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ORIGINAL ARTICLE

Relationship between self-reported functional stability and peroneal muscle structure in individuals with chronic ankle instability

Bahar ÖZGÜL[1], Chelsea STARBUCK[2], Mine Gülden POLAT[1], Rawan ABDEEN[2], Christopher NESTER[2]

Purpose: Chronic ankle instability is characterized by repeated ankle sprains. Peroneal muscles are important for control of the ankle and have been evaluated using electromyographic analyses, but there has been lack of study about any relationship between the peroneal muscle structure and self-reported function after ankle sprains. Therefore, this study aimed to investigate the relationship between self-reported functional stability and peroneal muscle structure in chronic ankle instability.
Methods: Thirty subjects aged between 18-45 years and reporting chronic ankle instability were evaluated. Participants completed the Cumberland Ankle Instability Tool questionnaire to determine ankle stability experience. Structural analysis of the peroneal muscles was performed using musculoskeletal ultrasound scanning. Cross sectional area and thickness of peroneal longus and brevis were scanned.
Results: The mean Cumberland Ankle Instability Tool score of subjects was 15.40±6.23. A statistically significant positive moderate correlation was found between stability scores and total cross-sectional area of peroneal muscles ($r=0.405$, $p=0.027$). In another words; subjects with higher levels of self-reported ankle stability had larger peroneal cross-sectional area.
Conclusion: The subjects with chronic ankle instability who had larger peroneal cross-sectional area may have greater peroneal strength. Thereafter, this group may have better ankle stability than those with perceived low ankle stability. This potential for a structural relationship associated with improved stability may be relevant to physiotherapists and rehabilitation programmes. Further research may focus on other muscular structures around the ankle joint in chronic ankle instability.
Keywords: Ankle, Joint instability, Muscles, Ultrasonography.

Kronik ayak bileği instabilitesi olan bireylerde subjektif fonksiyonel stabilite ile peroneal kas yapısı arasındaki ilişki

Amaç: Kronik ayak bileği instabilitesi tekrarlayan ayak bileği burkulmaları ile karakterize edilir. Peroneal kaslar ayak bileğinin kontrolü için önemlidir ve elektromyografik analizler kullanılarak değerlendirilir ancak peroneal kas yapısı ile ayak bileği burkulmalarından sonra bildirilen subjektif fonksiyon arasındaki ilişki hakkında yeterli çalışma bulunmamaktadır. Bu nedenle, bu çalışmanın amacı, kronik ayak bileği instabilitesinde birey tarafından beyan edilen fonksiyonel stabilite ile peroneal kas yapısı arasındaki ilişkiyi araştırmaktı.
Yöntem: Çalışma kapsamında 18-45 yaş aralığında, kronik ayak bileği instabilitesi olan 30 birey değerlendirildi. Olgular ayak bileği stabilite deneyiminin belirlenmesi için Cumberland Ayak Bileği Instabilite Ölçeği'ni doldurdu. Peroneal kasların yapısal analizi kas iskelet sistemi ultrason görüntüleme yöntemiyle gerçekleştirildi. Peroneus longus ve brevisin kesit alanı ve kalınlığı görüntülendi.
Bulgular: Olguların Cumberland Ayak Bileği İnstabilite Ölçeği skoru ortalama 15,40±6,23 idi. Stabilite skorları ile peroneal kasların kesit alanı arasında istatistiksel olarak anlamlı pozitif ve orta düzeyde bir korelasyon saptandı ($r=0,405$; $p=0,027$). Diğer bir deyişle; subjektif ayak bileği stabilitesi yüksek olan olgular daha geniş peroneal kesit alanına sahipti.
Sonuç: Daha geniş peroneal kesit alanı olan kronik ayak bileği instabilitesi olan olgular daha yüksek peroneal kuvvete sahip olabilir. Bu durumda, bu grup düşük seviyede algılanan ayak bileği stabilitesi olan olgulardan daha iyi ayak bileği stabilitesine sahip olabilir. Geliştirilmiş stabilite ile ilgili bu yapısal ilişki potansiyeli fizyoterapistleri ve rehabilitasyon programlarını ilgilendirebilir. Daha fazla araştırma kronik ayak bileği instabilitesinde ayak bileği eklemi çevresindeki diğer kas yapılarına odaklanabilir.
Anahtar kelimeler: Ayak bileği, Eklem instabilitesi, Kaslar, Ultrasonografi.

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1: Marmara University Health Sciences Faculty Physiotherapy and Rehabilitation Department, Istanbul, Turkey.
2: University of Salford Health Sciences Faculty, Salford, Greater Manchester, United Kingdom.
Corresponding Author: Bahar Özgül: fztbaharozgul@gmail.com
ORCID IDs (order of authors): 0000-0001-5821-2725; 0000-0001-6266-2876; 0000-0002-9705-9740; 0000-0002-6706-2949; 0000-0003-1688-320X
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Chronic ankle instability (CAI) is characterized by repetitive ankle inversion instability and injury, resulting in numerous sprains and the subjective feeling of the ankle "giving way" after an initial ankle sprain.[1] The criteria for CAI identified by the International Ankle Consortium[2] includes a history of at least 1 significant ankle sprain and "*feeling of giving way*" and/or "*feeling of ankle joint instability*". The latter has been defined as "*the situation whereby during activities of daily living and sporting activities the subject feels that the ankle joint is unstable and is usually associated with the fear of sustaining an acute ligament sprain*".[2,3]

Determining the underlying mechanism of CAI is important in the pursuit of effective prevention and rehabilitation strategies. It is still not entirely clear what contributes to the high recurrence rate of ankle sprains in some cases more than others.[4] Some studies have suggested that structural damage of the lateral ligaments results in excessive joint laxity and risk of inversion.[5] This could be compensated by increased ankle eversion moments from action of peroneus longus and peroneus brevis. However, deficits in neuromuscular control of ankle muscles due to joint mechanoreceptor damage may limit the effectiveness of this compensatory mechanism.[6-8] The peroneal muscles are the primary evertors of the foot and ankle.[9] Although the neuromuscular role of the peroneal muscles in ankle joint stability has been studied[4,5,10,11], whether the structure of the peroneals has an association with instability has not been yet investigated in detail.

The force generated by the peroneals depends on many factors including muscle architecture.[12] The ability to generate muscle force is related to the muscle physiological cross-sectional area (CSA)[13] and this is an important measure for evaluating human movement capabilities.[14] Muscle thickness is also relevant and changes in CSA or thickness have been used as an index of muscle weakness and atrophy or, conversely, strength and hypertrophy.[15] Muscle architecture is thus related to muscle activity and potentially its role in maintaining joint and postural stability.

An analysis of muscle structure may help to explain variations between individuals in movement performance and risk of injury. Musculoskeletal ultrasound scanning (MSUS) is one of the imaging techniques used to characterize ankle ligaments, muscles, and tendons.[16,17] It is also inexpensive and a practical alternative to gold standard measures such as magnetic resonance imaging.[18] Although measures taken from MSUS are operator-dependent, it has been shown to be a valid and reliable tool for assessing muscle cross-sectional area[19] and thickness.[20]

This paper investigates whether structural features of the peroneal muscles are associated with severity of ankle instability in cases of CAI. This is based on an assumption that, in cases of CAI, the peroneal muscles may be more active, used more often, or required to generate more force, and that this might necessitate a change in its CSA or thickness.

METHODS

Participants aged between 18-45 years who had lateral ankle sprain in last two years volunteered to attend for MSUS assessment at the Salford University. Thirty participants from the University community were recruited between September 2017 and June 2018. Each provided written consent to participate. Ethics approval was obtained from Marmara University Ethics Committee (Approval number: 193, date: 19/01/2019).

Participants who met the International Ankle Consortium criteria[2] for CAI were included. They had: (A) a history of at least one significant unilateral inversion ankle sprain. Each episode must have resulted in pain, swelling, limited weight bearing or full immobilization for a minimum of three days, a failure to return to pre-injury function and repeated episodes of ankle sprain. The most recent injury must have occurred more than 3 months prior to study enrolment; (B) self-reported ankle dysfunction scoring ≥24 on the Cumberland Ankle Instability Tool (CAIT).[21] Where cases were bilateral, the limb with greatest CAIT score (worse stability) was selected. Exclusion criteria were;

a history of previous surgery to musculoskeletal structures (i.e., bones, joint structures, nerves) in the either lower limb

a history of fracture in either lower limb

acute injury to musculoskeletal structures of the lower extremity in the previous 3 months, which impacted on joint integrity and function (i.e., sprains) resulting in at least 1 interrupted day of desired physical activity

current and/or intermittent pain

a systematic musculoskeletal disease (e.g. inflammatory arthritis)

A validated self-reported ankle instability questionnaire was used to profile ankle instability experience. The CAIT was developed by Hiller et al at 2006[21] and is a valid and reliable measure of the severity of CAI based on self-reported symptoms. It consists of a 9-item 30-point scale and identified an unstable ankle as a score of 24 or less.[21]

MSUS was used to evaluate CSA and thickness of the peroneal muscles. A portable Venue 40 musculoskeletal ultrasound system (GE Healthcare, UK) with a 5–13 MHz wideband linear array probe with 12.7 mm x 47.1 mm surface area was used. The thickness and CSA of peroneal muscles was imaged by certificated physiotherapist who have trained MSUS for two years. Good contact was maintained between probe and skin by applying minimum pressure and three assessments were taken at each structure with the probe removed between each recording.

Scanning Protocol: Inter and intra reliability study of this protocol was performed previously[22]. MSUS was performed in the supine position and with the probe at 30% of the distance between fibula head and lateral malleolus.[22] Peroneus Longus (PL) and Peroneus Brevis (PB) were scanned together transversely by positioning the long axis of the probe perpendicular to muscle fibers to obtain the image of CSA (Figure 1). For the thickness of peroneals, the probe was rotated into a longitudinal orientation. In the corresponding image, CSA was defined as an area of muscle perpendicular to its longitudinal direction along the line between fibular head and lateral malleoli. The thickness was defined as the distance between the aponeuroses of each peroneal muscle (Figure 1).

Data analysis: Ultrasound images were measured using ImageJ software (National Institutes of Health (Bethesda, MD, USA).[23] An average of three measurements was calculated. The CSA and thickness of PL and PB were measured and recorded separately and combined for each image (Figure 1). Normalized thickness and CSA values were also calculated by dividing the scanned and measured parameter to body weight as kilogram. Statistical analyses were performed by SAS Statistics version 9.4 (SAS Institute, Inc., Cary, NC). P-values of less than 0.05 were considered statistically significant. As the distribution of data met the parametric test criteria (data distribution histograms, examining the mean and standard deviation values and Kolmogorov-Smirnov test), Pearson correlation test was performed to investigate any correlation between CAIT scores and values of peroneal muscle thickness and CSA. The r-value was interpreted respectively as 0.01–0.40="weak correlation", 0.41–0.69="moderate correlation", 0.70–1.00="strong correlation".[24] The square of r-value was calculated to determine % of the variance of relationship between severity of self-reported ankle stability and peroneal thickness or CSA.

RESULTS

Demographic characteristics of the 30 participants are shown in Table 1, with 46.7% female (n=14).

The mean CAIT score was 15.40±6.23, ranging from 2 to 24 (Table 2). The thickness and CSA of PB (15.47±3.28 mm and 337.8±80.7 mm^2 respectively) was greater than PL (8.06±2.56 mm and 173.0±51.0 mm^2).

There was a moderate level of positive correlation between CAIT scores and the CSA of the peroneal muscles (r=0.405, p=0.027, Table 3 and Figure 2), with participants with a higher level of self-reported ankle stability associated with larger total peroneal CSA. The detected moderate correlation (r=0.4) explained r^2=16% of the variance of relationship between self-reported ankle stability and peroneal CSA.

DISCUSSION

The results presented herein revealed a statistically significant positive moderate correlation between CAIT scores and CSA of total peroneal muscles. The subjects with higher self-reported ankle stability had larger peroneal CSA, but not peroneal thickness. However, this correlation explains only 16% of the variance of

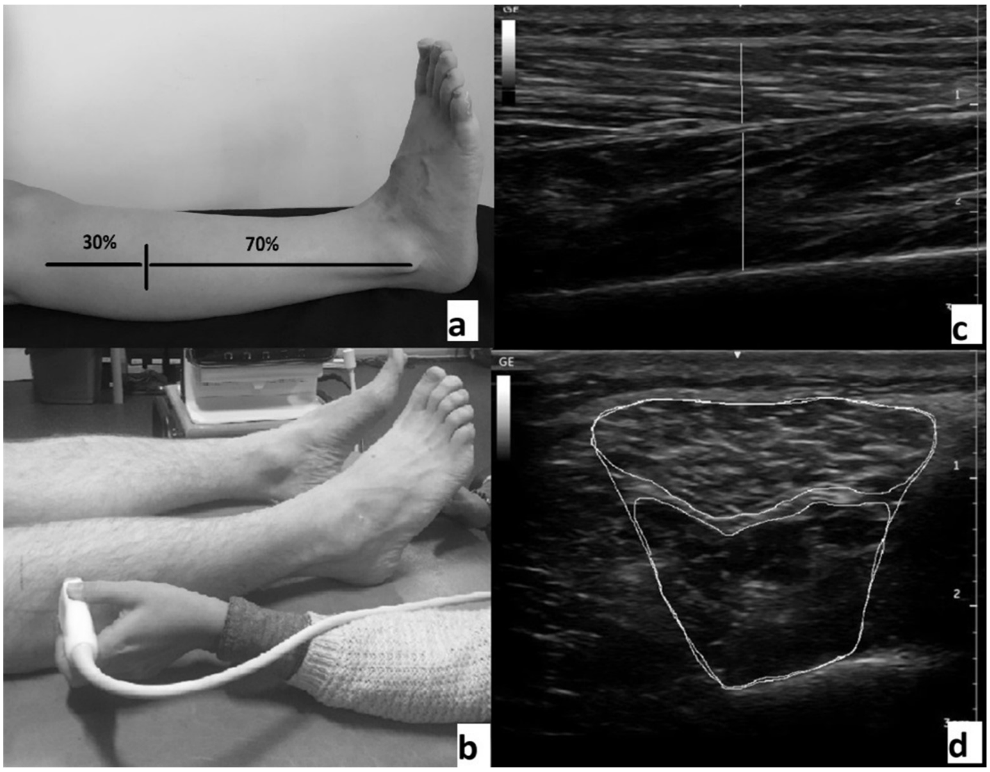

Figure 1. Participants' position probe location (a and b) and ultrasound images of peroneal muscles (c and d). Muscle thickness (c) and cross sectional area (d) of PL (top of the image) and PB (bottom of the image).

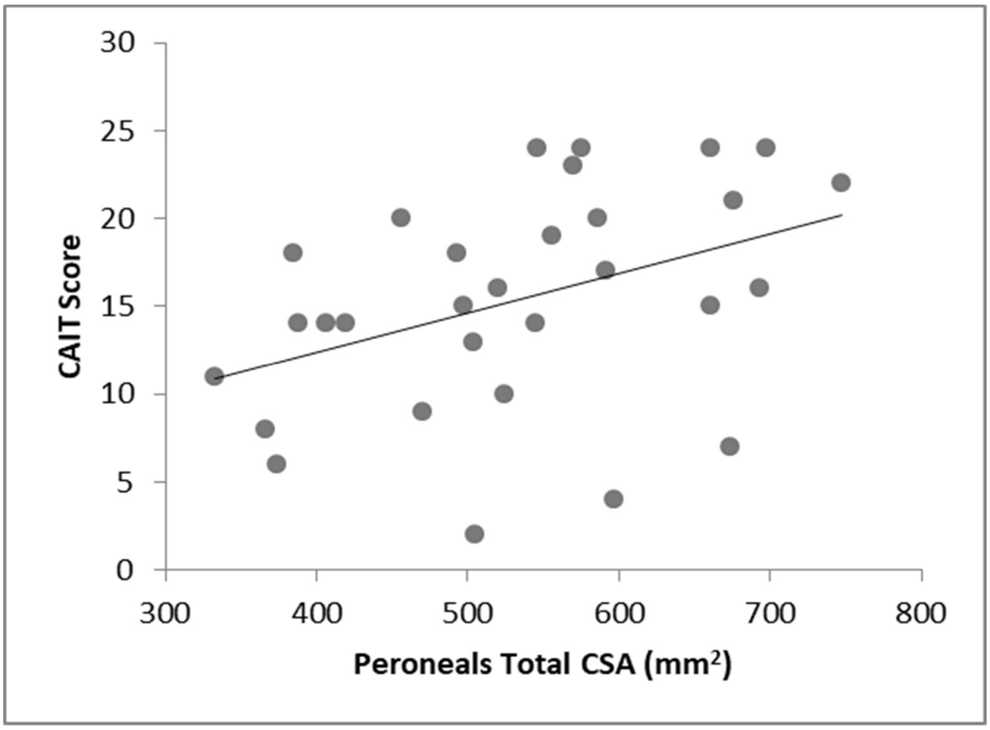

Figure 2. The correlation between CAIT scores and Total Peroneal CSA (CAIT: Cumberland Ankle Instability Tool, CSA: Cross-Sectional Area).

Table 1. Demographic characteristics of the patients.

	Mean±SD
Age (years)	29.00±8.06
Height (cm)	168.86±8.89
Body weight (kg)	70.31±11.51
Body mass index (kg/m²)	24.67±3.63

Table 2. The Cumberland Ankle Instability Tool (CAIT) scores and peroneal thickness and Cross-Sectional Area (CSA) values of the patients.

	Mean±SD
CAIT Score	15.40±6.23
PL T (mm)	8.06±2.56
PL T (BW%)	0.115±0.033
PB T (mm)	15.47±3.28
PB T (BW%)	0.022±0.004
Peroneals T (mm)	23.53±3.71
Peroneals T (BW%)	0.034±0.004
PL CSA (mm²)	173.05±51.01
PL CSA (BW%)	0.025±0.006
PB CSA (mm²)	337.88±80.75
PB CSA (BW%)	0.048±0.009
Peroneals CSA (mm²)	533.84±112.16
Peroneals CSA (BW%)	0.076±0.012

CAIT: Cumberland Ankle Instability Tool. PL: Peroneus longus. PB: Peroneus brevis. L: Length, T: Thickness. CSA: Cross-Sectional Area. BW%: Normalized to Body Weight.

the relationship between self-reported ankle stability and peroneal CSA.

Neuromuscular control of the ankle joint is provided by both reflexes and voluntary muscle responses. For reflex responses, the size and speed of changes in muscle length will be detected by muscle spindles in the peroneal muscles as they are stretched during rapid ankle inversion.[4] For this reason, peroneal muscle function in CAI has previously been investigated using electromyography and differences in peroneal activation and reaction time have been detected.[8,25,26] In contrast, however, others have reported no difference in peroneal reflex latency[27,28], nor proprioceptive function[11,29] between healthy and CAI cases. Therefore, there is little consensus on the role of the peroneal muscles in CAI at present. The results of this current study suggest that there might be a small association between peroneal structure and ankle instability. Smaller peroneal CSA was associated with self-reported instability to a moderate level. Further research is needed to understand the functional consequences of the structural differences between people with and without ankle joint instability, and the roles of other passive and muscle structures that might prevent an inversion injury.

Table 3. The correlations between CAIT scores and peroneal thickness and CSA values, and normalized peroneal thickness and normalized CSA values.

	CAIT score r (p)
Thickness	
Peroneus Longus	0.022 (0.908)
Peroneus Brevis	0.269 (0.151)
Total	0.253 (0.178)
Cross-Sectional Area	
Peroneus Longus	0.272 (0.146)
Peroneus Brevis	0.334 (0.072)
Total	0.405 (0.027)*
Thickness (BW%)	
Peroneus Longus	-0.102 (0.593)
Peroneus Brevis	0.097 (0.609)
Total	0.018 (0.925)
Cross-Sectional Area (BW%)	
Peroneus Longus	0.213 (0.259)
Peroneus Brevis	0.220 (0.242)
Total	0.311 (0.094)

* $p<0.05$. r: Pearson Correlation Coefficient. CAIT: Cumberland Ankle Instability Tool. PL: Peroneus longus. PB: Peroneus brevis. L: Length, T: Thickness. CSA: Cross-Sectional Area. BW%: Normalized to body weight.

Scanning of peroneals is challenging because of the complex structural proximity between PL and PB. Lobo et al. showed that the PL CSA is smaller in subjects with lateral ankle sprain compared with that in subjects without lateral ankle sprain.[30] Conversely, in our study, the subjects with a lower level of ankle stability, and therefore, we assume, the greatest risk of sprain, had smaller peroneal CSA. Unfortunately, we did not involve healthy controls, therefore it is not possible to discuss our findings with results of Lobo et al. In another recent study, it has been shown individuals with CAI has smaller PL CSA on the injured side compared to uninjured side, though this did not reach statistical significance.[31] In the same study; higher echogenicity of the peroneals was also reported. Echogenicity represents the brightness of the muscle tissue in ultrasound images[31] and it believed to be associated with muscle strength.[32]

Muscle force/strength is proportional to its CSA and thickness.[33] Changes in CSA or thickness are used as an index of muscle weakening and atrophy or, conversely, strengthening and hypertrophy.[15] For example; the correlation between the thickness of vastus medialis and isometric maximum voluntary contraction force has been reported.[34] Because of the magnitude of the maximum voluntary contractile force is known to be correlated with the CSA of muscle[15], individuals with less peroneal CSA may have lower peroneal strength. In addition, when we focused on the normalized data no correlation between normalized values indicates importance of individualized factors on the results. Indeed, weak evertors are observed in CAI individuals and attributed to reduced ability to maintain the ankle joint instability.[31,35,36] At the same time, it has been reported that deficits in ankle evertors' strength are not correlated with CAI.[37] This distinct result was explained by the the eccentric control of the ankle invertors for the lateral displacement of the lower leg during closed-chain stance and movements independently from evertor muscle group. But it is still a theory which requires further investigations.

Limitations

This study has a number of limitations that should be acknowledged. For instance, owing to the nature of correlational analysis we cannot say whether smaller CSA leads to instability or whether instability results in smaller CSA. Furthermore, we detected only a moderate correlation ($r = 0.4$, $r^2 = 16\%$), and therefore 84% of the variance in ankle stability remains unexplained. Factors such as ligamentous laxity[10,38], proprioceptive deficits[5,10], bony deformity[39] or weakness of other muscles[35,36,40] might contribute, as will activity level and footwear habits. In addition to limitations, the power analysis for determining number of subjects should be participating in the current study had not perform before data collection.

Conclusion

Participants with a lower level of self-reported ankle stability had smaller peroneal CSA. The factors contributing to ankle stability look to include peroneal muscles, but its contribution is small. Prior to changing any rehabilitation strategy further research is needed on the contributions from other muscular structures around the ankle joint in CAI.

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