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Original Article

Immediate effects of elastic tape application on the foot sole: a randomized controlled trial

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Abstract. [Purpose] In this study, we investigated the effectiveness of elastic tape in increasing the dorsiflexion angle and plantar flexor strength in healthy individuals. [Participants and Methods] This randomized controlled trial included 24 healthy university students who were categorized into the following groups (12 participants in each group): the intervention group (elastic tape was applied to the dominant foot) and the control group (no intervention was performed). We performed intergroup comparison of the pre- and post-intervention dorsiflexion angles and plantar flexor strength. Additionally, we performed subgroup analyses based on a straight-leg raise angle of 70°. [Results] We observed no significant intergroup differences in the dorsiflexion angle or plantar flexor strength. However, the post-intervention dorsiflexion angle was significantly greater than the pre-intervention angle in the subgroup with a straight-leg raise angle of <70° among participants in the elastic tape group. [Conclusion] Elastic tape application may effectively increase the dorsiflexion angle in individuals without hamstring extensibility.
Key words: Elastic tape on the foot sole, Dorsiflexion angle, Randomized controlled trial

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INTRODUCTION

Range of motion (ROM) is a significant aspect of physical therapy, and physical therapists aim to improve limited ROM[1)]. A previous study has indicated that reduced ankle ROM is a risk factor for lower extremity injuries and impaired standing balance[2, 3)]. Although static stretching has been demonstrated as an effective method for improving ankle dorsiflexion ROM[4)], it may also temporarily reduce maximal muscle strength[5)].

One study has reported that myofascial release on the foot sole can immediately increase flexibility in the lower back and hamstrings[6)]. As the plantar fascia and the Achilles tendon are connected[7)], interventions targeting the plantar fascia may also improve ankle dorsiflexion ROM. Although previous reports have demonstrated that elastic tape application in healthy individuals may enhance muscle strength[8)], no research on the immediate effects of elastic tape application on ankle dorsiflexion ROM and calf muscle strength has been conducted. Hence, this study aimed to investigate the effects of elastic tape application to the foot sole on dorsiflexion angle (DFA) and plantar flexor strength (PFS).

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PARTICIPANTS AND METHODS

This study was an assessor-blinded, parallel, randomized controlled trial conducted in accordance with the Consolidated Standards of Reporting Trials statement[9]. It included 24 healthy university students (12 males and 12 females, with a mean age of 20.6 ± 0.6 years). Participants were excluded if they were aged <18 years; had sustained a soft tissue, bone, or nerve injury in the past 3 months; or had received fascial treatment such as myofascial release in the past 3 months. Recruitment occurred via an announcement on university bulletin boards, and all the participants provided their written informed consent. The study was approved by the ethics review board of the research facility, and all procedures were conducted in accordance with the Declaration of Helsinki (institutional review board approval number: 19-lo-184). The participants were randomized using an online randomization software (GraphPad, https://www.graphpad.com/quickcalcs/randomize1/), and allocation tables were created by investigators who were blinded to participant demographics. The randomization algorithm stratified by gender and used a one-to-one block design. Enrollment and allocation were centrally managed, and allocation concealment was implemented. The participants were assigned to groups in the order in which they were enrolled by investigators who had no access to the allocation table.

The participants in the elastic tape group received an intervention involving the application of a half-foot length of an elastic tape (Iotape 38 mm, RINDSPORTS, Osaka, Japan) to the sole of their dominant foot. The tape was applied starting from 3 cm behind the heel, with the first 1 cm left unstretched to serve as an anchor, while the remainder was stretched to 120% of its original length. The intervention was performed by the same therapist for all the participants in this group. Meanwhile, the control group received instructions for bed rest. DFA and PFS were measured as primary outcomes. A digital inclinometer smartphone application was used to measure DFA, using the method described by Banwell et al[10]. The participants were instructed to bend their lower leg forward while keeping their knees straight and their sole on the floor, and the DFA was measured by attaching a smartphone to the center of the ventral lower leg. The DFA was calculated as the maximum anteversion angle of the lower leg after calibrating the floor to 0° (Fig. 1). A smaller DFA value indicates a greater ROM for ankle dorsiflexion. PFS was measured using a hand-held dynamometer (Mobie MT-100; SAKAI Medical, Tokyo, Japan). While seated on the floor with both knees extended, the participants' muscular strength was assessed. The product of the measured amount of ankle plantar flexion and the lever arm was used to calculate the PFS. Demographic information (Table 1), ROM, and muscle strength were assessed at baseline, and DFA and PFS were reassessed immediately after the intervention. To control for the physical effects of the baseline assessments, post-intervention assessments were conducted 30 min after the baseline assessment for both groups. All the investigators who were blinded to the assignment performed the measurements.

Data were analyzed using the intention-to-treat principle. The reliability of the smartphone application for evaluating DFA was first assessed in a sample of 20 healthy university students (10 males and 10 females, with a mean age of 20.6 ± 0.7 years). To assess reliability, one assessor calculated the intraclass correlation coefficients (ICCs) and minimal detectable change 95 (MDC95) and performed a Bland–Altman analysis based on two DFA measurements. Subsequently, the data from the two groups were compared using a two-way analysis of variance with group and time as factors, followed by a simple main effects test. Additionally, the proportion of participants whose DFA changed by MDC95 or more was compared between groups using the Fisher exact test. Finally, a subgroup analysis was conducted by classifying the participants into those with a straight-leg raising angle (SLR) of <70° and those with an SLR of >70°, based on the results of a previous study[11] to demonstrate the difference in the treatment effects between the two groups. Previous study reported that manual therapy could immediately increase the ROM of SLR in individuals who are able to raise the leg straight to more than 70 degrees[11].

Fig. 1. Measurement of dorsiflexion angle.

Table 1. Demographic data

Variable	Elastic tape (n=12)	Control (n=12)
Age, years	20.7 ± 0.7	20.5 ± 0.5
Gender, n (%)		
Male	7 (58.3)	6 (50.0)
Female	5 (41.7)	6 (50.0)
Height, cm	165.9 ± 8.9	164.5 ± 10.3
Weight, kg	63.1 ± 14.5	57.2 ± 8.7
SLR, degrees	70.2 ± 11.1	73.4 ± 9.4

Mean ± standard deviation.
SLR: straight-leg raising angle.

The SLR measurement was performed using the same smartphone application as the DFA measurement, and the participant's active movement angle was measured. The smartphone was fixed to the center of the participant's lateral thigh. The same procedures as those of the efficacy test were used for the subgroup analysis. All the statistical analyses were conducted using the SPSS Statistics Ver. 27 (IBM, Armonk, NY, USA), and significance was set at $p<0.05$.

RESULTS

The ICC (1,1) for DFA was 0.995. The Bland–Altman analysis did not reveal any significant fixed or proportional errors (fixed bias: $p>0.130$; proportional bias: $p>0.513$). The MDC95 was 1.4°. The mean age was 20.7 years for the elastic tape group (7 males and 5 females) and 20.5 years for the control group (6 males and 6 females). All the participants received their assigned treatment and participated in post-intervention outcome measures. The results of the two-way analysis of variance demonstrated no main effects of group or time on DFA or PFS and no significant interaction between these factors. No significant difference in the percentage of participants who had improved DFA beyond MDC95 was observed between the elastic tape and control groups (Table 2). Demographic data of the two subgroups indicated no significant differences between the elastic tape and control groups (Table 3). In the subgroup with an SLR of ≥70°, no main effects of group or time on DFA or PFS and no significant interaction between these factors were observed. In the subgroup with an SLR of <70°, no main effects of group or time on DFA were noted, although a significant interaction between the factors was observed ($F=5.908$, $p=0.033$). A simple main effect test revealed that DFA after the intervention was significantly improved in the elastic tape group compared to that before the intervention ($p=0.033$) (Table 4). Additionally, no main effects of group or time on PFS and no significant interaction between these factors were observed.

DISCUSSION

No significant differences in DFA and PFS were observed between the elastic tape and control groups, indicating that applying an elastic tape to the foot sole had no effect on these variables, which was contrary to our hypothesis. However, the subgroup analysis demonstrated that DFA significantly increased post-intervention compared to pre-intervention in those with an SLR of ≤70°, which indicates hamstring extensibility. Thus, applying an elastic tape to the foot sole would be effective for improving DFA under certain conditions.

Several previous studies have reported on the effectiveness of elastic tape application for ankle dorsiflexion ROM in healthy individuals, with conflicting results. Although one study has identified a significant increase in ankle dorsiflexion

Table 2. Results of group comparisons

Outcome		Elastic tape (n=12)	Control (n=12)
DFA, angle	Pre	43.0 ± 7.1	38.6 ± 8.3
	Post	41.5 ± 9.1	37.9 ± 8.9
PFS, Nm	Pre	77.1 ± 19.5	79.8 ± 38.7
	Post	81.5 ± 20.0	76.9 ± 40.5
1.4 >DFA change, n (%)		7 (58.3)	5 (41.7)

Mean ± standard deviation.
DFA: dorsiflexion angle; PFS: plantar flexor strength.

Table 3. Demographic data in each subgroup

Variable	SLR ≥70 degree		SLR <70 degree	
	Elastic tape (n=5)	Control (n=6)	Elastic tape (n=7)	Control (n=6)
Age, years	21.0 ± 0.0	20.5 ± 0.5	20.4 ± 0.8	20.5 ± 0.5
Gender, n (%)				
Male	0 (0)	0 (0)	7 (100)	6 (100)
Female	5 (100)	6 (100)	0 (0)	0 (0)
Height, cm	159.8 ± 5.1	156.2 ± 6.7	170.3 ± 8.7	172.9 ± 4.6
Weight, kg	54.1 ± 7.4	52.2 ± 5.9	69.5 ± 15.3	62.1 ± 8.5
SLR, degree	80.0 ± 9.0	81.0 ± 6.6	63.1 ± 5.8	65.8 ± 3.4

Mean ± standard deviation.
SLR: straight leg raising.

Table 4. Results of group comparisons in each subgroup

Outcome		SLR ≥70 degree		SLR <70 degree	
		Elastic tape (n=5)	Control (n=6)	Elastic tape (n=7)	Control (n=6)
DFA, angle	Pre	46.8 ± 8.6	40.0 ± 8.0	40.3 ± 4.7	37.2 ± 9.2
	Post	48.2 ± 9.3	37.0 ± 8.2	36.7 ± 9.8†	38.8 ± 5.4
PFS, Nm	Pre	57.5 ± 4.8	47.9 ± 16.5	91.1 ± 11.7	111.7 ± 24.0
	Post	67.3 ± 10.4	44.4 ± 26.7	91.6 ± 19.3	109.4 ± 18.8
1.4 >DFA change, n (%)		1 (20.0)	4 (66.7)	6 (85.7)*	1 (16.7)

Mean ± standard deviation.
†p<0.05: comparison with the value of pre DFA in elastic tape group in the subgroup of SLR <70 degree.
*p<0.05: comparison with the control group in the group of SLR <70 degree.
SLR: straight leg raising; DFA: dorsiflexion angle; PFS: plantar flexor strength.

ROM[12], two other studies have reported no change[13, 14]. Therefore, the efficacy of elastic tape application for ankle dorsiflexion ROM is uncertain. In a previous study that has reported an increase in ankle dorsiflexion ROM, a Y-shaped elastic tape was applied from the navicular tuberosity of the plantar to the medial and lateral heads of the gastrocnemius muscle[12]. On the other hand, in previous studies that reported no change, elastic tape was not applied to the gastrocnemius but around the ankle joint[13, 14]. DFA of the participants in present study did not increase, which may be owing to the difference in the area of tape application compared to that in previous studies. The superficial back line, a fascial connection from the plantar fascia to the gastrocnemius muscle[15], may have been more effectively influenced by the method used in the previous study, in which an elastic tape was applied from the gastrocnemius muscle to the Achilles tendon to the foot sole. However, our results revealed that the DFA of participants in the elastic tape group only increased in those with an SLR of <70°, suggesting that the degree of hamstring extensibility may affect the effect of the elastic tape on the sole on ankle dorsiflexion ROM. Fereydounnia et al.[16] and Espejo-Antúnez et al.[17] have reported that elastic tape application to the posterior thigh increased SLR in athletes with short hamstrings. However, no reports have compared the effects of elastic tape application according to the degree of hamstring extensibility. Thus, these issues should be addressed in future studies.

In both the main and subgroup analyses, no significant difference in PFS between the elastic tape and control groups was observed. The immediate effects of elastic tape application on maximal muscle strength in healthy individuals have conflicting results. While some studies have reported that elastic tape application increases hand grip and hip extensor strength[8, 18, 19], others have demonstrated that it does not affect ankle dorsiflexion strength[8]. The lack of effects on PFS in this study may be attributed to two reasons. First, the elastic tape was not applied to the major muscles responsible for plantar flexion of the ankle. In three previous studies that have reported increases in maximal muscle strength, an elastic tape was applied along the wrist extensors[18, 19] and gluteus maximus[8]. The method used in this study which was the application of an elastic tape to the foot sole may not have sufficiently enhanced the strength of the triceps surae muscle that causes plantar flexion of the ankle. Second, the application of an elastic tape to the foot sole may not have facilitated the muscle strength of the plantar intrinsic foot muscles. A recent research has demonstrated that plantar flexion of the ankle is caused by the combined activity of the triceps surae and plantar-specific muscles[20]. As the plantar aponeurosis connects the plantar muscles and skin, the application of an elastic tape may not have created sufficient tension to stimulate the plantar-specific muscles.

This study properly addressed the measurement errors in the DFA in order to maintain internal validity. Previous studies have established the reliability of the DFA measurement method, which involves using a smartphone application to measure DFA while a participant was standing[10]. Our study also observed high data reliability. To visualize the percentage of participants who experienced changes beyond the measurement error, we calculated the MDC95 of the DFA. In the subgroup analysis, the elastic tape group demonstrated a significantly higher percentage of participants that had DFA changes exceeding the MDC95 than the control group.

This study has some limitations that should be considered. First, the study design was not double-blinded, which could potentially introduce bias and result in an overestimation of the effect. Conducting a multi-arm study with a placebo group would be preferable in the future. Second, the study sample comprised healthy university students, so the results may not be generalizable to athletes or patients. Specifically, the degree of hamstring extensibility may have influenced the results. To address these issues, designing a study with a more diverse pool of participants would be necessary. Third, a gender bias was observed in the attributes of the participants classified into subgroups. Although previous studies on the therapeutic effects of elastic tape have reported no effect of gender[21], interpretation of the results should be done with caution. Finally, this study did not explore the physiological mechanisms underlying the observed increase in DFA. Previous studies have examined factors such as changes in skin blood flow[22] and the excitability of motor neurons[23] in relation to elastic tape application; however, these factors were not investigated in this study. In addition, the impact of physiological phenomena represented by the alpha-gamma linkage and the axon reflex on the intraweight muscle should also be considered. Therefore, the potential benefits and risks of interventions need to be carefully considered when prescribing elastic tape application. In conclusion,

this study did not provide evidence for the effectiveness of elastic tape application in increasing ankle dorsiflexion ROM or plantar flexor strength in healthy university students. However, the use of an elastic tape may increase ankle dorsiflexion ROM only in participants with low flexibility.

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