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Original research

Immediate effect of walking with talus-stabilizing taping on ankle kinematics in subjects with limited ankle dorsiflexion

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ABSTRACT

Objective: To determine the effects of walking with talus-stabilizing taping (TST) on ankle dorsiflexion (DF) and heel-off time in the stance phase of gait and ankle DF passive range of motion (PROM).
Design: Pre- and post-intervention study.
Setting: University motion analysis laboratory.
Participants: Ten subjects participated in this study. Sixteen ankles with limited ankle DF PROM were tested.
Main outcome measures: Ankle DF PROM was measured using a goniometer, and maximum ankle DF before heel-off and time to heel-off in the stance phase of gait were measured using a 3D motion analysis system before and after walking with TST. Data were analyzed using a paired *t*-test.
Results: Ankle maximum DF before heel-off ($p = 0.001$), time to heel-off during the stance phase of gait ($p = 0.005$), and ankle DF PROM ($p < 0.001$) were significantly increased post-intervention compared with pre-intervention.
Conclusions: Walking with TST is an effective self-exercise for improving ankle kinematics during gait and increasing ankle DF PROM in individuals with limited ankle DF PROM.

1. Introduction

Ankle dorsiflexion (DF) with at least 10° of passive range of motion (PROM) is required to prevent ankle injuries (Johanson et al., 2006; Kibler, Goldberg, & Chandler, 1991; Willems et al., 2005). Limited ankle DF PROM is associated with ankle injuries such as plantar fasciitis, Achilles tendinitis, and ankle sprain (Kibler et al., 1991; Schepsis, Jones, & Haas, 2002; Willems et al., 2005). Tightness of the triceps surae muscle and lack of posterior gliding of the talus are risk factors for limited ankle DF PROM (Sahrmann, 2010). Such limited ankle DF PROM allows altered foot alignment and abnormal ankle movement, which may induce ankle injuries (Donatelli & Wooden, 1996; Willems et al., 2005).

Limited ankle DF PROM may be responsible not only for ankle injuries but also for abnormal gait patterns (Cornwall & McPoil, 1999; Johanson, Cooksey, Hillier, Kobbeman, & Stambaugh, 2006; Johanson, Cuda, Koontz, Stell, & Abelew, 2009). Maximum ankle DF with the knee in nearly full extension generally occurs just before heel-off during the stance phase of gait (Johanson, Cooksey, et al., 2006, 2009). Limited ankle DF PROM with the knee in nearly full extension could restrict the function of the ankle rocker, referred to as tibial advancement over the foot, which leads to early heel-off during the stance phase of gait (Perry & Burnfield, 2010; Sahrmann, 2010). Cornwall and McPoil (1999) reported that individuals with limited ankle DF PROM showed significant early heel-off compared to individuals with normal ankle DF PROM. Early heel-off may increase the time of weight bearing on the forefoot and subsequent tissue stress during the stance phase of gait, resulting in lower-extremity overuse injuries (Donatelli & Wooden, 1996; Johanson et al., 2006). Therefore, clinicians should consider interventions that increase ankle DF PROM to prevent an abnormal gait pattern and secondary lower-extremity overuse injuries in individuals with limited ankle DF PROM.

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Historically, mobilization with movement (MWM) techniques (Collins, Teys, & Vicenzino, 2004; Vicenzino, Branjerdporn, Teys, & Jordan, 2006), gastrocnemius stretching exercises (Dinh, Freeman, Granger, Wong, & Johanson, 2011; Johanson et al., 2006), and serial casting (Selby-Silverstein, Farrett, Maurer, & Hillstrom, 1997) have been used to increase ankle DF PROM. Because MWM for the talocrural joint is performed using a combination of anterior-to-posterior gliding of the talus by manual assistance and active ankle DF, an improved talus gliding movement after MWM for the talocrural joint is considered to increase ankle DF PROM (Collins et al., 2004; Vicenzino et al., 2006). Additionally, previous studies have shown that gastrocnemius stretching exercises and serial casting increased ankle DF PROM and suggested that these can be performed effectively as a home or self-exercise (Dinh et al., 2011; Selby-Silverstein et al., 1997). However, it is difficult for individuals with limited ankle DF PROM to perform MWM independently (Vicenzino et al., 2006), and gastrocnemius-stretching exercises have no effect on reducing compensatory ankle movement during gait (Johanson et al., 2006). Although serial casting increases ankle DF during gait (Selby-Silverstein et al., 1997), functional activities can be restricted while wearing a cast.

Walking with talus-stabilizing taping (TST) has recently been suggested as a novel intervention to increase ankle DF PROM (Sahrmann, 2010). Sahrmann (2010) stated that the application of tape to the talus in an anterior-superior to posterior-inferior direction assists with further DF at the talocrural joint when individuals perform functional activities requiring tibial advancement over the foot. In contrast to traditional treatments for increasing ankle DF ROM (Dinh et al., 2011; Selby-Silverstein et al., 1997; Vicenzino et al., 2006), walking with TST may not interfere with functional activities in individuals with limited ankle DF PROM.

Although clinicians have demonstrated the effects of physical therapy interventions on ankle DF PROM, it is unknown whether these interventions can increase ankle DF with the knee extended and prevent compensatory movement, such as early heel-off, during gait (Collins et al., 2004; Dinh et al., 2011; Selby-Silverstein et al., 1997; Vicenzino et al., 2006). Additionally, previous interventions to increase ankle DF PROM have been associated with difficulty in independent performance of exercises and with restriction of functional activities (Collins et al., 2004; Selby-Silverstein et al., 1997). The theoretical effects of walking with TST on ankle DF PROM have been suggested in the literature (Sahrmann, 2010); however, evidence for this intervention is lacking.

In this study, we examined the effects of walking with TST on ankle DF before heel-off and time to heel-off during the stance phase of gait as well as ankle DF PROM in individuals with limited ankle DF PROM. Changes in ankle movement during gait and ankle DF PROM after walking with TST will provide information useful for the design of self-prevention programs for ankle injuries and abnormal gait patterns. We hypothesized that maximum ankle DF before heel-off, time to heel-off during the stance phase of gait, and maximum ankle DF PROM would be increased after walking with TST.

2. Methods

2.1. Participants

In total, 16 ankles with limited DF PROM among 10 participants (four females, six males) were included in the study. The mean age of the participants was 25.80 ± 2.82 years, and the mean ankle DF PROM in the knee-extended position on the limited side was 7.71 ± 1.80°. For this study, 67 university student volunteers (41 females, 26 males) were recruited through advertisement on the university message board, and examiners measured ankle DF PROM in all volunteers. Among 67 volunteers, 10 with unilateral or bilateral limited ankle DF PROM were selected as participants for the present study. Among the participants, four female participants had bilateral limited ankle DF PROM, four males had unilateral limited ankle DF PROM, and two males had bilateral limited ankle DF PROM. Inclusion criteria were (1) unilateral or bilateral ankle DF PROM of $<10^{\circ}$ in the knee-extended prone position; (2) ankle DF PROM of $>10^{\circ}$ in the knee-flexed prone position; and (3) ankle DF PROM of at least 5° more in the knee-flexed prone position than in the knee-extended prone position (Dinh et al., 2011). Exclusion criteria were a history of surgery in the ankle or knee, ankle fracture, knee flexion contracture, or neurological disease. Based on previous findings (Cornwall & McPoil, 1999), 16 ankles would provide at least 80% statistical power at an alpha level of 0.05 to detect changes in ankle movement during gait. All participants read and signed an informed consent form approved by the Inje University Ethics Committee for Human Investigations prior to their participation.

2.2. Measurement of ankle DF PROM

Ankle DF PROM was measured using a 14-inch stainless steel goniometer by experienced physical therapists in a single-blind design. First, ankle DF PROM in the knee-extended prone position was measured. The participants were positioned prone on the table with the foot protruding past the end of the table. An examiner maintained a neutral subtalar joint position and applied force to the plantar surface of the forefoot and midfoot until further movement was restricted with firm resistance. A second examiner confirmed the neutral position of the subtalar joint and measured the ankle DF PROM. The fulcrum of the goniometer was placed over the lateral malleolus, and the stationary and moving arms were aligned with the fibular head and parallel to the fifth metatarsal, respectively (Fig. 1). Measurement of ankle DF PROM in the knee-extended prone position was repeated three times, and the goniometer was moved away from the lower extremity between measurement trials. Next, measurement of ankle DF PROM in the knee-flexed prone position was performed 5 min after measurements of ankle DF PROM in the knee-extended position. Participants were positioned prone on the table with 90° of knee flexion. An examiner applied force to the plantar surface of the foot while maintaining neutral subtalar joint alignment. When an examiner encountered firm resistance with restriction of further ankle DF, a second examiner measured ankle DF PROM using a goniometer. The goniometer was placed on the same landmarks as those used in the knee-extended position, and it was removed from the lower

Fig. 1. Measurement of ankle dorsiflexion passive range of motion.