

Impact of Routine Gastrocnemius Stretching on Ankle Dorsiflexion Flexibility and Injury Rates in High School Basketball Athletes

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Background: Achilles tightness exacerbates a variety of foot and ankle conditions while increasing the risk of lower extremity injuries. The correlation between Achilles tightness and lower extremity injury rates in a young, athletic population is unknown.

Purpose: To evaluate the impact of routine gastrocnemius stretching on ankle flexibility and lower extremity injury rates in youth basketball athletes.

Study Design: Cohort study; Level of evidence, 3.

Methods: A prospective cohort study enrolling 8 high school basketball teams (4 male teams, 4 female teams) was conducted over a 3-month sporting season. Two schools (2 male teams, 2 female teams) were assigned to a daily gastrocnemius stretching protocol. Two control schools (2 male teams, 2 female teams) followed no protocol. Passive ankle dorsiflexion was measured bilaterally in both groups at 4 time points: preseason, 1 month and 2 months after the start of the season, and postseason (3 months from the start of the season). The number of injuries sustained during the season and the number of games missed because of a lower extremity injury were recorded. Differences in dorsiflexion flexibility measurements and injury rates were analyzed between the protocol and control groups.

Results: A total of 106 athletes (46 male, 60 female) were included in the study. The protocol group included 51 athletes (mean age, 15.7 ± 1.2 years) versus 55 athletes (mean age, 16.2 ± 1.0 years) in the control group. Athletes undergoing routine gastrocnemius stretching had significantly higher ankle dorsiflexion flexibility measurements compared with control athletes at all time points ($P < .05$ for each time point) while also demonstrating a significant increase in dorsiflexion between the preseason and postseason time points ($P = .04$). No significant difference in injury rates was appreciated between the protocol and control groups, and no difference in dorsiflexion flexibility measurements was appreciated between injured and uninjured athletes.

Conclusion: The implementation of a gastrocnemius stretching protocol in youth basketball athletes increased ankle dorsiflexion over a single season without decreasing the injury incidence relative to controls in our study. Because the size of our study limited statistical power, a confirmation of the results in a larger study is required.

Keywords: Achilles tightness; gastrocnemius stretching; pediatric; Achilles injury; athlete; basketball

Musculoskeletal injuries are common in athletes of all ages, with more than 2.6 million youth athletes treated in emergency departments annually for sport- and recreation-related injuries in the United States alone.^{1,2} Achilles tendon tightness with a resultant decrease in ankle dorsiflexion flexibility leads to increased stresses through the midfoot and forefoot during impact activities,¹ resulting in worsening of a number of adult^{2,6} and pediatric⁵ lower

extremity conditions. Moreover, recent studies have identified a high rate of Achilles tightness in children presenting with lower extremity injuries and pain.^{5,11,13} As a result, physicians treating youth athletes generally recommend routine lower extremity stretching exercises in those presenting with foot and ankle conditions with concurrent Achilles tendon tightness.

We hypothesized that based on prior studies,^{11,13} the implementation of a routine stretching program targeted at the gastrocnemius musculotendinous unit, thereby addressing Achilles tendon tightness and ankle dorsiflexion flexibility, may lead to decreased rates of lower

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extremity injuries and time lost from sport in youth athletes. The Achilles tendon is the confluence of tendons from both the gastrocnemius and the soleus muscle bellies. The stretching protocol employed in this investigation focused primarily on stretching of the gastrocnemius with the knee in extension.

No prior investigation has examined the use of a routine gastrocnemius stretching program as a means of primary prevention for lower extremity injuries in an athletic youth population. The purpose of this study was to prospectively examine the impact of a daily gastrocnemius stretching protocol on 4 high school basketball teams compared with 4 control teams on ankle dorsiflexion flexibility, incidence of lower extremity injuries, and time lost from play because of an injury over the course of the sporting season.

METHODS

The study protocol was preapproved by the institutional review board of the University Hospitals Cleveland Medical Center. After approval from athletic trainers, coaches, and athletic directors, 2 suburban and 2 urban high schools agreed to participate in the study. Male and female basketball athletes from participating schools were included within the study once consent was obtained from the athlete and guardian. Schools were randomized using a random-number generator to assign 1 suburban high school and 1 urban high school to the stretching protocol, while the remaining suburban and urban schools were not assigned any routine stretching protocol. Dorsiflexion measurements were performed by a single author (D.M.K.) on 4 separate occasions at each school for all teams over the course of the winter basketball sporting season: preseason (before any preseason games or scrimmages were played), 1 and 2 months after the start of the season, and postseason. All preseason and in-season measurements were performed after practices. Final postseason measurements were performed 1 day after the conclusion of the basketball season for each team, approximately 3 months from the start of the season.

Immediately after preseason measurements, athletes involved in the stretching protocol were observed and instructed by athletic trainers on the proper performance of gastrocnemius stretches while also being provided with an instructional sheet. The instructional sheet detailed the importance of keeping the knee of the stretched leg straight with the heel flat on the ground while slightly bending the front knee and pushing the hips toward a wall, holding the position for 10 seconds, and repeating the exercise 20 times for each foot 3 times daily over the course of the study.

Athletic trainers and coaches at stretching protocol schools were instructed to have their athletes perform the stretches at the beginning of practices and games while also reminding athletes on a daily basis to independently perform stretches 3 times daily. While no formal gastrocnemius stretching protocol was assigned to the remaining suburban and urban high schools, control athletes were not forbidden from engaging in any gastrocnemius stretching exercises. Athletes were excluded from the study if (1) a completed consent form was not returned to the study investigators before preseason measurements ($n = 42$ athletes), (2) athletes were rehabilitating from a pre-existing lower extremity injury sustained before study initiation that prevented the athlete from participating in practices or games ($n = 7$ athletes), or (3) athletes missed preseason or postseason measurements ($n = 14$ athletes).

Passive ankle dorsiflexion was measured using the methodology published by Liu and Xie.¹¹ The knee was extended to tension the gastrocnemius, the foot was inverted to lock the midfoot,^{4,6} and the ankle of each athlete was first brought through a gentle range of motion with full passive dorsiflexion stretching performed 3 times before measurements. Given that it has been our experience that adolescent Achilles tightness is almost always localized to the gastrocnemius,¹¹ stretches isolating the soleus were not performed. A goniometer was then placed on the lateral border of the foot with the other limb along the axis of the midtibia and the ankle flexed to maximal dorsiflexion, with the perpendicular angle between the anterior leg and lateral border of the foot defined at 0° (Figure 1). Any amount of dorsiflexion past this neutral point was measured and assigned a positive whole degree value. Measurements of both left and right ankles were obtained and were averaged at each time point to generate a single value. During the course of the study, any lower extremity injury sustained by participating athletes was communicated to the study investigators by the athletic trainers, along with the total number of games missed secondary to an injury and injury management (rest, ice, physical therapy referral, physician referral, emergency department evaluation with radiographs). Games missed were defined as athletes being unable to participate in an upcoming game(s) as a result of an injury during a prior practice or game. All injuries, treatments, and games missed were then verified with athletes at the subsequent measurement encounter.

Power analysis was performed using an alpha value of 0.05 and a target beta value of 0.8 with G*Power 3 statistical software.⁷ For an estimated small effect size ($d = 0.2$), the necessary sample size would be 394 participants in each of the 2 groups, while a medium effect size ($d = 0.5$) would

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Ethical approval for this study was obtained from the University Hospitals Cleveland Medical Center (No. 07-15-15).



Figure 1. Method for measuring ankle dorsiflexion.

require at least 64 participants in each group.³ Chi-square analysis was used to compare the consent form return rate based on athlete sex, study group, and high school location (urban vs suburban). After a nonsignificant Levene test, an unpaired *t* test was used to determine the impact of routine gastrocnemius stretching on ankle dorsiflexion flexibility in athletes enrolled in the stretching protocol versus control athletes at each time point while also comparing athletes sustaining injuries versus those without injuries in each group. Repeated-measures analysis of variance was used to compare measurements at each time point between athletes in the protocol group and those in the control group, with a nonsignificant Mauchly test. All analyses were performed using SPSS statistical software (v 25.0; IBM).

RESULTS

A total of 148 consent forms were initially distributed. Female athletes were significantly more likely to return consent forms compared with male athletes (88% vs 61%, respectively; $P < .001$), while athletes in the control group returned consent forms at a significantly higher rate when compared with athletes in the protocol group (83% vs 62%, respectively; $P = .005$). No significant difference in consent form return rates was appreciated when comparing urban versus suburban schools (78% vs 66%, respectively; $P = .010$).

In total, 106 athletes (46 male, 60 female) meeting inclusion criteria participated in the investigation. The mean age at the time of preseason measurements was 15.9 ± 1.2 years; athletes in the control group were significantly older than those in the protocol group (16.2 ± 1.0 vs 15.7 ± 1.2 years, respectively; $P = .02$) (Table 1). Athletes in the protocol group had significantly greater ankle dorsiflexion flexibility at the initiation of the study and at each time

TABLE 1
Overall Demographics and Characteristics of Athletes^a

	Protocol Group (n = 51)	Control Group (n = 55)	<i>P</i>
Age, y	15.7 ± 1.2	16.2 ± 1.0	.02
Ankle dorsiflexion, deg			
Preseason	12.7 ± 4.9	8.2 ± 5.1	<.001
1 mo	12.7 ± 4.9	9.6 ± 4.7	.001
2 mo	13.6 ± 4.3	10.0 ± 4.1	.012
Postseason	14.6 ± 4.4	9.5 ± 4.7	<.001
LE injuries, n	13	14	.37
Athletes with games missed, n	4	4	.98
Games missed because of LE injury, n	8	21	.45

^aData are reported as mean ± SD unless otherwise specified. Bolded *P* values indicate a statistically significant difference between groups ($P < .05$). LE, lower extremity.

point when compared with control athletes. Repeated-measures analysis of variance demonstrated that athletes in the protocol group had a significant increase in dorsiflexion between the preseason and postseason time points ($P = .04$). No significant increase was noted between any time points in control athletes (overall model, $P = .30$).

The protocol group included 51 athletes (26 male, 25 female) versus 55 athletes (20 male, 35 female) in the control group (Table 2). No significant difference in ankle dorsiflexion flexibility measurements was appreciated at any time point between male and female athletes in the protocol group. Female athletes were found to possess significantly greater dorsiflexion flexibility when compared with male athletes at all time points in the control group.

A total of 27 lower extremity injuries were reported during the course of the season, with 52% (14/27) of injuries involving athletes in the control group. Injuries primarily involved ankle sprains (22 sprains in 20 athletes), followed by knee sprains (2 sprains in 2 athletes) and quadriceps strains (2 strains in 2 athletes). One athlete in the control group was found to sustain a fifth metatarsal stress fracture without any known acute trauma, which was treated conservatively using a boot. No significant difference in the incidence of lower extremity injuries or the number of games missed because of an injury was appreciated between athletes in the protocol versus control group (Table 1) or based on athlete sex (Table 2). No significant difference in mean dorsiflexion measurements at any time point was appreciated in athletes sustaining injuries versus those without injuries in the protocol group, control group, or both the protocol and control groups (Table 3). A total of 4 athletes in the protocol group missed a total of 8 games (range, 1-3 games) due to injury compared with 4 athletes missing a total of 21 games (range, 3-10 games) in the control group. Athletes missing games in the protocol and control groups had no significant difference in dorsiflexion flexibility measurements when compared with athletes in the same group not missing games because of an injury.

TABLE 2
Demographics and Characteristics of Athletes by Sex^a

	Protocol Group			Control Group		
	Male (n = 26)	Female (n = 25)	P	Male (n = 20)	Female (n = 25)	P
Age, y	15.8 ± 1.3	15.5 ± 1.2	.35	16.3 ± 1.0	16.1 ± 1.1	.79
Ankle dorsiflexion, deg						
Preseason	13.2 ± 5.0	12.3 ± 4.9	.50	5.7 ± 4.9	9.4 ± 4.8	.008
1 mo	12.3 ± 4.2	13.0 ± 5.5	.63	7.8 ± 4.2	10.6 ± 4.7	.03
2 mo	13.0 ± 3.9	14.3 ± 4.7	.34	8.3 ± 4.1	11.1 ± 3.8	.03
Postseason	14.3 ± 3.5	15.0 ± 5.3	.59	6.7 ± 3.3	11.0 ± 4.7	<.001
LE injuries, n	8	5	.38	5	9	.83
Athletes with games missed, n	3	1	.32	2	2	.46
Games missed because of LE injury, n	5	3	.66	4	17	.31

^aData are reported as mean ± SD unless otherwise specified. Bolded *P* values indicate a statistically significant difference between groups (*P* < .05). LE, lower extremity.

TABLE 3
Dorsiflexion Measurements in Injured
Versus Noninjured Athletes^a

	Injured Athletes	Noninjured Athletes	P
Protocol group			
Preseason	13.0 ± 4.1	12.6 ± 5.2	.80
1 mo	12.8 ± 4.3	12.6 ± 5.1	.88
2 mo	13.3 ± 3.3	13.7 ± 4.6	.75
Postseason	13.3 ± 4.1	15.1 ± 4.5	.19
Control group			
Preseason	9.9 ± 5.5	7.7 ± 4.7	.23
1 mo	11.8 ± 4.5	9.0 ± 4.6	.08
2 mo	11.7 ± 3.9	9.4 ± 4.1	.11
Postseason	10.9 ± 4.5	9.1 ± 4.7	.23
Both groups			
Preseason	11.5 ± 5.0	10.0 ± 5.6	.33
1 mo	12.3 ± 4.4	10.4 ± 5.1	.23
2 mo	12.5 ± 3.6	11.5 ± 4.8	.78
Postseason	12.1 ± 4.4	11.6 ± 5.3	.88

^aData are reported as mean ± SD (in degrees).

DISCUSSION

The principal findings from this investigation were that youth athletes enrolled in a routine gastrocnemius stretching program experienced increased ankle dorsiflexion flexibility by 0.6° when compared with control athletes over the course of the study. Participation in the routine stretching protocol, however, did not provide a protective effect on the incidence of lower extremity injuries when compared with control athletes. Meanwhile, ankle dorsiflexion measurements were not found to have an impact on the number of games missed after lower extremity injuries in the context of an underpowered study.

Athletes performing routine gastrocnemius stretching were found to have increased ankle dorsiflexion flexibility when postseason measurements were compared with preseason measurements (*P* = .04) and when compared with control athletes at all 4 time points measured (*P* ≤ .01 for all). A systematic review by Radford et al¹⁴ of results from 5

trials similarly found that routine Achilles stretching led to a small (2.1°-3.0°) but statistically significant increase in ankle dorsiflexion. However, the included studies did not look at the pediatric population. Ultimately, those authors were unable to conclude if their results were clinically relevant with regard to the injury risk or perceived function by the patient.

While no difference in ankle dorsiflexion was appreciated between male and female athletes in the protocol group, female athletes in the control group demonstrated significantly greater dorsiflexion at all time points when compared with male athletes in the same group. An investigation by Hoge et al⁹ examined musculotendinous stiffness of the gastrocnemius and ankle joint range of motion in young male (n = 13; mean age, 21 ± 2 years) and female (n = 19; mean age, 21 ± 3 years) participants after acute passive dorsiflexion stretching. They reported a significant increase in ankle dorsiflexion in female but not male participants, while male participants were found to possess significantly higher musculotendinous stiffness values after stretching. A study by Riemann et al¹⁵ also reported higher ankle stiffness in dorsiflexion in healthy 18- to 30-year-old men (n = 12) when compared with similarly aged women (n = 12). As such, male patients appear to require higher intensity or longer durations of stretching to achieve comparable increases in ankle dorsiflexion when compared with female patients, accounting for the significant difference in dorsiflexion measurements between male and female athletes in the control group.

In this study, no reduction in the incidence of lower extremity injuries was appreciated in athletes undergoing routine stretching compared with control athletes. These findings are in line with 2 separate systematic reviews that similarly failed to show any correlation between Achilles stretching and the injury rate.^{8,16} Although this study found fewer overall games missed in athletes participating in the stretching protocol, the difference was not statistically significant. As such, the true impact of routine Achilles/gastrocnemius stretching on the incidence and severity of lower extremity injuries remains unknown, necessitating larger athlete sample sizes and longer follow-ups.

There are several important limitations of this study. No intraobserver reliability calculations were performed. However, a single grader performed all measurements, which eliminated the potential for interobserver variability. Moreover, because the primary purpose of this study was a comparison between groups rather than raw values, we felt that having a single grader was adequate. Despite the randomization of schools to protocol and control groups, the investigators were not blinded to the respective grouping of each school. A small sample size of athletes was enrolled in the study secondary to the number of participating schools and the number of athletes meeting inclusion criteria, as many potential participants failed to return completed consent forms. As such, our study sample size was underpowered to detect even a moderate-sized difference. This is reflected by the fact that even though the control group had 21 games missed versus 8 games missed in the protocol group, there was still no significant difference.

Despite reinforcing the importance of athletes remaining compliant with the stretching protocol, the overall compliance of athletes performing stretches 3 times daily in the treatment protocol is unknown and was not evaluated during the investigation. In addition, the difference in preseason dorsiflexion flexibility measurements between the protocol and control groups may have confounded subsequent flexibility measurements. While a statistically significant difference between groups was appreciated, it is unknown whether such a difference is clinically relevant. The mean increase of only 0.6° over the course of the study between the protocol and control groups is likely secondary to the study being underpowered. Furthermore, a previous study¹⁰ examining reliability measurements of ankle dorsiflexion in 20 healthy participants using a standard goniometer with a novice rater reported the standard error of measurement to be 1.8° to 2.8°, falling within the mean range of change measured in the protocol group over the course of our investigation.

CONCLUSION

The implementation of a gastrocnemius stretching protocol in active, youth basketball athletes increased ankle dorsiflexion flexibility over the course of the sporting season and at all time points when compared with athletes not enrolled in the stretching program. Increased ankle dorsiflexion was not found to provide a protective effect in decreasing the incidence of lower extremity injuries when compared with control athletes, although our study was underpowered. As such, further studies in a larger number of athletes across multiple sports are necessary to determine the impact of a strictly implemented gastrocnemius stretching protocol on the incidence of lower extremity injuries over the course of a sporting season.

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