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The Influence of Walking on the Crural Muscle Tone and Stiffness in Pronated Foot

This study aimed to investigate the influence of walking on crural muscle tone and stiffness in individuals with bilateral pronated foot. This study consisted of 16 healthy male. Subjects were divided into a pronated foot group (n = 8) and a normal foot group (n = 8). The navicular drop test on both foot and muscle tone and stiffness in tibialis anterior muscle, medial gastrocnemius muscle, and peroneus longus muscle of both lower extremities were measured before and after 30 min of walking. In this study, the measured navicular drop test before walking was significantly different between pronated foot group and a normal group($p < .05$). After 30 min of walking, significantly, increased medial gastrocnemius muscle stiffness of the non-dominant leg was found in the pronated foot group ($p < .05$). However, there was no significant difference in medial gastrocnemius muscle stiffness between the two groups ($p > .05$).
Based on this study, pronated foot needs to be managed to prevent the abnormally increased medial gastrocnemius muscle stiffness.

Key words: *Crural muscle; Pronated foot; Stiffness; Walking*

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INTRODUCTION

A pronated foot is accompanied by changes in muscle activity of the ankle joint, footwork, and lower extremity muscles during walking [1]. This increases the probability of hammer toes and overlapping toes [2]. As such, it is associated with specific foot disorders and therefore requires appropriate management.

Reductions in the foot arch are accompanied by changes in muscle activity, muscle tone, and stiffness in soft-tissue structures [1,3] and require absorbance of greater energy, thus increasing the risk of injury [4]. As compared with a normal foot, the pronated foot is characterized by high muscle tone and stiffness in the tibialis anterior (TA) and medial gastrocnemius (GCM) muscles of the dominant leg [3]. Previous studies of gait characteristics related to a pronated foot mainly focused on changes in muscle activity of the calf muscles [1,5].

A flat foot is accompanied by changes in ankle joint moments, foot motion, and muscle activity of the lower extremities during walking [1]. Comparisons of changes that occur in crural muscle tone and stiffness during walking on a pronated foot with those that occur during walking on a normal foot are needed to provide objective information for clinical assessments of patients and interventions in clinical practice.

SUBJECTS AND METHODS

Subjects

The purpose of this study was to investigate the influence of walking on bilateral pronated foot on crural muscle tone and stiffness in male subjects. The participants were divided into a normal foot group and a pronated foot group, with eight subjects in each group. Those who were determined to have more than 10 mm in a navicular drop test were included in the pronated foot group. Individuals who had experienced musculoskeletal injuries and received treatment within the last 6 months were excluded. To achieve homogeneity among the participants, only males in their 20s were selected as subjects. Only participants who agreed not to perform exercises that would affect leg muscles and ankle joints, such as running, sitting, and squats, for 3 days before the test were included. The subjects were informed with the purpose of the study, and all subjects provided informed consent. The age, height, and weight of the normal foot group were 23.6 ± 1.7 years, 175.3 ± 2.0 cm, and 67.8 ± 2.7 kg, respectively. The age, height, and weight of the pronated foot group were 23.1 ± 1.1 years, 174.3 ± 1.9 cm, and 71.4 ± 4.0 kg, respectively.

Measurement Methods

Navicular drop test

In the navicular drop test, while the participant sat in a chair, flexing his knees at 90°, the investigator correctly aligned the ankle joints of the participant and then marked the most protruding region (skin marker) of the navicular tubercle. Next, while the subject bore weight on his foot, the change in vertical height of the skin marker was measured using a ruler [6,7]. The reliability within the examiner and between the examiners of this test was reported to be .83 and .73, respectively [8].

Muscle tone and stiffness

Myoton®PRO (MyotonAS, Estonia) was used for measuring the participants' muscle tone and stiffness of the legs. The reliability of this measuring instrument has been verified [9]. The TA muscles, medial GCM muscles, and peroneus longus (PL) muscles of both legs were selected for the measurement. According to the established measurement positions, the TA muscle was measured in the supine position, the medial GCM muscle was measured in the prone position, and the PL muscle was measured in the lateral recumbent position. In each position, the highest point in the muscle was marked using a skin marker. The tip of the Myoton was placed vertically on each muscle, and muscle tone and stiffness were then measured during five cycles of vibration. The measurement was repeated twice for all muscles and the resulting mean values were reclassified according to the dominant foot or non-dominant foot, and these values were used for the data analysis. The same physical therapist performed all the measurements.

Walking

After the initial measurement, the participants walked on a treadmill for 30 min. The walking speed was set to 4.2 km/h, with reference to the average walking speed of 1.175 m/s for Korean males [10]. The second measurement was performed immediately after walking. The measurement was carried out in the same manner as the initial measurement.

Data analysis

In this study, the statistical analysis was performed using a statistical processing program (SPSS 21.0/PC, USA). The Kolmogorov-Smirnov test was employed to test the normal distribution in each group. The Wilcoxon signed-rank test was conducted to analyze differences in muscle tone and stiffness of each muscle measured after walking in each group. The Mann-Whitney test was used to analyze inter-group differences. The significance level in all tests was set to $\alpha = .05$.

RESULTS

Change in navicular drop test

In this study navicular drop test measured before walking were compared in a pronated foot group and a normal group. The results revealed that navicular drop test was high in the pronated foot group than in the normal group($p < .05$)〈Table 1〉.

Table 1. Change in muscle tone, stiffness on the crural muscles

Variable		Dominant leg		Non-dominant leg	
		Before	After	Before	After
Navicular drop test(mm)	Pronated foot	1.15±.05†	1.11±.05	1.19±.14†	1.14±.03
	Normal foot	.53±.06	.60±.08	.59±.07	.60±.06

Values are means ± SE

† Significant difference between pronated foot and normal foot ($p < .05$)

Table 1. Change in muscle tone, stiffness on the crural muscles

Variable			Dominant leg		Non-dominant leg	
			Before	After	Before	After
Tibialis anterior	Muscle tone (Hz)	PF	22.11±.96	21.56±.69	22.01±.71	21.47±.60
		NF	21.64±.75	21.27±.46	21.09±.76	21.21±.76
	Stiffness(N/m)	PF	487.81±24.10	468.19±12.50	484.13±19.95	467.88±16.22
		NF	458.56±24.80	450.50±14.96	459.75±27.08	464.69±28.50
Peroneous longus	Muscle tone (Hz)	PF	16.01±.25	16.31±.25	15.69±.27	15.93±.40
		NF	16.18±.30	16.79±.30	15.83±.35	16.60±.48
	Stiffness(N/m)	PF	301.69±3.35	300.69±5.50	292.63±5.95	299.06±9.26
		NF	304.94±5.74	308.63±8.01	292.00±7.38	308.63±12.65
Medial GCM	Muscle tone (Hz)	PF	16.91±.42	17.05±.38	16.81±.58	17.64±.82
		NF	16.24±.41	17.20±.68	16.79±.37	17.21±.49
	Stiffness(N/m)	PF	292.81±10.23	302.25±10.14	279.50±8.39	293.88±11.77*
		NF	275.50±9.14	295.44±15.00	269.50±8.06	274.31±8.37

Values are means ± SE
GCM: gastrocnemius, PF: pronated foot, NF: normal foot
*Significant difference between before and after walking in each group ($p < .05$)

Change in muscle tone, stiffness on the crural muscles

In this study, muscle tone and muscle stiffness measured before walking were compared in a pronated foot group and a normal group. The results revealed that TA muscle and medial GCM muscle tone and stiffness muscle were significantly higher in the pronated foot group than in the normal group. In addition, PL muscle tone and muscle stiffness were lower in the pronated foot group than in the normal group. However, these differences were not statistically significant.

After 30 min of walking, PL muscle tone and stiffness and medial GCM muscle tone and stiffness increased on average in both groups, whereas TA muscle tone and stiffness decreased on average. Only medial GCM muscle stiffness of the non-dominant leg in the pronated foot group showed a statistically significant increase($p < .05$)〈Table 2〉.

DISCUSSION

A flat foot requires much effort in stabilization and postural control due to excessive mobility of the foot [7]. A flat foot is characterized by high muscle tone and stiffness in the TA muscle and medial GCM muscles of the dominant foot as compared with a normal foot [3]. In this study, although there were no significant differences in muscle tone and stiffness of each muscle before walking between the normal foot and pronated foot groups, overall, TA muscle and GCM muscle tone and stiffness were higher in the pronated foot group as compared with muscle tone and stiffness in the normal foot group. Muscle tone and stiffness in the medialis GCM muscles of both foot increased in an effort to maintain the foot arch during walking, and medial GCM muscle stiffness of the non-dominant leg, in particular, significantly increased. But, there was no significant difference between the two groups.

Increased unilateral foot pronation causes biomechanical changes on ipsilateral and contralateral side of lower extremity. Unilateral foot pronation increased pelvic drop of contralateral side [11]. A pronated foot causes alignment and biomechanical changes at the lower extremity [11], but degree of severity of the disability is not influenced by pronated foot with non-specific low back pain [12].

A pronated foot is associated with frequent knee pain in older adults [13]. Obesity cause a higher prevalence of poronated foot [14].

Therefore, pronated foot may also influence muscle tone and stiffness of lower extremity with musculoskeletal injuries.

Unlike Electromyography measurement equipment, the instrument used in this study for measuring muscle tone and stiffness cannot measure the dynamic movement of the muscle. Thus, changes in muscle tension and stiffness according to the gait cycle could not be examined. However, adult males with pronated foot had elevated levels of crural muscle tone and stiffness during walking in daily life.

The taping intervention applied to the pronated food reduced abnormal plantar pressure and pronation of the foot [6,15] and lowered medial gastrocnemius muscle stiffness [16].

Therefore, taping [6,15] and footwear modifications [17] applied to care options for pronated foot.

CONCLUSION

Based on the results of this study, physical therapy–based management, such as therapeutic exercise and taping is recommended that can improve the increased stiffness in the medial gastrocnemius muscle caused by walking on pronated foot in daily life.

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