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CLINICAL STUDY

The acute effects of ankle mobilisations on lower extremity joint kinematics

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Previous investigations have identified compensatory movement strategies (CMS) within the lower extremity or lumbopelvic complex during closed chain exercises may be associated with a loss of ankle dorsiflexion range of motion (ROM). The aim of this study was to investigate the acute effects of ankle mobilisations on proximal joint kinematics during a movement task that demands a high amount of ankle dorsiflexion ROM.
Methods: Eight healthy males (mean (SD) age 25 (4) years) demonstrating side-to-side asymmetry during the weight-bearing lunge test (WBLT) and CMS during the single-leg step-down exercise were accepted for this study. Participants completed five repetitions of a single-leg step-down, both before and after an ankle mobilisation intervention aimed at improving joint athrokinematics. A Vicon motion capture system recorded 3D joint and segment kinematics of the ankle, knee, hip and pelvis. A paired samples *t*-test was used to identify significant changes of lower extremity joint kinematics during the single-leg step-down, before and after mobilisation.
Results: Following the mobilisation intervention, statistically significant gains in ankle dorsiflexion ROM were identified during the WBLT [mean difference 2.425 (0.9377) centimeters, $t = -7.315$, $p < 0.01$]. No evidence was found of altered joint kinematics during the single-leg step-down.
Conclusion: These findings indicate that increases in ankle dorsiflexion ROM do not automatically integrate into functional movement tasks.

1. Introduction

Compensatory movement strategies (CMS) within the lower extremity (Granata and Marras, 1995; Hewett et al., 2005; Marras and Granata, 1997) and lumbopelvic region (Pococco et al., 2013) are theorised as a risk factor for many sports injuries. The ability to control these abnormal joint motions from occurring may be potentially crucial in preventing damage to relevant stabilising structures (Mottram and Comerford, 2008). When CMS are present, changes in normal muscle recruitment patterns have been observed (Cowan et al., 2008; Hollman et al., 2009; Mauntel et al., 2013; Padua et al., 2012; Zazulak et al., 2005). This occurrence has led numerous practitioners to propose exercise-based interventions be implemented in order to correct muscle recruitment dysfunctions (Hewett et al., 2010; Hides et al., 2001; Hodges, 2003; O'Sullivan, 2000).

However recent research indicates that CMS may not be exclusively attributed to local motor control deficiencies. Fundamentally, reduced activity in stabilising muscles may in fact be a symptom of an underlying mobility deficiency elsewhere in the lower extremity (Bell et al., 2008). For instance, limited ankle dorsiflexion range of motion (ROM) has been shown to impede normal movement pathways, therefore demanding various CMS to allow for the completion of functional activities (Macrum et al., 2012; Mauntel et al., 2013; Padua et al., 2012). In this example, for the continued forward translation of the tibia to occur a mobile talonavicular and calcaneocuboid joint (composing the midtarsal joint) is required (Tiberio, 1987a, 1988, Tiberio et al., 1989). A reduction in structural congruency of the midtarsal joint allows for compensatory dorsiflexion at the midfoot, offsetting the loss of ankle joint movement (Tiberio, 1987a,b, 1988; Tiberio et al., 1989). During stance this may only occur through increased calcaneal eversion (Tiberio, 1987a,b, 1988; Tiberio et al., 1989).

Due to the mechanics of the subtalar joint, increased calcaneal eversion is proximally coupled with internal rotation of the tibia, and consequently the femur (Lundberg et al., 1989). Extreme tibial

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and femoral transverse plane motion is also associated with greater knee abduction and hip adduction joint angles, driving a rise in knee valgus moments (Chuter and Janse de Jonge, 2012; Tiberio, 1987a,b). This movement sequence necessitates gluteal activation in order to prevent harmful loading situations from occurring within the lower extremity and lumbopelvic complex (Preece et al., 2008). However gluteus maximus and medius activity may be inhibited if a hypomobile talocrural is present. A loss of ankle dorsiflexion ROM may require excessive femoral internal rotation in order to permit additional calcaneal eversion, and therefore midfoot dorsiflexion as a CMS. As such, subjects possessing a lack of ankle dorsiflexion ROM have demonstrated increased activation of the hip adductors relative to the gluteal muscles (Mauntel et al., 2013; Padua et al., 2012). This altered recruitment strategy is likely employed in order to facilitate the CMS, allowing for completion of the task. This evidence would suggest that muscle recruitment patterns around the hip joint may be constrained by distal mobility restrictions.

Artificial interventions aimed at replicating increases in ankle dorsiflexion ROM have revealed acute positive changes in lower extremity performance during functional tasks. Following the insertion of a 5.08 centimetre (cm) wooden block under participants heels, Padua et al. (2012) demonstrated improvements in dynamic joint alignment during a bilateral squat. Healthy subjects exhibited less medial knee displacement and consequently, optimised muscle recruitment patterns within the lower extremity (Padua et al., 2012). A similar investigation by Macrum et al. (2012) demonstrated comparable results when imitating ankle dorsiflexion hypomobility.

Evidence exploring methods to increase real ankle dorsiflexion ROM suggest practitioners may consider employing joint mobilisations as an intervention to regain lost motion (Vincenzino et al., 2007). Mobilisations with movement (MWM) applied at the ankle complex have the potential to enhance posterior glide of the talus relative to the tibiofibular mortise (Maitland, 1977; Vicenzino et al., 2006), and posterior-superior glide of the inferior fibula relative to the tibia (Delahunt et al., 2013; Mulligan, 1995). Restoring these accessory joint motions are critical in achieving normal physiological ROM (Denegar et al., 2002; Loudon and Bell, 1996). As such, MWM have been shown to acutely increase ankle dorsiflexion ROM (Cho et al., 2012; Collins et al., 2004; Green et al., 2001; Vincenzino and O'Brien, 1998; Vicenzino et al., 2001, 2006), improve balance (Hoch and McKeon, 2010; Hoch et al., 2012) and enhance performance in locomotion (Guo et al., 2006) and jump orientated tasks (Delahunt et al., 2013).

Following mobilisation, immediate alterations in joint kinematics displayed during functional tasks have been shown in both injured (Hoch and McKeon, 2010) and healthy subjects (Guo et al., 2006; Yoon et al., 2013). However, whether acute increases in ankle dorsiflexion ROM lead to immediate reductions in the CMS developed as a consequence of the hypomobility, remain unclear. Research illustrates an immediate reduction in proximal CMS when synthetically simulating enhanced ankle dorsiflexion ROM (Padua et al., 2012), although little evidence exists identifying this occurrence with interventions aimed at improving actual mobility. Therefore the aim of this study was to investigate the acute effects of ankle joint mobilisations on proximal joint kinematics, during a single-leg squat variation that requires large amounts of ankle dorsiflexion ROM.

2. Methods

2.1. Participants

Eight healthy males volunteered to participate in this study (age = 25 (4) years, height = 182.9 (7.0) cm, mass = 88.6 (14.5) kg). All participants reported to be in good general health, with no history of surgical procedures to the lower extremity or lower back region. Participants were excluded if they had suffered from a recent history of injury to the lower extremity or lower back region, preventing them from exercise for three successive days in the six months preceding testing. Volunteers were accepted for this study if they satisfied the following criteria: (1) presented with asymmetrical ankle dorsiflexion ROM above 1 cm during the weight-bearing lunge test (WBLT) as described by Vicenzino et al. (2001); (2) on initial screening, participants presented with CMS during a single-leg step-down, using the criteria outlined by Crossely et al. (2011). All participants provided written informed consent and completed a PAR-Q form before their participation was approved. Ethical approval for this study was obtained through the School of Sport, Health and Applied Sciences at St Mary's University.

2.2. Procedures

Prior to data collection, all participants underwent a pre-screening session to qualify for testing. Firstly all participants were screened for asymmetrical ankle dorsiflexion ROM. Participants who demonstrated an asymmetry of ankle dorsiflexion ROM of more than 1 cm were then assessed performing the single-leg step-down exercise on the restricted leg. Altered dynamic alignment of the lower extremity or lumbopelvic complex was then assessed. A single investigator determined performance in real-time (Weeks et al., 2012).

All eight participants met the inclusion criteria, with a mean asymmetry of 2.4 (1.2) cm being exhibited. Each participant then reported for a single testing session. Participants repeated the WBLT and then completed five repetitions of the single-leg step-down on the hypomobile leg, both before and after ankle joint mobilisation. Three ankle joint mobilisations were applied, varying in their primary purpose. Ankle joint mobilisations applied were: (1) non-weight-bearing posterior glide of the talus relative to tibia and fibula; (2) non-weight-bearing posterior-superior glide of the inferior fibula relative to the tibia; (3) weight-bearing MWM posterior glide of talus relative to tibia and fibula. Three-dimensional motion analysis was used to determine differences in lower extremity joint angles during the single-leg step-down.

2.3. Weight-bearing lunge test

Weight-bearing lunge test (see Fig. 1) has frequently been used to measure both active and passive ankle dorsiflexion ROM (Vicenzino & O'Brien, 1998) and as such, has been standardised (Bennell et al., 1998). The test was performed barefoot. Participants stood facing a bare wall, with the tested foot positioned closest to the wall. The second toe, centre of the calcaneus and centre of the patella were all aligned perpendicular to the wall. Each participant's subtalar joint was placed and maintained into a neutral position throughout the test, preventing compensation through the midtarsal joint (Tiberio, 1987b).[42] Participants then attempted to lunge forward until the knee made contact with the wall. Upon a successful completion of a lunge with the heel maintaining contact with the floor, the foot was relocated 1 cm further from the wall. This protocol was repeated until the knee could no longer touch the wall without obvious compensations presenting. Measurement in cm was recorded between the wall and the great toe on the tested leg using a tape measure, from the last successful attempt. Results were concealed from participants at all times. This data was used to represent maximum ankle dorsiflexion ROM.