrated the ability to distribute their weight with less than a 5% deviation from symmetry. A digital camera was aligned so that the image plane was parallel with the plane of

![Figure 1](image.png) Experiment set-up. Note landmarks, placement of the metatarsal heads, and knee orthosis.
motion of the ankle and centered so that the field of view was aligned with the ankle-joint axis of rotation.

The subjects were instructed to stand with their backs against a sliding board that was placed against the wall to reduce friction between their backs and the wall. They were then instructed to suspend their heels beyond the edge of the platform with equal weight distribution. The feet were placed in a standardized position so that the metatarsal heads rested on and at the edge of the platform (Figure 1). The distance from the distal end of the great toe to a permanent line on the platform was measured while the subject’s ankle remained in a neutral position to improve accuracy of foot placement with consecutive trials over the 3 days. Once properly positioned, the subjects were instructed to actively dorsiflex their ankles and then relax, allowing their heels to drop down. All subjects were allowed 5 seconds to get accustomed to the platform and the desired position during passive ankle dorsiflexion. During this time, before each photograph was taken, the subjects were reminded to stand with their weight equally distributed between their feet (which were shoulder-width apart), keep their backs against the wall, knees extended, arms at their sides, and head forward and to remain fully relaxed. This method of stretching was chosen because it approximates a common self-stretching technique described in resources used by many physical therapists.

The initial measurement of ADROM was made after 5 seconds, which allowed active dorsiflexion of the ankle and enough time to give the subject a verbal reminder of proper positioning during the stretch. After obtaining the initial image, the control-group subjects stepped down from the platform and stood stationary next to it so as not to provide an unintentional stretch. After 3 minutes, they were given 15 seconds to reposition themselves into ankle dorsiflexion and relax before the second image was taken. The subjects were instructed to follow the same procedures as described earlier. Subjects in the experimental group were instructed to stand and stretch on the platform for 3 minutes as described above. A digital image was taken every 30 seconds while the experimental subjects stretched for the duration of 3 minutes. The measurements were obtained for 3 consecutive days at approximately the same time of day (± 1 hour).

Digital images for all subjects were printed out, and 2 lines were drawn connecting the distal and proximal landmarks. The same investigator used a protractor to measure the intersection of the 2 lines, and the measurement was expressed in degrees of ROM. This measurement procedure has been documented in other publications. A reliability coefficient of .92 has been reported.

While transferring the digital images of ADROM onto paper, we discovered that one of the disks was corrupted, resulting in a loss of 4 individual images, all from the control group. The results of our multifactorial analysis were dependent on the values of ADROM for the initial image on day 1 and the final image on day 3 of the experiment. Two of the individual
images lost occurred on the initial or final image. Only 2 of the 4 subjects were able to return and repeat their trials; therefore, 2 images (out of 324 total images, out of 24 control images) were missing. The missing values for these 2 images were replaced using estimation methods (linear interpolation) for replacing missing values according to the guidelines suggested in the SPSS program, version 9.0 (SPSS Inc, Chicago, Ill). The replacement of missing values is advisable and justified according to Little and Rubin.25 Our analysis of the data incorporated these replacement values.

Data Analysis

Before calculating statistics relevant to the purpose of this study, we examined the reliability of the measurements using the initial ADROM values of each day of the control group. The intraclass correlation coefficient (ICC2,1) was .898. The standard error of the measurement was 1.82°.

Descriptive statistics were used to summarize the change in ADROM measured over the 3-minute period. The means and standard deviations of ADROM were calculated for the subjects in the control group and the experimental group. A 2 × 2 × 3 mixed-model multifactorial analysis of variance (ANOVA) was used to examine the effects of group (experimental vs control), measurement (each day’s initial vs final measurement), and day (day 1, day 2, and day 3) on ADROM. In addition, 1-way repeated-measures ANOVAs and trend analysis were used to examine the nature of changes over the course of the 3-minute stretch in the experimental group (alone) on each day. That analysis employed the initial and final measurement, as well as measurements obtained at 30-second intervals. Data analysis was conducted with the Systat 9.0 statistical package (SPSS Inc).

Results

Table 2 summarizes the individual measurements of ADROM for both the control and the experimental group. In an effort to further clarify the results, Table 2 summarizes the changes in ADROM for both groups over a 3-minute time period (180 seconds). These findings revealed that each day, the subjects undergoing the 3-minute stretching regimen had a larger mean difference in ADROM (2.9°, 5.5°, 5.0°) than that of subjects in the control group (–0.6°, 1.3°, 0.7°). The mean score on the Borg rate of perceived discomfort scale during these stretches was 2.4/10.0, indicating that all subjects judged the stretch to be associated with minimal discomfort.

The 2 × 2 × 3 multifactorial ANOVA for the effects of group, measurement, and day on ADROM revealed that there was no significant difference in ADROM between groups (F = 0.001, df = 1, P = .975) or days (F = 2.421, df = 2, P = .101). That is, ADROM was not greater in the experimental group than in the control group and was not greater on the third than on the first or second day. ADROM after 3 minutes, however, was greater than
<table>
<thead>
<tr>
<th>Time (s)</th>
<th>Control</th>
<th>Experimental</th>
<th>Control</th>
<th>Experimental</th>
<th>Control</th>
<th>Experimental</th>
<th>Control</th>
<th>Experimental</th>
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<tbody>
<tr>
<td>0</td>
<td>23.0 ± 5.7</td>
<td>21.4 ± 10.1</td>
<td>21.6 ± 6.2</td>
<td>18.9 ± 8.9</td>
<td>20.7 ± 5.5</td>
<td>19.3 ± 9.5</td>
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<tr>
<td>30</td>
<td>23.3 ± 10.6</td>
<td>19.9 ± 10.5</td>
<td>20.5 ± 10.1</td>
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<tr>
<td>60</td>
<td>22.8 ± 10.6</td>
<td>21.1 ± 10.5</td>
<td>21.2 ± 10.4</td>
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<tr>
<td>90</td>
<td>22.9 ± 10.2</td>
<td>21.8 ± 11.6</td>
<td>21.5 ± 10.8</td>
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<tr>
<td>120</td>
<td>23.0 ± 10.7</td>
<td>23.5 ± 11.0</td>
<td>22.5 ± 10.4</td>
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<tr>
<td>150</td>
<td>24.0 ± 10.8</td>
<td>23.7 ± 10.7</td>
<td>23.4 ± 10.4</td>
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<tr>
<td>180</td>
<td>22.4 ± 5.9</td>
<td>24.3 ± 10.7</td>
<td>22.9 ± 5.8</td>
<td>24.4 ± 11.2</td>
<td>21.4 ± 5.4</td>
<td>24.3 ± 9.9</td>
<td></td>
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</tr>
<tr>
<td>Change, 0–180</td>
<td>−0.6 ± 0.2</td>
<td>2.9 ± 0.6</td>
<td>1.3 ± 0.4</td>
<td>5.5 ± 2.3</td>
<td>0.7 ± 0.1</td>
<td>5.0 ± 3.0</td>
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it was on the initial measurement ($F = 32.567, df = 1, P < .001$). There was also a group-by-measurement interaction ($F = 20.599, df = 1, P < .001$), indicating that the experimental group demonstrated a greater increase over 3 minutes of stretching than the control group demonstrated over 3 minutes of standing.

The follow-up ANOVA on experimental-group data revealed that ADROM measurements increased significantly ($F = 17.818, df = 1, P < .0005$) over the course of each day’s stretching period (180 seconds). Trend analysis revealed a significant linear trend for these within-day ROM measurements ($F = 33.328, df = 1:11, P < .0005$). Figure 2 illustrates this linear trend of passive ADROM during the 3-minute stretch for each of the 3 days the experimental group participated in the stretching regimen.

Discussion

Our results indicated that a single 3-minute passive stretch of the ankle joint repeated over 3 days produced no significant increase in ADROM across days. There was, however, a significant increase in ADROM during the 3 minutes that experimental subjects underwent stretching on each day. This increase notwithstanding, the mean ADROM measurements at the end of each day were almost identical for subjects in the experimental group. We are unsure as to what contributed to this finding.

Figure 2  Trend analysis of passive ankle-dorsiflexion range of motion for the experimental group.
Increases in ADROM accompanying our stretching regimen were consistent with the results of Bohannon et al, who reported that a single 5-minute stretch at the ankle produces small increases in ADROM. The magnitude of the difference on each day ($2.9^\circ$, $5.5^\circ$, and $5.0^\circ$) was greater than those of Bohannon et al ($2.3^\circ$), possibly as a result of our method and duration of stretch over 3 days. Our findings were also consistent with those of Worrell et al, Grady et al, and Kirsh et al, who all reported a significant increase in ADROM in healthy subjects. Table 1 provides readers with an overview of the studies investigating the effects of stretching on ADROM. Those studies did not address lasting changes.

We undertook our study believing that studies focusing on multiple bouts of stretching over time appear more relevant in clinical practice because individuals who participate in a stretching exercise program will most likely perform the stretching exercises repeatedly over a period of time rather than in a single bout. Several studies conducted on other muscle groups have reported that the effects of stretching over multiple days have resulted in gains in ROM. Li et al, for example, found that static stretching of the hamstrings for 15 seconds, 10 times daily, over the course of 3 weeks increased hip flexion. Halbertsma et al identified significant increases in hip flexion after a series of 15-second static stretches, 10 times each day, for a period of 3 weeks. Bandy et al reported that 30 seconds of static stretching performed 5 days a week for 6 weeks was more effective in increasing hamstring flexibility than was no stretching. The differing biomechanics between the hip and ankle joint might explain why more of the hamstring studies we examined produced significant results over multiple days. Although Selby-Silverstein reported gains in ADROM after bivalved serial casting for 40 minutes, 2 times a day, over a period of 6 weeks, it might be attributable to the longer duration and frequency of stretch than in our study.

These findings suggest that passive stretching does increase ADROM temporarily. This we would attribute to creep, that is, the tendency of a viscoelastic material (musculotendinous unit) to deform as a load (body weight) is applied over time (3 minutes). Unfortunately, the effect largely disappeared over the 24-hour hiatus between days, indicating that a 3-minute passive stretch did not produce lasting changes in ROM. Our results indicate that although the muscle-tendon unit will respond to passive stretch, it has a tendency to return to its initial resting length after the deforming load is removed. Structural changes, therefore, appear not to have taken place.

Given daily use, one would expect some degree of resistance to stretch by the ankle plantar flexors. Baggett and Young explained that during ambulation, the ankle (and other lower limb segments) is subject to both internal and external forces. These forces produce torques that result in the desired limb-segment motion. Without the appropriate amount of ADROM, the joint would not function properly. The triceps surae might be
one example of a muscle group that responds differently than other muscle groups to stretch, given its role in daily functional activities.

The results of our study did not concur with those of other studies that examined gains in ROM with stretching over multiple days. In part, we attribute this to our methods. We were only able to measure the effects of 3 days of passive stretch because of the subjects’ schedules. In future studies, the use of longer-duration studies should be considered. Another change that might alter the outcomes would be to measure the forces applied by the subjects on each day. Furthermore, we did not quantify the subjects’ ability to relax during the stretching regimen.

Although electromyography (EMG) could be used to measure the amount of activation of the muscle, it is not typically used during sport stretching regimens. Although EMG might result in increased control, it could also threaten generalizability. Finally, we examined the effect of stretching on ADROM in a healthy population; these same applications might have a different response in those with pathological conditions.

Conclusion

The results of this study indicate that a 3-minute passive stretch of the ankle over 3 days produces linear increases in ADROM over the course of each day’s 3-minute stretch. It did not, however, produce a sustained increase in ADROM among apparently healthy individuals. Therefore, we cannot recommend a stretching regimen such as we employed if the goal is to increase ADROM. Further research is necessary to determine the appropriate stretching frequency and duration to result in lasting changes in ADROM.

Acknowledgment

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References


