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Original Article

Relationship between chronic ankle sprain instability and ultrasonographic evaluation of the peroneus during a single-leg standing task

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Abstract. [Purpose] This study aimed to examine the relationship between chronic ankle sprain instability and ultrasonography of the peroneus muscles during a single-leg standing task. [Participants and Methods] We examined nine college-aged students with a history of lateral ankle joint sprain with chronic ankle sprain instability scores less than 24. Participants underwent ultrasonographic measurement of the pennation angle and muscle thickness of the peroneal and gastrocnemius muscle groups of both legs. In addition, participants were evaluated for fluctuation by the root mean square calculated from accelerations in the anteroposterior, lateral-horizontal, and vertical directions during the single-leg standing position by affixing the accelerometer to their waist. Measurement results were compared between sprain and non-sprain sides. [Results] Ultrasonography revealed a significant reduction in the feathered pennation angle of the long peroneal muscle on the side of the sprain, but no other significant differences. Also, significant extension was observed on the side of the sprain in the anteroposterior and vertical directions during single-leg standing; however, no significant differences were found in the lateral-horizontal direction. [Conclusion] Participants with chronic ankle sprain instability exhibited greater fluctuation in the anteroposterior and vertical directions. Such fluctuations are believed to be compensatory in nature because the feathered horn of the long peroneal muscle is decreased, and pronation of the forefoot is difficult during one-leg standing.
Key words: Chronic ankle instability, Ultrasonography, Accelerometer

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INTRODUCTION

Ankle sprain often occurs during turning or jump-landing in various sports. The ankle sprain has a high recurrence rate, which can lead to a condition of chronic anxiety and repetitive sprains, defined as chronic ankle instability (CAI)[1)]. It has been widely reported that weakness of the valgus muscle in the ankle and delayed muscle contraction in the peroneal muscle group occur after internal ankle sprain[2, 3)], and thus considered to be a factor in current ankle sprain. Previous studies determined the muscle strength of the ankle joint with isokinetic contraction and afferent contraction, and timing of muscle activity by electromyography [4, 5)]. In this time, we examined the effects of transcutaneous electrical nerve stimulation during balance exercise on patients with functional instability of the ankles, including the ability to land after jumping at the center of foot pressure. Ankle instability on the sprain side was significantly reduced under the balance exercise with simultaneous transcutaneous electrical nerve stimulation therapy condition before and after the challenge. Peroneal muscles showed increased activity caused by common peroneal innervation[6)]. Previous studies suggest a decrease in peroneal muscle activity, but none of the long and short peroneal muscles were evaluated separately. We focused on reports showing the effectiveness of skeletal muscle assessment in ultrasound[7)]. In many previous studies using ultrasonography[8–10)], pennation angles and

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muscle thickness are used as indices to observe the structure when assuming muscle strength. Therefore, this study investigated the effectiveness of muscle shape evaluation of the long and short peroneal muscles in ultrasonography in relation to one-leg standing balance for cases with CAI.

PARTICIPANTS AND METHODS

The participants were nine university students (Average age 21.1 years, average height 167 ± 4.3 cm, average weight 59.2 ± 4.1 kg) who scored 24 points or less using the Cumberland Ankle Instability Tool (CAIT), which has a history of recurrent ankle sprain of one leg. Exclusion criteria were those with disabilities other than sprains and those with bilateral sprains. Participants had no pain at the time of measurement and had joint instability during movement. In terms of sprain side, there were 4 cases for the right foot and 5 cases for the left foot. Among them, the dominant leg was sprained in 3 cases. The dominant foot was the side kicking the ball. Participants were asked to participate in the athletic club of the university to which the researchers belong. The pennation angle and muscle thickness of the peroneal muscle group and the gastrocnemius lateral head of both legs were measured using ultrasonic measuring device (SNiBLE, Konica Minolta) at three times, and made the average value the adopted value. Ultrasonic measurements used a Briglt-ness Inode (B mode) at a frequency of 10 MHz. The participant's measured position was on the bed in the supine position with the sole of the foot on the wall and a towel placed under the knee joint to give a knee joint with a slight flexion in the middle of the ankle joint (Fig. 1). The measurement site was the peroneal muscle group at the proximal 1/3 of the lower leg length of each lower leg, and the

	Left	Right	Score
1. I have pain in my ankle			
Never	☐	☐	5
During sport	☐	☐	4
Running on uneven surfaces	☐	☐	3
Running on level surfaces	☐	☐	2
Walking on uneven surfaces	☐	☐	1
Walking on level surfaces	☐	☐	0
2. My ankle feels unstable			
Never	☐	☐	4
Sometimes during sport (not every time)	☐	☐	3
Frequently during sport (every time)	☐	☐	2
Sometimes during daily activity	☐	☐	1
Frequently during daily activity	☐	☐	0
3. When I make SHARP turns, my ankle feels unstable			
Never	☐	☐	3
Sometimes during running	☐	☐	2
Often when running	☐	☐	1
When walking	☐	☐	0
4. When going down the stairs, my ankle feels unstable			
Never	☐	☐	3
If I go fast	☐	☐	2
Occasionally	☐	☐	1
Always	☐	☐	0
5. My ankle feels UNSTABLE when standing on one leg			
Never	☐	☐	2
On the ball of my foot	☐	☐	1
With my foot flat	☐	☐	0
6. My ankle feels unstable when			
Never	☐	☐	3
I hop from side to side	☐	☐	2
I hop on the spot	☐	☐	1
When I jump	☐	☐	0
7. My ankle feels unstable when			
Never	☐	☐	4
I run on uneven surfaces	☐	☐	3
I jog on uneven surfaces	☐	☐	2
I walk on uneven surfaces	☐	☐	1
I walk on a flat surface	☐	☐	0
8.Typically, when I start to roll over (or "twist") on my ankle, I can stop it			
Immediately	☐	☐	3
Often	☐	☐	2
Sometimes	☐	☐	1
Never	☐	☐	0
I have never rolled over on my ankle	☐	☐	3
9. After a typical incident of my ankle rolling over, my ankle returns to "normal"			
Almost immediately	☐	☐	3
Less than one day	☐	☐	2
1 or 2 days	☐	☐	1
More than 2 days	☐	☐	0
I have never rolled over on my ankle	☐	☐	3

Fig. 1. Cumberland Ankle Instability Tool.
The definition of CAI is a history of ankle sprain that has no load, fixation, or lameness, history of multiple ankle sprains in the past, experience of multiple ankle 'giving ways', and a CAIT score of 24 or less.

lateral head of triceps surae muscle was the maximum lower leg. The muscle thickness is the distance between the surface layer apophysis at the center of the image and the deep layer apophysis. The muscle thickness and the pennation angle were measured based on the center line of the measurement screen (Fig. 2). The examination of the reliability of the ultrasonic measurement determined the intraclass correlation coefficient (ICC) as relative reliability. In addition, the participants were measured the muscle strength of the ankle joints valgus and varus using a manual muscle meter. As a measurement position, the participant was seated at an ankle middle position with the hip and knee joints flexed by 90 degrees. The participants measured the muscle strength of valgus and varus isometric contractions by referring to Daniels's Muscle Manual Testing[10] with the center of the belt of a manual muscle tester on the Lisfranc joint. The measurement was explained by guiding the movement direction manually, and the average value measured twice after one exercise was taken as the adopted value. For balance evaluation, the participant was kept on the one leg standing position for 30 seconds with the knee joint of one leg by 90 degrees and held with the upper limbs folded in front of the chest. At that time, an accelerometer (MVP-RF8-HC-500, Micorostone: Japan) was measured accelerations in the sagittal (x), lateral (y), and vertical (z) directions with the height of the 4 lumbar spine with a dedicated belt. The root-mean-square (RMS) calculated from the acceleration was used as the evaluation of the mobility during one-leg standing[11]. The measurement was performed twice, and the average of the measured values was treated as the adopted value, and the sampling frequency was 1,000 Hz. The participants' sprain side and non-sprain side measurements were compared using Mann-Whitney U test. The significance level was 5%. All statistical analyses were performed using the SPSS version 12.0 software (SPSS Japan, Japan). This study was approved by the ethics committee of the author's institution (Examination number 18-21).

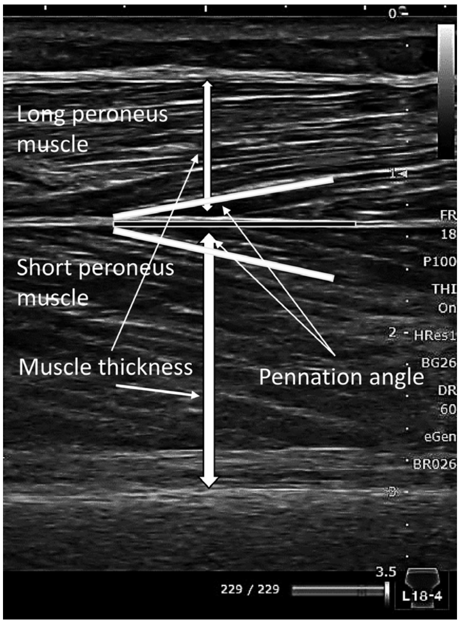

Fig. 2. Pennation angle and muscle thickness of peroneus muscle group by ultrasound imaging.
The muscle thickness of the peroneal muscle group and the triceps femoris muscle was taken as the distance between the surface layer apophysis at the center of the image and the deep layer aponeurosis. Pennation angle was the angle between the surface apoplexy and the muscle bundle.

RESULTS

Ultrasonography of muscle thickness of the peroneal muscle group and the gastrocnemius muscle: the long peroneus muscle; sprain side (9.2 ± 0.9 mm), non-sprain side (10.5 ± 1.2 mm), the short peroneus muscle; sprain side (14.6 ± 2.3 mm), non-sprain side (13.5 ± 2.1 mm), the gastrocnemius muscle: sprain side (11.6 ± 2.1 mm), non-sprain side (13.5 ± 2.1 mm). There was no significant difference in muscle thickness of each muscled group between the sprain side and the non-sprain side (Table 1).

The results of ultrasonography of pennation angle: the long peroneus muscle; the sprain side (9.2 ± 1.2 mm), non-sprain side (12.2 ± 2.2 mm), short peroneal muscle; the sprain side (13.1 ± 3.3 mm), non-sprain side (11.8 ± 3.4 mm), gastrocnemius muscle; the sprain side (13.1 ± 3.2 mm), non- sprain side (11.8 ± 3.1 mm). The sprained side had significantly reduced muscle pennation angle of the long peroneus muscle compared to the non-sprained side. The ICC (1.1) confirmed the reliability of the measurements of pennation angle and muscle thickness of the peroneal muscle group and the gastrocnemius muscle [the peroneal muscle group: muscle thickness (ICC=0.71), pennation angle (ICC=0.76), gastrocnemius muscle: muscle thickness (ICC=0.81), pennation angle (ICC=0.74)] (Table 2).

Results of the manual muscle meter: Varus muscle strength of sprain side (4.41 ± 1.6 kg) and non-sprain side (4.08 ± 1.02 kg). The valgus muscle strength of sprain side (2.96 ± 1.45 kg) was significantly lower than the non-sprain side (4.26 ± 1.43 kg) (Table 3). The RMS calculated from the accelerometer during one-leg standing were compared with the sprain side and the non-sprain side. The x direction distance was significantly greater in the sprain side (454.5 ± 334.3 mm) compared to the non-sprain side (169.3 ± 110.9 mm). The y direction distance of the sprain side (626.5 ± 261.5 mm) was not significantly greater than the non-sprain side (482.3 ± 259.7 mm). The z direction distance of the sprain side (133.6 ± 101.1 mm) was significantly greater than the non-sprain side (101.6 ± 89.7 mm) (Table 4).

DISCUSSION

We measured ankle joint muscle strength, pennation angle of the peroneal muscle group and the gastrocnemius muscle,

Table 1. Ultrasound evaluation of thickness of the peroneus muscles

Thickness of the peroneus muscle groups			
The long peroneus muscle		The short peroneus muscle	
Sprain side	Non-sprain side	Sprain side	Non-sprain side
9.2 ± 0.9 mm	10.5 ± 1.9 mm	14.6 ± 2.8 mm	13.5 ± 2.1 mm
p=0.09		p=0.51	

Values are expressed as mean ± SD.

Table 2. Ultrasound evaluation of pennation angle of the peroneus muscles

Pennation angle of the peroneus muscle groups			
The long peroneus muscle		The short peroneus muscle	
Sprain side	Non-sprain side	Sprain side	Non-sprain side
9.2 ± 1.7°*	12.2 ± 2.2°	13.1 ± 3.3°	11.8 ± 3.1°
p=0.03		p=0.32	

Values are expressed as mean ± SD. *p<0.05, significant difference between sprained side and non-sprained side.

Table 3. Evaluation of the ankle joint muscle by manual muscle meter

Varus muscle strength		Valgus muscle strength	
Sprain side	Non-sprain side	Sprain side	Non-sprain side
4.4 ± 1.6 kg	4.1 ± 1.0 kg	2.9 ± 1.4 kg *	4.2 ± 1.4 kg
p=0.82		p=0.02	

Values are expressed as mean ± SD. *p<0.05, significant difference between sprained side and non-sprained side.

Table 4. Evaluation of the accelerometer during one-leg standing

Sagtital (mm)		Lateral (mm)		Vertical (mm)	
Sprain side	Non-sprain side	Sprain side	Non-sprain side	Sprain side	Non-sprain side
3,881.1 ± 2,966.4*	1,400.0 ± 1,003.6	5,6276.1 ± 2,230.4	4,4956.7 ± 2,236.8	12,885.2 ± 8,595.9*	10,659 ± 7,746.7
p=0.01		p=0.62		p=0.04	

Values are expressed as mean ± SD. *p<0.05, significant difference between sprained side and non-sprained side.

and muscle thickness using ultrasonography in participants with CAI. We also assessed stability in one-leg standing using an accelerometer and examined the relationship between muscle morphology and muscle strength in the peroneal muscle group. In this time, it was founded valvular muscle strength of the ankle joint and the panation angle of the long peroneus muscle were reduced on the sprain side. In addition, the RMS in the sagittal and vertical directions was increased at the one leg standing. In past studies, criteria for participants in patients with ankle sprain are often not unified. Evaluation of ankle joint instability at the International ankle consortium in 2014 recommended either CAIT or AII (Ankle Instability Instrument) idFAI (Identification of functional Ankle instability) to assess instability[12–14]. In this study, we adopted the evaluation criteria using CAIT to evaluate CAI (CAI was defined with a CAIT score of 24 or less[15]). Previous reports of muscle strength in the ankle joints of participants with CAI are conflicting in terms of the presence or absence of valgus muscle weakness in the ankle joint[4]. In this study, we noted significant muscle weakness in the ankle joint on the sprain side compared to the non-sprain side. Previous studies have examined the relationship between muscle morphological evaluation and muscle strength by ultrasonography, showing that the pennation angle of the gastrocnemius muscle and increase in ankle flexor muscle strength, the pennation angle of the brachial muscle and insrease in the elbow joint flexion musle strength[16, 17]. Also, the effect of strength training on triceps and quadriceps is correlated with an increase in pennation angle[18]. Myomorphological evaluation using ultrasound has the advantage of being inexpensive, portable, non-invasive, and safe and easy to measure compared to Magnetic Resonance Imaging and computed tomography (CT)[19], with good accuracy. Therefore, carrying at sports sites is convenience. Previous research has shown that evaluation of pennation angle is more reliable than muscle thickness in relation to muscle strength[20]. We speculate that the pennation angle reflects the difference in the shape of the peroneus muscle from the sprain side and the non-sprain side rather more so than muscle thickness. A significant risk factor for recurrent ankle sprain is poor balance ability. It is reported that the length of center of pressure (COP) is extended in participants with CAI during one-leg standing[21]. In our past study[22], the length of COP was extended in the one-leg standing and side-jump-landing, and we interpreted this to mean that supportability on the sprain side is reduced. The results of the current study show that the sprain side highly sways in the sagittal and vertical directions in one-leg standing. This is likely to be a compensatory motion occurring in the dorsiflexion direction of the ankle joint to reduce the reaction of the long peroneal muscle and also to reduce retrograde movement of the ankle joint. As a result, it is presumed that this causes compensatory movement occurring in the direction of the ankle flexors. A previous study showed that a patient with a history of ankle joint sprains has an outsole load during gait or one-leg standing[23]. In the current study, we infer that it is difficult for our participants to similarly load on their toe side. In other words, it is predicted that movement in the plantar flexion direction and valgus direction is difficult in the forefoot region at the time of loading, suggesting reduced activity of the long peroneus muscle. Thus, we theorize that lowering the pennation angle of the long peroneus muscle with CAI participants is a factor that reduces balance in one-leg standing. Therefore, ultrasonic evaluation of individual muscle shapes might be useful to determine the influence of the valiant muscle in CAI. The limitation of this study is that the number of participants is not enough. In addition, the effect of intervention by rehabilitation on the sprained side has not been determined. In the future, we would like to examine whether training the long peroneus muscle can improve the stability of movement.

Conflicts of interest

The authors indicate no conflicts of interest.

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