Association between Achilles tightness and lower extremity injury in children

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Abstract *Background:* It is unclear whether isolated gastroc/soleus tightness can increase the risk of lower extremity injury in an otherwise healthy child. *Questions/Purposes:* (1) Is there a difference in gastroc/soleus tightness, as represented by ankle dorsiflexion with the knee extended, in children presenting with upper versus lower extremity complaints? (2) Is there a difference in gastroc/soleus tightness in children presenting with atraumatic versus traumatic lower extremity complaints? *Methods:* We performed a cross-sectional study of 206 consecutive walking age children presenting to a county orthopedic clinic with new upper or lower extremity complaints. Passive ankle dorsiflexion was measured based on the lateral border of the foot versus the anterior lower leg with the knee fully extended and the foot in inversion. *Results:* Average age was 10.0 ± 4.5 years. In the 117 patients presenting with upper extremity complaints, ankle dorsiflexion was $15.0^\circ \pm 11.6^\circ$. Of the lower extremity patients, 40 presented without trauma, with dorsiflexion of $11.8^\circ \pm 14.5^\circ$, while 49 presented with trauma, with dorsiflexion of $6.5^\circ \pm 12.0^\circ$. Multiple regression analysis found significantly decreased ankle dorsiflexion with increasing age and in the lower extremity trauma group. Twelve percent of upper extremity patients had 0° or less of dorsiflexion, as compared to 25% of lower extremity nontrauma patients and 41% of lower extremity trauma patients. *Conclusions:* Patients presenting with lower

extremity trauma had significantly more gastroc/soleus tightness in their well leg than patients presenting with upper extremity complaints. Gastroc/soleus tightness may present a simple target for reducing lower extremity injury rates in children.

Keywords Achilles contracture · pediatric lower extremity trauma · pediatric foot · pediatric ankle

Introduction

Tightness of the gastroc/soleus mechanism is known to exacerbate a number of adult [4, 9] and pediatric [15] conditions. The biomechanical importance of ankle dorsiflexion is widely described, and gastroc/soleus tightness leads to increased forces through the midfoot and forefoot [1], and altered gait mechanics have been found when a gastroc/soleus contracture is simulated [14]. Given this, it is common for physicians to include gastroc/soleus stretching and lengthening in their treatment plans for a variety of foot and ankle conditions.

The consequences of isolated tightness of the gastroc/soleus are less clearly defined. Studies have described increased ankle sprain incidences in patients with decreased ankle dorsiflexion [7, 17]. All of the patients from these studies were 15 years of age or older, and we are not aware of studies in younger children.

We have suspected a high rate of gastroc/soleus tightness in children presenting with ankle and foot injuries and pain. If this association were true, it could provide a simple target for reducing ankle and foot injury rates in children. To better define a potential relationship, we designed a cross-sectional study to answer the following questions: (1) is there a difference in gastroc/soleus tightness in children presenting with upper versus lower extremity complaints? (2) Is there a difference in gastroc/soleus tightness in children presenting with atraumatic versus traumatic lower extremity complaints?

Level of Evidence: Prognostic Study Level II

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Patients and Methods

This cross-sectional study was approved by our institutional review board with consent waived. All children were retrospectively evaluated in a single county clinic by the same physician. Inclusion criteria included new patients to the clinic who were of walking age. Exclusion criteria were any patient older than 18 years, children presenting with spine or combination upper and lower extremity issues, and children presenting with neuromuscular issues. Patients were separated into three groups: (1) upper extremity: upper extremity complaints of any type; (2) lower extremity atraumatic: lower extremity complaints without any trauma within the past two weeks; and (3) lower extremity traumatic: lower extremity complaints where the child developed symptoms after an inciting event within 2 weeks of presentation. We recorded age, sex, diagnosis, and maximal passive ankle dorsiflexion at the initial visit.

Despite its ubiquity, there is no standardized methodology for measuring ankle dorsiflexion [5]. In this study, dorsiflexion was measured by the same physician on all patients based on visualizing the angle between the anterior border of the distal lower leg and the lateral border of the foot. A perpendicular angle was set at 0°, positive indicated dorsiflexion past neutral, and values were rounded to the nearest 5° (Fig. 1). For each measurement, the knee was extended to tension the gastrocnemius and the foot was inverted to lock the midfoot [6, 9]. To investigate the reliability of visually measuring this angle, 20 ankles were clinically measured by the primary author and photographed from a lateral view with the camera pointing from medial to lateral. The primary author then measured the angle between the anterior tibial shaft and lateral border of the foot 2 weeks later without access to the clinical scores until after all digital measurements were made using ImageJ software (National Institutes of Health, Bethesda, MD).

Fig. 1. The ankle is held by the examiner with the knee extended and the foot inverted, followed by maximal dorsiflexion. The ankle is viewed from medial to lateral, and the complement of the angle between a line perpendicular to the anterior border of the lower leg and a line along the lateral border of the foot is measured.

For the lower extremity traumatic group, only contralateral ankle dorsiflexion was tested. For the other groups, both sides were tested and averaged. With the understanding that there is no standardized definition for gastroc/soleus tightness, we chose 0° or less based on a previous definition of less than 5° constituting major tightness [5].

Chi-squared analysis was used to compare rates of gastroc/soleus tightness between the three groups. Intraclass correlation coefficients were used to test the reliability of the ankle dorsiflexion measurements and to compare measurements between the right and left sides. Multiple variable linear regression analysis was used to determine the relative effects of age, sex, and diagnosis group on ankle dorsiflexion. In the multiple regression analysis, multicollinearity was assessed as negative based on $VIF < 10$ and coefficient tolerance > 0.1 , normal probability plots of the regression standardized residual were inspected for normality, scatterplots of the standardized residuals were inspected for homoscedasticity, and the lack of any undue influence from outliers was confirmed with a Cook's distance < 1 . All analyses were done using SPSS Statistics version 21.0 (IBM Corporation, Armonk, NY).

Results

A total of 206 children were enrolled. There were 86 females and 120 males. Average age was 10.0 ± 4.5 years. Demographics for each group are listed in Table 1, and injury locations are listed in Table 2.

Intraobserver comparison of 20 patients where dorsiflexion was measured visually versus measured on digital photographs found excellent correlation with an intraclass correlation coefficient of 0.87. Average overall ankle dorsiflexion was $12.4^\circ \pm 12.7^\circ$. For children with ankle dorsiflexion measured on both sides, there was excellent correlation between the two sides (intraclass correlation coefficient 0.98). A total of 44 children (21%) had gastroc/soleus tightness based on neutral or negative dorsiflexion.

There was a difference in gastroc/soleus tightness prevalence between upper and lower extremity patients. Table 1 demonstrates decreasing gastrocnemius tightness in the upper extremity group ($15.0^\circ \pm 11.6^\circ$), lower extremity atraumatic ($11.8^\circ \pm 14.5^\circ$) and lower extremity traumatic group ($6.5^\circ \pm 12.0^\circ$), with chi-squared analysis revealing significant differences between the upper extremity and lower extremity trauma groups ($P < 0.001$) and between upper extremity versus lower extremity atraumatic ($P = 0.048$). Figure 2 plots the distribution of gastrocnemius tightness in the three groups.

There were also some difference in gastroc/soleus tightness between atraumatic and traumatic lower extremity patients. There was no statistically significant difference between lower extremity atraumatic and lower extremity trauma patients in the chi-squared analysis ($P = 0.12$). On the other hand, multiple regression results (Table 3) showed that both increasing age and lower extremity traumatic etiology were associated with decreased ankle dorsiflexion.

Table 1 Demographics and ankle dorsiflexion for the three groups

	Number	Female/male	Age $\pm$ SD	Ankle DF $\pm$ SD	Ankle DF ≤ 0
Upper extremity	117	45/72	9.3 $\pm$ 4.3	15.0 $\pm$ 11.6	14 (12%)
Lower extremity atraumatic	40	21/19	9.8 $\pm$ 4.8	11.8 $\pm$ 14.5	10 (25%)
Lower extremity traumatic	49	20/29	11.6 $\pm$ 4.5	6.5 $\pm$ 12.0	20 (41%)

When evaluating only foot and ankle injuries in the trauma group, ankle dorsiflexion was $4.2^\circ \pm 10.9^\circ$, and tightness was found in 15/32 (47%). Within the entire lower extremity traumatic group, 25 children presented with fracture, 11 with sprain, 5 with rule out fracture, 2 each with contusion and simple laceration, and 1 each with muscle hernia, meniscus tear, digital nerve injury, and exacerbation of Osgood Schlatter.

Discussion

The association between gastroc/soleus tightness and routine pediatric lower extremity trauma has not been well investigated. Our study questions were whether there exists a difference in prevalence between upper and lower extremity patients, and between lower extremity atraumatic and traumatic patients. Our study found significant differences between gastrocnemius tightness rates in children presenting to our clinic with upper versus lower extremity pathology, and particularly high rates in children sustaining lower extremity injury in the multiple regression analysis. The increased rate of tightness in lower extremity atraumatic patients is somewhat expected. It is well known that gastroc/soleus tightness exacerbates a variety of conditions, and one would expect to see a higher incidence in children having enough symptomatology or concern to present to an orthopaedic clinic. The even higher and significantly increased rate in the lower extremity traumatic group was somewhat surprising, as it suggests that gastroc/soleus tightness plays a role in predisposing children to lower extremity injury.

The definition of a tight gastroc/soleus has not been well standardized in the literature [5]. Normal gait appears to require 10° – 18° of ankle dorsiflexion [3], leading some to suggest dorsiflexion less than 10° as a cutoff [8, 9].

However, a cutoff of 5° has been shown to delineate the increase in forefoot pressures [16]. Previous authors have described a two-stage system defining less than 10° as mild tightness and less than 5° as major tightness [5]. Using this system, and since our measurements were estimated to the nearest 5° , we chose neutral or lower dorsiflexion on passive exam with the knee extended and the foot inverted as the cutoff for tightness.

Given a 12% rate of tightness in upper extremity patients in our study, we would expect a similar rate in the general population. Assuming that there is a causative association, a simple approach to the widespread issue of gastrocnemius tightness in otherwise healthy adolescents would be to instruct those with tightness on simple home stretches. Studies on stretching in patients with foot and ankle pathology have shown modest and mixed results ranging from 2° to 12° [10–12, 18]. We are not aware of studies detailing the effectiveness of stretching on idiopathic gastrocnemius tightness in children without symptoms. Overall, further study is necessary to demonstrate the effectiveness of stretching as a preventative technique and we currently have a prospective study in progress.

This study has important limitations. Given that this was a cross-sectional study, rather than a longitudinal study, it cannot prove a causal effect between gastrocnemius tightness and lower extremity injury. However, the difference in gastrocnemius tightness rates between the lower extremity traumatic group and the upper extremity control group was significant and somewhat striking. One might also question the difference in ages between the lower extremity trauma group and other two groups. However, our multiple regression analysis found similar results after the effect of age on

Table 2 Distribution of injuries by group

	Upper extremity	Lower extremity atraumatic	Lower extremity traumatic
Shoulder	16		
Elbow	17		
Forearm	13		
Wrist	31		
Hand	40		
Hip		3	1
Knee		16	11
Lower leg		6	5
Ankle		3	18
Foot		12	24

Ankle Dorsiflexion Versus Chief Complaint **Fig. 2.** Plot of the mean and 95% confidence intervals for ankle dorsiflexion for the three groups.

Table 3 Multiple regression analysis of predictors for ankle dorsiflexion

	Standardized beta	Unstandardized beta			P value
		Beta	Lower bound	Upper bound	
Age	−0.472	−1.33	−1.67	−0.99	<0.0005
Gender	0.072	1.84	−1.21	4.90	0.236
LE atraumatic	−0.092	−2.94	−6.84	0.95	0.138
LE traumatic	−0.186	−5.54	−9.21	−1.86	0.003

The values for the lower extremity groups are in comparison to the upper extremity group. Lower and upper bounds for unstandardized beta define the 95% confidence interval

LE lower extremity group

ankle dorsiflexion had been statistically factored out. The clinician measuring ankle dorsiflexion was aware of the clinical presentation for each patient, and so bias may have been introduced by this knowledge.

The measurements in this study were obtained without a goniometer. Other studies have demonstrated the lack of reliability of goniometers for measuring gastroc/soleus tightness [2, 13], and there was concern in this study that trying to maintain the younger children in an appropriate position to adequately use a goniometer would lead to a less accurate measurement, as they tend to move their feet faster than a goniometer can be properly positioned and often resist the examination as time passes. Although multiple ankle dorsiflexion measurement devices do exist, their validity is not well established [5], and their ability to measure children of widely different sizes is not validated and likely limited. We found good reproducibility with an intraclass correlation coefficient of 0.87 when comparing visual measurement to digital images, even through the visual measurements were rounded to the nearest 5° while the digital images were rounded to the nearest tenth degree. By having a single examiner collecting this data for all the patients, we were able to more consistently compare between the different patient groups.

Since ankle dorsiflexion was only measured with full knee extension, our data cannot differentiate between isolated gastrocnemius tightness versus tightness of both the gastrocnemius and soleus. Examination in flexion was not included in the study design because it has been our experience that tightness of the soleus is very rare in children without other foot or ankle pathology. Isolated gastrocnemius tightness has been reported in adults [8].

In summary, this study found large and significant differences in gastroc/soleus tightness rates in children with lower extremity trauma as compared to children with upper extremity complaints. This data suggests that gastroc/soleus tightness may play a significant role in predisposing children to lower extremity trauma. Future study is necessary to determine whether simple home stretching exercises could present an effective preventative strategy. Overall, this data warrants further prospective study and highlights an important factor to consider in children presenting with lower extremity injuries.

Compliance with Ethical Standards

Conflict of Interest: Raymond W. Liu, MD, reports other from Orthopediatrics Corp., outside the work. Katherine K. Xie, BS, declares that she has no conflict of interest.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was waived from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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