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Original article

Immediate combined effect of gastrocnemius stretching and sustained talocrural joint mobilization in individuals with limited ankle dorsiflexion: A randomized controlled trial

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ABSTRACT

Background: Although gastrocnemius stretching and talocrural joint mobilization have been suggested as effective interventions to address limited ankle dorsiflexion passive range of motion (DF PROM), the effects of a combination of the two interventions have not been identified.
Objective: The aim of the present study was to compare the effects of gastrocnemius stretching combined with joint mobilization and gastrocnemius stretching alone.
Design: A randomized controlled trial.
Methods: In total, 24 individuals with limited ankle DF PROM were randomized to undergo gastrocnemius stretching combined with joint mobilization (12 feet in 12 individuals) or gastrocnemius stretching alone (12 feet in 12 individuals) for 5 min. Ankle kinematics during gait (time to heel-off and ankle DF before heel-off), ankle DF PROM, posterior talar glide, and displacement of the myotendinous junction (MTJ) of the gastrocnemius were assessed before and after the interventions. The groups were compared using two-way repeated measures analysis of variance.
Results/findings: : Greater increases in the time to heel-off and ankle DF before heel-off during gait and posterior talar glide were observed in the stretching combined with joint mobilization group versus the stretching alone group. Ankle DF PROM and displacement of the MTJ of the gastrocnemius were increased significantly after the interventions in both groups, with no significant difference between them.
Conclusions: These findings suggest that gastrocnemius stretching with joint mobilization needs to be considered to improve ankle kinematics during gait.

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1. Introduction

To prevent and manage lower extremity injuries, it is essential to have sufficient ankle dorsiflexion passive range of motion (DF PROM), with at least 10° of ankle DF PROM with the knee extended (Gross, 1995; Donatelli and Wooden, 1996; Sahrmann, 2010). It has been reported that limited ankle DF PROM is a risk factor for lower extremity injuries (Kibler et al., 1991; Pope et al., 1998; Schepsis et al., 2002; Willems et al., 2005). Also, limited ankle DF PROM contributes to compensatory movements during gait including early heel-off, subtalar joint pronation, and midtarsal joint DF (Gross, 1995; Donatelli and Wooden, 1996; Karas and Hoy, 2002), which increases loading duration on the forefoot and contributes to a hypermobile midfoot (Dananberg et al., 2000; Karas and Hoy, 2002). Because excessive stresses on the foot and ankle complex caused by compensatory movements are cumulative during functional activities, it is believed that such compensatory movements contribute to

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pain in the foot and ankle complex (Dananberg et al., 2000; Tabrizi et al., 2000; Karas and Hoy, 2002; Schepsis et al., 2002).

Compensatory movements caused by limited ankle DF PROM are apparent during gait, especially in the mid-stance phase (Gross, 1995; Johanson et al., 2006a, 2006b; Drewes et al., 2009; Johanson et al., 2009). Limited ankle DF PROM disturbs tibial advancement over the foot during the mid-stance phase, and consequently an early heel-off strategy is adopted to progress the body over the foot during the stance phase of gait (Karas and Hoy, 2002; Perry and Burnfield, 2010; Sahrmann, 2010). Ultimately, early heel-off, together with insufficient tibial advancement, increases stress on the forefoot throughout the increased time of weight-bearing and pressure on the forefoot (Dananberg et al., 2000; Yoon et al., 2014), which may affect foot and ankle injuries (Kibler et al., 1991; Wilder and Sethi, 2004). From this viewpoint, intervention to increase ankle DF together with time to heel-off during the stance phase of gait should be considered when designing intervention programs for individuals with limited ankle DF PROM.

Gastrocnemius stretching exercises are often performed to increase ankle DF PROM with the knee extended (Dinh et al., 2011; Nakamura et al., 2011). Gastrocnemius stretching exercises lead to greater ankle DF PROM with the knee extended because of increased tolerance to stretching, modification in sensation (Weppler and Magnusson, 2010), and changes in the architecture of the gastrocnemius muscle-tendon unit, especially in the displacement of the myotendinous junction (MTJ) of the gastrocnemius (Morse et al., 2008; Nakamura et al., 2011; Mizuno et al., 2013). A previous study using ultrasonography identified decreased muscle stiffness, together with increased displacement of the MTJ of the gastrocnemius, after 5 min of gastrocnemius stretching (Nakamura et al., 2011). However, no significant difference in ankle DF before heel-off or time to heel-off was found after gastrocnemius stretching (Johanson et al., 2006b, 2009), despite significant increases in ankle DF PROM and displacement of the MTJ of the gastrocnemius (Morse et al., 2008; Nakamura et al., 2011).

To correct compensatory movements during gait, interventions in addition to general gastrocnemius stretching should be considered. Because limited ankle DF PROM with the knee extended may result from gastrocnemius tightness and/or inadequate accessory motion of the talocrural joint (Hubbard and Hertel, 2006; Sahrmann, 2010), talocrural joint mobilization may be such an appropriate additional intervention. Previous studies found significant increases in the amount of posterior talar glide and ankle DF PROM after sustained anterior-to-posterior talocrural joint mobilization with movement (Vicenzino et al., 2006). Additionally, the force provided by sustained anterior-to-posterior talocrural joint mobilization fixes the talus at the end-range of the posterior talar glide, and such stabilization force consequently facilitates relative tibial advancement over the fixed foot during closed-chain activities (Sahrmann, 2010; Kang et al., 2014).

Considering the influences of gastrocnemius stretching (Dinh et al., 2011) and talocrural joint mobilization (Vicenzino et al., 2006), the combined use of both interventions may lead to greater improvement in the ankle DF PROM and gait patterns. However, no reported study has examined the combined effect of both interventions. Thus, the aim of the present study was to compare the effects of gastrocnemius stretching combined with sustained talocrural joint mobilization and gastrocnemius stretching alone in individuals with limited ankle DF PROM with the knee extended.

2. Methods

This study was a single-blind, randomized (stretching combined with joint mobilization versus stretching alone group, 1:1), parallel-group study, conducted at Inje University, South Korea. The study was registered in the Clinical Research Information Service, with registration number KCT0001097.

2.1. Participants

In total, 24 male participants were recruited at the local university in Gimhae, South Korea, from April to May 2014. Only males were recruited to minimize any potential effect of gender on outcome measures (Morse, 2011). Volunteers with <10° of ankle DF PROM with the knee extended, > 10° of ankle DF PROM with the knee flexed, and >5° in difference in the ankle DF PROM between the knee flexed and knee extended positions in the unilateral or bilateral side were eligible for this study (Dinh et al., 2011; Kang et al., 2014). Volunteers with prior surgical histories in the lower extremity, fractures, neurological diseases, or hip and knee flexion contracture were excluded. In cases where participants showed bilateral limited ankle DF PROM, the foot on the dominant leg side was included based on a previous finding that showed no main effect of side on ankle DF PROM after intervention in individuals with bilateral limited ankle DF PROM (Johanson et al., 2006b). All participants were randomized to stretching combined with joint mobilization ($n = 11$) or stretching alone ($n = 11$) groups by an individual who was not involved in the recruitment of the participants, using computer software (Fig. 1). Because the same examiners were involved in the outcome measurements and interventions, they were not blinded to the group assignments, whereas participants were not told of their group allocation or the purpose of the study. This study was approved by the Inje University Institutional Research Review Committee. All participants provided written informed consent prior to participation.

The sample size was calculated based on our pilot test. Six volunteers (three volunteers in the stretching combined with joint mobilization group and three in the stretching only group) participated in the pilot test used to calculate the number of participants required for this study. The results of the pilot test (mean difference, 2.33°; standard deviation, 2.15°) indicated that 12 participants per group were required to detect a difference in posterior talar glide between the two groups using a one-tailed test, an α level of 0.05, and power of 80%.

2.2. Outcome measures

The main outcome variables of interest were time to heel-off and ankle DF before heel-off. Secondary outcome variables were ankle DF PROM with the knee extended, posterior talar glide, and displacement of the MTJ of the medial gastrocnemius.

Gait analysis. Time to heel-off and ankle DF just before the heel-off, the primary outcome measures, were assessed using the Vicon MX-T10 motion analysis system (Vicon Motion Systems Ltd., Oxford, UK) with eight cameras at a sampling rate of 100 Hz. Two force plates (Advanced Medical Technology, Inc., Watertown, USA) embedded in the middle of the walkway were used to detect heel-strike and toe-off during gait. An examiner attached 16 reflective markers on the lower extremity according to the Vicon Plug-in-Gait marker set (Kang et al., 2014). Shank segments were constructed using markers on the lateral knees, tibias, and malleoli, while feet segments were constructed using lateral malleoli, second metatarsal heads, and posterior calcanei markers. After attachment of the markers, participants were asked to walk on the 8-m walkway at a comfortable speed. Time to heel-off and ankle DF just before the heel-off were calculated using the Nexus software (ver. 1.7; Vicon Motion Systems Ltd.). Time to heel-off was normalized to the stance phase (% stance phase). The heel-off was determined as the point at which the calcaneus marker was consistently elevated

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