Effects of Stretching the Gastrocnemius Muscle

Many authors currently disagree on the amount of time necessary to provide an adequate stretch flexibility. Since gastrocnemius equinus has been recognized as a cause of athletic injury, the authors performed a study to test what may be an adequate amount of stretching a gastrocnemius to improve flexibility. This study could not be conducted blind, and it was hoped that the contralateral leg could offer some control. The results of this study are presented here and should be kept in mind when evaluating and treating patients with ankle equinus, especially when considering surgical intervention.

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Flexibility exercises have become synonymous with athletic training. Surveying recent sports medicine-related articles along with popular sports magazines has not yielded concise findings on the amount of stretching required to create an increase in flexibility (1–13). It is acknowledged that stretching is important in order to increase flexibility and therefore, the range of motion of the involved joint area and muscle efficiency (1, 2, 13, 14). Many fitness-minded individuals concern themselves with strengthening muscles without taking time out to increase flexibility (4). Many injuries are due to a lack of flexibility (4, 14). As a result, physicians often prescribe stretching as a part of a treatment plan for many types of injuries.

Though it is easy to find many articles describing the benefits of stretching and how it improves athletic performance, there is a distinct lack of literature on how long a period of time it takes to get actual lengthening of a muscle (2–14). In 1941, Cureton noted flexibility exercises, "if built up to sufficient dosage, may condition muscles, tendons, ligaments, and bones to greater tensile strength and elasticity, a factor to which is basic to prevent injury in many sports" (14). Unfortunately, no studies have been made defining the "sufficient dosage" required. One recent study done by Madding *et al.* (1) measured flexibility immediately after stretching, but not on a long term basis. A study was done in Sweden on soccer players, testing the same basic area this project investigates, flexibility of the posterior leg muscles. Wiktorsen-Moller *et al.* (13) tested the effects of various combinations of massage (kneading the muscle group for an average of 12 min.) warming up (15 min. on an exercise bicycle), and stretching (the time period was not specified), on the flexibility of the lower extremity. Ankle dorsiflexion, which indicates flexibility of the posterior leg muscles, was measured using a fleximeter. The experimenters found the combination of stretching and a warm up produced greater than the warm up alone. (Stretching was not tested alone because it would not ordinarily be utilized without a warm up by soccer players.) Wiktorsen-Moller *et al.* noted no previous studies on the effects of stretching, massage, and warm up on the flexibility of the lower extremity.

There is also very little data on the duration of the specific stretch required to give beneficial results. Anderson (2) claims a stretching position must be held for 30 sec. in order to receive any benefit from the stretch. Some further predict a year's time may be needed to see benefits from the stretching. One study on EMG analysis has shown the type of stretching is insignificant, however, the majority of the literature reviewed states that a gradual or static stretch has best therapeutic results (1, 3, 10–12).

It is recognized that all persons cannot stretch to the same degree (1, 8). Frankel and Nordin (15) give a range of dorsiflexion for the ankle joints axis of 10 to 20 but note it can vary widely. In another Swedish experiment involving soccer players, Ekstrand and Gillquist (7) sought to correlate muscle tightness and injury. To evaluate the soccer players relative "tightness," they used a control group of 20- to 30-year-old males who did not play the sport. The soccer players' dorsiflexion value at the ankle joint, which again indi-

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0449/2544/91/3005-0465$03.00/0

cates posterior leg muscle tightness, was $\bar{x} = 21.4 \pm 4.0$. The nonplayers had a value of $\bar{x} = 24.8 \pm 4.0$. These measurements were done using a fleximeter. This experiment suggested soccer players are, in general, less flexible than nonsoccer players (7). Variances are found even when athletes are playing the same sport. Oberg *et al.* (9) measured lower extremity flexibility, again with soccer players, using a fleximeter. The range of dorsiflexion at the ankle joint ranged from $\bar{x} = 25.0 \pm 5.0$ for goal keepers, to $\bar{x} = 20.4 \pm 3.1$ for forwards (9).

Consideration of surgical treatment may be based on failure of conservative measures, such as stretching. Authors have indicated surgical procedures such as tendon lengthening, recession, and advancement. Appropriate cases should be considered if the stretching, orthoses, and casting have failed (16). This manuscript addresses specifically how much flexibility can be gained solely by stretching. Treatment results by other measures including surgery have not been clearly described. For instance, the amount of ankle dorsiflexion that would be gained by a certain surgical procedure has not been explicitly described in literature. The authors are excluding specific discussion dealing with the technique and effects of surgery for gastrocnemius equinus in this manuscript.

Theory

The investigators in this particular study seek to quantitate flexibility at the ankle joint by directing stretching exercises to the gastrocnemius muscle. One can distinguish gastrocnemius tightness (equinus) from the soleus and deep posterior leg muscles by changing the position of the knee. When the knee is extended, the gastrocnemius (and to a lesser extent, the plantaris), which takes its origin from the femur, limits ankle dorsiflexion. When the knee is flexed, the gastrocnemius is relaxed, and the soleus and the deep posterior leg muscles' tightness limit ankle dorsiflexion. By implementing the "wall stretch" with the knee extended (Fig. 1), one can increase the flexibility of the gastrocnemius (10, 17).

Current literature reports a large range of values for ankle joint dorsiflexion. Clinically, values of 10 degrees (of dorsiflexion) past perpendicular of foot to leg with the knee extended and greater than 10 with the knee flexed are accepted (17). Classically in podiatric medicine, the diagnosis of gastrocnemius equinus is made when there is less than 10 degrees of ankle dorsiflexion with the knee extended (17). The ankle dorsiflexion values reported in the Swedish studies above are much higher (7, 9, 13). Conversely, Walsh and Blackburn (12) found an average 3 degrees of ankle dorsiflexion with the knee extended in over 1000 athletes. The investigators postulate the latter value is more clinically accurate with the normal population.

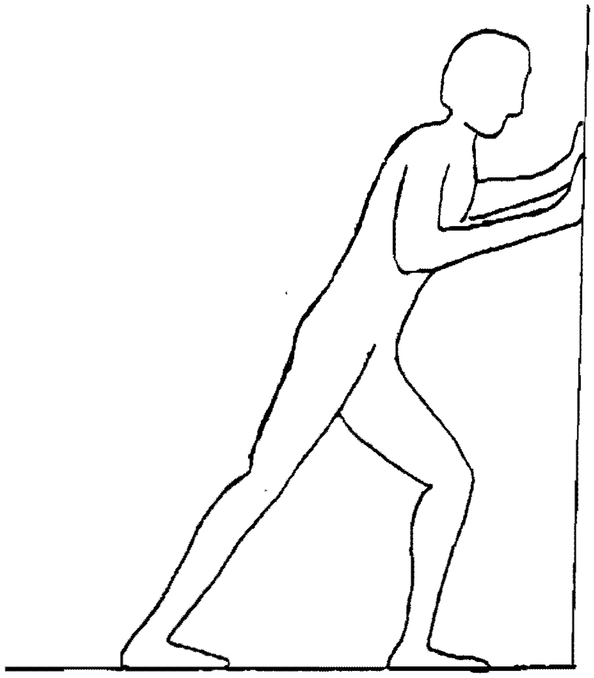

Figure 1. The "wall stretch" for increasing gastrocnemius flexibility. Note: Extended position of the knee on leg being stretched.

This study is designed to substantiate a normal range of values of ankle dorsiflexion with both the knees extended and flexed. This will be helpful clinically in order to avoid erroneously diagnosing and subsequently, treating a patient as having gastrocnemius equinus. Recently, Madding *et al.* showed that 15 sec. of static stretching was enough to temporarily increase flexibility; this study is concerned with actual clinical lengthening (1, 18). Therefore, the investigators seek to find the duration of static stretching needed to increase dorsiflexion of the ankle joint, over a 6-month time period. Because flexibility may vary greatly among individuals, especially with wide activity ranges, the investigators studied a healthy but relatively sedentary population. They propose flexibility can still be shown in relation to each individual's range of motion.

Material and Methods

The muscle tested was the gastrocnemius. The subjects in the study consisted of volunteer medical students. Each subject was carefully screened and evaluated for any type of foot, ankle, or leg deformity that could obscure results and hinder posterior leg flexibility (such as bony block ankle equinus and ligamentous laxity). Also recorded was each subject's age, present activity level, previous history of flexibility exercises, and the date of initial participation in the study. For each subject, bilateral measurements were taken for the amount of ankle dorsiflexion, both with the knee extended and flexed (yielding four separate measurements). During all measurements the foot was in a supinated position to avoid any component of dorsiflexion that occurs when the foot is allowed to pronate (17). Each measurement was recorded (in degrees of foot to leg dorsiflexion) by a tractograph, a commonly used clinical instrument (17, 19, 20). The lateral aspect of the fifth metatarsal was measured with respect to the longitudinal fibular bisector (15). Positive values (in degrees) indicate the foot-to-leg relationship is less than 90; negative values show the relationship to be greater than 90 (also known as equinus). Each screened volunteer was assigned a subject number. The subjects were instructed to stretch only one leg, which was randomly assigned. The opposite leg would serve as a control. Also randomly assigned was the time period (experimental group) for performing the stretch: 0.5, 2.0, and 5.0 min. a day. The gastrocnemius stretch was shown to each subject (Fig. 1). Upon proper demonstration by each subject, the investigators instructed them to perform the stretch once a day, barefoot, preferably at night. Subjects were told that they were to continue to stretch for a period of 6 months, and that random measurements of ankle dorsiflexion would be taken during that time frame. This was done to avoid any "incentive stretching" by subjects; if they knew when their measurement date was arriving, they may have increased the amount of flexibility exercises, giving falsely elevated results. Subjects were asked not to increase their activity level during the study.

The experiment was conducted uniblind (since the subjects had to know which experimental group they were in). Measurement of ankle dorsiflexion was performed by one investigator on all subjects (for consistency), while a second investigator recorded the values. Neither investigator knew of a particular subject's experimental group at the time of measurement.

The subjects' initial values of ankle dorsiflexion were collectively averaged to compare them with previous values recorded in the literature. These values were also compared between the groups to ensure that each experimental group had a similar range of ankle dorsiflexion. Measurements (after the initial values) were taken on randomly selected subjects at 3-, 6-, and 12-week intervals. Pre- (initial) and poststretch (26-week) values were compared to see whether a significant increase in flexibility could be attributed to the amount of time a muscle was stretched per day. The t-test was applied to the data collected to test for significant differences both within and between each experimental group.

Results

Twenty-five subjects with the mean average of 25.8 ± 2.52 years volunteered for the study. (There were 20 males and 5 females.) As a group, the initial average amount of ankle dorsiflexion with the knee extended was 2.86 ± 2.99; with the knee flexed, it was 9.02 ± 2.35 (Table 1).

Eight subjects (six males and two females) were randomly placed into the 0.5-min. stretch experimental group. These subjects' average age was 27.25 ± 3.96 years. This group's initial average ankle dorsiflexion with the knee extended and flexed was 2.84 ± 3.58 and 8.44 ± 2.60, respectively. At the conclusion of the study, the amount of increased ankle dorsiflexion with knee extended and flexed was 2.15 ± 3.25 and 2.60 ± 2.80, respectively. Of the eight subjects, seven improved their ankle dorsiflexion with both the knee extended and flexed on the side they were assigned to stretch. Three of the subjects (37.5%) in this group also increased the amount of ankle dorsiflexion with the knee extended on their contralateral (the unstretched) leg (Table 2).

The second experimental group, 2.0 min. of stretching, also had eight randomly assigned subjects (seven males and one female). The group's mean age was 25.15 ± 1.13 years. The initial amount of ankle dorsiflexion with the knee extended and flexed was 3.13 ± 2.77 and 10.13 ± 2.25, respectively. At the conclusion of the study, the amount of increased dorsiflexion with the knee extended and flexed was 2.30 ± 2.98 and −0.20

TABLE 1. **Statistics of subjects as a group**

Subjects = 25
Age = 25.8 ± 2.52 years
Degrees of ankle dorsiflexion with knee extended = 2.86 ± 2.99
Degrees of ankle dorsiflexion with knee flexed = 9.02 ± 2.35

TABLE 2. **Ankle dorsiflexion of the three experimental groups: 0.5, 2.0, and 5.0 min. of stretching**

	Initial Flexibility	Increase to Flexibility
0.5 Minutes		
Subjects = 8		
Age = 27.25 ± 3.96 years		
Dorsiflexion with knee extended	2.84 ± 3.58	2.15 ± 3.25
Dorsiflexion with knee flexed	8.44 ± 2.60	2.60 ± 2.80
2.0 Minutes		
Subjects = 8		
Age = 25.13 ± 1.13 years		
Dorsiflexion with knee extended	3.13 ± 2.77	2.30 ± 2.98
Dorsiflexion with knee flexed	10.13 ± 2.25	−0.20 ± 2.49
5.0 Minutes		
Subjects = 9		
Age = 25.11 ± 1.05 years		
Dorsiflexion with knee extended	2.64 ± 2.65	2.70 ± 3.90
Dorsiflexion with knee flexed	8.56 ± 2.21	2.20 ± 2.39

± 2.49, respectively. Six of the eight subjects improved their flexibility on the test leg with the knee extended and flexed with five subjects (62.5%) improving on the contralateral side (Table 2).

Nine subjects (seven males and two females) were randomly assigned to the third experimental group, which consisted of 5.0 min. of stretching. The group's mean age was 25.11 ± 1.05 years. The initial values of the ankle dorsiflexion with the knees extended and flexed were 2.64 ± 2.65 and 8.56 ± 2.21, respectively. Values of 2.70 ± 3.90 and 2.20 ± 2.39 for the amount of increased dorsiflexion with the knee extended and flexed, respectively, were recorded at the end of the study. Seven of the nine subjects improved their flexibility in the tested leg with both the knee flexed and extended. Additionally, three subjects (33.0%) increased their flexibility on the contralateral leg (Table 2).

The *t*-test was used to determine whether the prestretch values obtained at the conclusion of the study were significantly higher than the initial prestretch values of ankle dorsiflexion. This statistical analysis proved insignificant within each experimental group. The 5.0-min. group was the closest to being statistically significant ($p < 0.05$); a *t*-value of 1.720 was obtained ($t \leq 1.746$ was needed). The other *t*-values were 1.60 and 1.26 for the 2.0- and 0.5-min. experimental groups, respectively. The *t*-test and chi-square analyses were also applied to see whether there was a difference between each experimental group's mean amount of increased flexibility obtained. This was also statistically insignificant.

Discussion

The results indicated values for ankle dorsiflexion that are consistent with clinical findings (Table 1). Much higher values recorded in Scandinavian studies may be due to a difference in measurement procedure. In this country, a perpendicular or 90-degree relationship of the foot to the leg is recognized as the neutral (0) position of the ankle (12, 15, 17). Dorsiflexion of the foot from this position results in a positive value. Conversely, a plantarflexed attitude of the foot from neutral results in a negative value for ankle dorsiflexion (12, 15, 17). In the Scandinavian studies, the relaxed position of the foot, which is normally plantarflexion, may have been used as the neutral position of the ankle. This would increase the range and subsequently the amount of dorsiflexion recorded. Also, it is possible that the investigators in those studies allowed the foot to pronate, which allows for more ankle dorsiflexion.

This study substantiated that stretching the gastrocnemius increases the amount of ankle dorsiflexion with the knees extended. The results also allow one to predict that the longer one stretched, the greater the amount of increased flexibility (Fig. 2). An interesting finding from this particular study was that the contralateral limb, which the subjects did not stretch, showed increased flexibility in 11 of 25 (44%) of the subjects. This is consistent with research that has been done with proprioceptive neuromuscular facilitation. Patients who are unable to exercise an injured limb, exercise the unaffected side. This tends to decrease atrophy and limit the loss of flexibility and strength of the injured limb (21).

From the results of this study, one can predict that stretching for 0.5 min. a day increases flexibility and clinically lengthens the gastrocnemius. It would be interesting to see whether statistically significant results could be found with a larger subject population. However, it is hard to limit subjects' activities in order to isolate the empirical effect of stretching. Also, subjects may miss occasional days of stretching (which several subjects in this experiment admitted to doing).

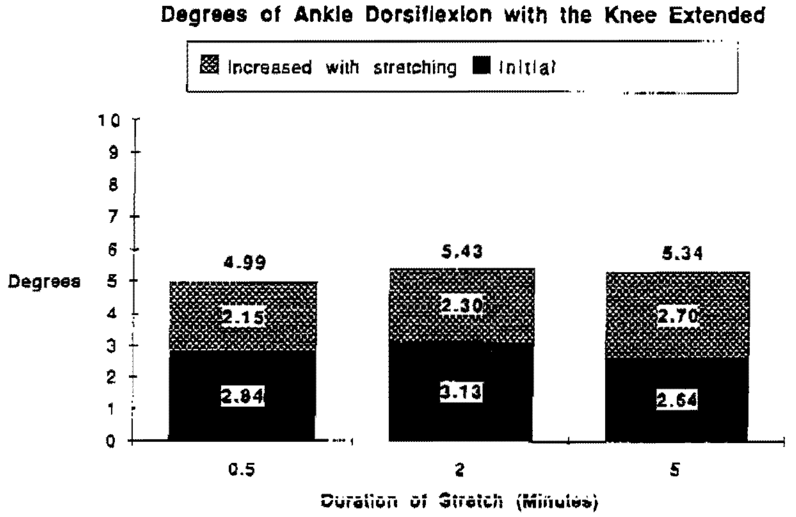

Figure 2. Degrees of ankle dorsiflexion with the knee extended.

Consideration of the study's findings, as compared with surgical planning to decrease ankle equinus should be heavily contemplated. Only if conservative treatment for ankle equinus of muscular etiology is unsuccessful in achieving a minimal increase in the ankle dorsiflexion should surgery be considered. Surgical procedures should increase ankle dorsiflexion more than conservative means, should surgical intervention be entertained. Stretching for at least 30 sec. increases ankle dorsiflexion; the amount of dorsiflexion increased by surgery is currently unspecified. Surgical gains may be lost to postoperative fibrosis and contracture, thus reducing dorsiflexion and necessitating additional conservative treatment (16). Clearly, additional investigation of both conservative and surgical treatment of the ankle (specifically gastrocnemius equinus) is needed.

The investigators suggest that controlled studies be done in order to demonstrate length of time, when stretching for a specific time period, to show increased flexibility. This would be helpful to clinicians evaluating patients' flexibility programs. The subjects in this particular study were healthy young adults, but not competitive athletes. Studies performed previously on athletes may be biased toward particular sports (7, 9, 12, 13). Athletes in sports that require jumping generally get increased strength in their anterior leg muscles, which can increase ankle dorsiflexion (22). Distance runners tend to obtain a relative atrophy of the anterior leg muscle compared with hypertrophy of their posterior leg muscle; this would decrease ankle dorsiflexion (2, 10, 11).

Conclusion

Much more research needs to be conducted regarding flexibility exercise in general, and certainly in gastrocnemius stretching. The results demonstrated here show the need for a larger study, to increase statistical significance. Nonetheless, the authors' consistent findings raise some interesting questions with regard to flexibility exercise. They also define what an average amount of dorsiflexion may be for this population (Table 1): 2.86 ± 2.99 with the knee extended, and 9.02 ± 2.35 with the knee flexed. Treatment, both conservative and surgical, may be altered based on these findings.

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