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Original citation: Holland, Christopher, Campbell-Karn, K. and Hutt, K. (2015) *Increased treatment durations lead to greater improvements in non-weight bearing dorsiflexion range of motion for asymptomatic individuals immediately following an anteroposterior grade IV mobilisation of the talus.* Manual Therapy, 20 (4). pp. 598-602. ISSN 1356-689X

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INTRODUCTION

Joint mobilisations are a set of techniques used to treat patients with joint hypomobility through the restoration of arthrokinematic movements that occur between joint surfaces (Green et al., 2001). These techniques are proposed by Maitland et al. (2001) and consist of the application of passive, oscillatory rhythmical forces (Venturini et al., 2007). The core tenet of the Maitland technique is a conceptual framework of clinical reasoning, which forms the basis for the selection of the specific grade, oscillatory frequency, treatment duration and volume (Banks & Hengeveld, 2010). This technique is founded on a grading system that varies from I to IV, with the latter grades being performed into resistance in order to restore joint range of motion (ROM) through the elongation of articular and periarticular tissue (Green et al., 2001).

Restrictions in ankle dorsiflexion (DF) can lead to limitations in gait and other functional activities (Collins et al., 2004; Chizewski & Chiu, 2012). Limited DF has been shown to increase the risk of ankle sprains in both healthy and symptomatic populations (De Noronha et al., 2006; Pope et al., 1998; Willems et al., 2005). Deficits in DF-ROM are often related to an anterior talar displacement and restricted talar glide (Hubbard & Hertel, 2006). Restrictions in the noncontractile tissues surrounding the ankle may inhibit the posterior talar glide decreasing ROM (Hertel, 2002). Static stretching techniques may not be sufficient to address these arthrokinematic restrictions, justifying the use of talocrural joint mobilisations (Denegar et al, 2002). A Maitland anteroposterior (AP) glide of the talus within the mortise has been shown to lead to improvements in DF-ROM

(Landrum et al., 2004; Van der Wees et al., 2006). Various treatment doses have been utilised by researchers in an attempt to study the effects of AP mobilisations of the talus on DF-ROM. Where needed the results of these studies have been converted using the research of Bennell et al. (1998), where about 3.60 of DF-ROM occurs for every 1cm in distance away from the wall during the weight bearing lunge test (Hock & McKeon, 2011). Hock & McKeon (2011a) concluded that significant increases in DF-ROM were detected in the order of 1.5-2^0 following two, 2 minute applications of grade III mobilisations in individuals with self-reported chronic ankle instability (CAI). In a smaller cohort study by Hock *et al*. (2012) increases in DF-ROM of 1.4cm, or 5^0 were recorded. However, the treatment dose had been increased to four, 2 minute grade III mobilisations. Furthermore, subjects were treated 6 times over a 2 week period and also utilised grade II tractions of the talus as an additional treatment protocol. An early randomised controlled trial by Green *et al*. (2001) investigated the effects of three, 1 minute mid-grade mobilisations concluding a statistically significant improvement of 4.3^0. In a methodologically similar study Yeo & Wright (2011) concluded an average increase of 3.5^0. Research has also shown that significant increases in DF-ROM can be gained from low dose AP mobilisation treatments. Venturini et al. (2007) concluded that a treatment prescription of two, 30 second bouts elicited a 2^0 improvement in DF-ROM, whilst Landrum et al. (2008) recorded an increase of 4.4^0 following a single 30 second mobilisation. These studies highlight how minimal treatment doses can produce clinically significant outcomes. However, research has shown that grade IV mobilisation produce greater mean force (Silvernail et al. 2011) and increased plastic deformation of

connective tissue (Bonutti et al., 1994; Moutzouri et al., 2008; Ulrich et al., 2010) than grade III techniques. This is of particular importance when improvements in ROM are sought within asymptomatic individuals. Indeed, many researchers have demonstrated ROM improvements at various joints following accessory mobilisation treatments in asymptomatic individuals (MacRae et al., 2012; Manske et al., 2010; McCollam & Benson, 1993; Thomson et al., 2009). Specifically, Venturini et al. (2007) and De Souza et al. (2008) revealed a statistically significant increase in DF-ROM following higher grade joint mobilisations in asymptomatic populations with no history of ankle injury. The use of asymptomatic individuals also limits confounding variables associated with clinical conditions, such as pain associated treatment limitations that may influence its application and subsequent response (George et al., 2006).The objective of the present study was to investigate whether varying treatment durations of a grade IV AP talus mobilisation produce differences in ankle DF-ROM within an asymptomatic population. It was hypothesised that greater improvement would occur with greater duration of treatment.

METHODOLOGY

Subjects

A total of 16 male football players (mean ±SD age = 27.1±5.3 yr) volunteered to participate in this randomised cross-over study. Subjects were excluded if they exhibited any ankle pathology, or any history of ankle injury in the past 6 months. Written consent was gained from all participants and data was anonymised then

securely stored. Ethical approval was obtained from London Metropolitan University's Research Ethics Review Panel.

Testing Procedures

All participants completed the same testing procedure and received either a control treatment where no mobilisation was performed (treatment 1), a mobilisation treatment of 30 seconds (treatment 2), 1 minute (treatment 3) or 2 minutes (treatment 4). A period of 1 week was given between treatment sessions, and the use of a balanced 4x4 Latin square was utilised to limit potential carry-over effects. Participants were randomly assigned, using a random numbers table, to one of the four testing groups and received the different treatment conditions in the order prescribed. To reduce any inter-tester reliability issues, all mobilisation treatments were conducted by the same therapist who was experienced in peripheral mobilisation techniques. ROM testing was conducted by an independent examiner who was blinded to the treatment duration that the participant had received. Study participants were all initially familiarised with the procedures.

Measurement of Dorsiflexion Range of Motion of the Ankle

Prior to treatment, weight bearing (WB) and non-weight bearing (NWB) DF-ROM were measured. NWB ROM was assessed using a 30cm universal goniometer (MSD Europe BVBA) following the procedure proposed by Jonson & Gross (1997). During the procedure the participant would lay prone on the plinth with the knee in extension. The subject was instructed to dorsiflex the foot actively to

a maximal position. This method demonstrates an intra-class correlation coefficient of 0.98, indicating high reliability (Venturini et al., 2007). The weight-bearing lunge test was used to measure weight bearing ROM, utilising the knee-to-wall principle described by Hoch & McKeon (2011b). Subjects positioned the test foot so that heel line and big toe were aligned with the tape measure. A controlled lunge was then performed such that the knee flexed as the participant attempted to touch it to a vertical line marked on the wall with adhesive tape. Foot alignment was maintained on the tape measure secured to the floor, whilst the tester watched for knee contact with the wall and monitored the heel to ensure contact with the floor. The maximum distance that the participant could achieve the knee-wall contact whilst maintaining heel-floor contact was recorded. This method demonstrates an excellent intra-class correlation coefficient of 0.97-0.99 (Chisholm et al., 2012). For all measurements of DF-ROM only a single measurement was taken ensuring that there was no cumulative effect upon ROM from repeated assessment. Following the initial DF measurements participants received the joint mobilisation intervention based on their group assignment. Immediately after the treatment NWB and WB DF-ROM measurements were again taken utilising the same protocol. Participants were blinded from their test scores to ensure that results would not be artificially augmented.

Joint Mobilisation Intervention

The joint mobilisation was performed with the participant in supine with their foot comfortably positioned over the end of the plinth. The ankle was placed at 20^0 to plantar flexion in order to achieve loose-packed position of the talocrural joint

(Magee, 2013; Mulligan, 2011). In this position, the talus was held slightly anterior to the mortise, allowing greater pressure application during the mobilisation, the force of which was transmitted to the posterior periarticular tissues (Wright et al., 2000). The stabilising hand was placed proximal to the malleoli to stabilise the distal leg, whilst the mobilising hand cupped the anterior talus using the 1st web space. The talus was then glided posteriorly with downward force applied by the mobilising hand (AP) (Houglum, 2010). The joint mobilisation was operationally defined as a grade IV, 1 second rhythmic oscillation with translation taken to tissue resistance (Landrum et al., 2008). The oscillatory technique was chosen in order to load and unload the tissue in a similar way to that which would occur functionally (Banks & Hengeveld, 2010).

Statistical Analysis

A two-way repeated measures analysis of variance (ANOVA) using an alpha level of 0.05 was performed with a within-subjects contrast using Statistical Package for the Social Sciences 19 (SPSS). Mauchly's sphericity test was conducted on all ANOVA measures to test whether the assumption of sphericity had been violated. The Greenhouse-Geisser adjustment was included for all significant outputs of the Mauchly's sphericity test.

Minimal Detectable Change Scores

Minimal detectable change scores were calculated at the 90% confidence interval (MDC_{90}) to determine the minimal change required within the dependent variables to achieve changes beyond the error of the measurements. The 90%

confidence level is acceptable when decisions regarding effectiveness of intervention are concerned (Haley & Fragala-Pinkham, 2006; Portney & Watkins, 2009). The calculation of an MDC value is important for clinical decision making, increasing clinical application and bridging the gap between evidence and practice (Donoghue et al., 2009).

RESULTS

Dorsiflexion Range of Motion

Mean (±SD), standard error of measurement (SEM), minimal detectable change at the 90% confidence interval (MDC_{90}), and absolute and percentage change scores for both NWB and WBROM are presented in Tables 1 and 2. All treatment doses produced increases in both NWB ROM and WB ROM. For the NWB ROM a significant main effect of treatment dose ($F_{3.0,\ 45.0} = 31.8$, $p < 0.001$) and measurement time ($F_{1.1,\ 16.6} = 96.7$, $p < 0.001$) was revealed. WB ROM achieved significant main effect for treatment dose ($F_{1.9,\ 28.6} = 12.3$, $p < 0.001$) and measurement time ($F_{1.0,\ 15.6} = 58.6$, $p < 0.001$). There was also a significant interaction effect between these variables for both NWB and WB measurement protocols respectively ($F_{2.8,\ 42.5} = 47.2$, $p < 0.001$; $F_{2.0,\ 30.5} = 54.3$, $p < 0.001$).

Dorsiflexion Range of Motion Comparison

A mean increase in NWB ROM of 2° (14.2%) following treatment 2, 3° (21.6%) following treatment 3, and 4.5° (32.8%) following treatment 4 was observed. Treatment 1 showed an increase of 0.1° (0.01%) over the same period (Table 1). With the exception of treatment 1 all NWB ROM improvements were above the

minimal detectable change score (MDC_{90}).The within-subjects contrasts revealed significant interactions between the post-treatment measurements and pre-treatment measurements for treatment 2 compared with treatment 1 ($F_{60.1, 46.9}$ = 19.2, p = 0.001), treatment 3 compared with treatment 2 ($F_{16.0, 42.0}$ = 5.7, p < 0.05), and treatment 4 compared with treatment 3 ($F_{42.3, 21.8}$ = 29.1, p < 0.001). There was a mean increase in WB ROM of 0.6cm (5.0%) following treatment 2, 0.9cm (7.6%) following treatment 3, and 1.3 (10.9%) following treatment 4. Treatment 1 showed an increase of 0.1cm (0.01%) over the same period (Table 2). However, none of these measurements was above the minimal detectable change score (MDC_{90}). The within-subjects contrasts revealed significant interactions between the post-treatment measurement and pre-treatment measurement for treatment 2 compared with treatment 1 ($F_{4.62, 3.0}$ = 23.4, p = 0.001), treatment 3 compared with treatment 2 ($F_{1.6, 1.5}$ = 16.4, p = 0.001), and treatment 4 compared with treatment 3 ($F_{2.4, 0.6}$ = 62.4, p < 0.001).

DISCUSSION

Results showed that all treatment durations produced statistically significant improvements in NWB and WB ROM (p < 0.001). The effectiveness of grade IV accessory mobilisations can therefore be accepted in asymptomatic individuals. The anteroposterior accessory mobilisation technique addresses arthrokinematic restrictions that may be inhibiting DF-ROM (Hertel, 2002). This is achieved through elongation of the articular and periarticular tissue associated with the specific joint (Green et al., 2001). However, these explanations are principally associated with individuals who have sustained some form of lateral ankle sprain

injury. These arthrokinematic changes may not fully explain the observed increases in DF-ROM within the asymptomatic population studied, however the results highlight that even low duration treatments can produce statistically significant ROM improvements within an asymptomatic population.

A direct comparison of the current findings to existing research is problematic due to methodological differences in study design; however, some inference can be drawn. A study by Venturini et al. (2007) on asymptomatic individuals, elicited a 2˚ improvement in DF-ROM following two 30 second grade III mobilisations. Within the current study this magnitude of improvement is seen with a single 30 second grade IV mobilisation, with longer durations eliciting greater improvements (Table 1). Comparisons with studies by Hock et al. (2012) and Yeo & Wright (2011) also highlight the benefit of utilising grade IV mobilisations over lower grades. Whilst Yeo & Wright utilised three 1 minute higher grade mobilisations, only a 3.5^0 increase in WB DF-ROM was recorded. Similar improvements are seen in both the 1 minute and 2 minute treatment groups within this study. The 1.4cm, or 5^0, improvement witnessed by Hock et al. (2012) following four 2 minute grade III mobilisations is comparable to the 1.3cm increase observed in this study's 2 minute treatment group, even though Hock et al. also utilised grade II talar tractions as an additional treatment. These results show the benefit of utilising grade IV mobilisations for improvements in ROM. Although grade III and IV mobilisations can work at the end of the available ROM, grade IV mobilisations produce a greater oscillatory frequency and mean force (Silvernail et al., 2011). As such, greater loads are being experienced by the

connective tissue, resulting in greater microfailure of the tissue that is restricting motion and explains the greater improvements observed within the current study.

The comparisons of treatment dose utilising the within-subjects contrasts revealed statistically significant results ($p < 0.05$) between all mobilisation durations of pre and post DF-ROM measurements. However, only the NWB scores were above the values for minimal detectable change. This shows that there is a significant benefit to utilising longer treatment durations if improvements in NWB DF-ROM is being sought, whilst, it can be assumed that greater improvements are elicited as the treatment dose increases. Grade IV mobilisation works at the end of the available range and aims to produce a microfailure of the connective tissue that is restricting motion (Silvernail et al., 2011). Hooke's law states that there is a proportional relationship between force and elongation, where the increase in tissue length is directly related to the load being applied (Shukla & Srivastava, 2006). During a grade IV mobilisation the elastic limit is reached, meaning that the tissue elongates at a much greater rate (Alter, 2004). This cumulative effect of longer treatment durations on the elongation of tissue may therefore lead to the observed increases in DF-ROM. The minimal changes associated with the WB DF-ROM in comparison to NWB DF-ROM may be a consequence of the testing method and positions used. It has been reported that knee position has a significant effect upon DF-ROM, with the knee extended position increasing the passive tension in gastrocnemius and the general stiffness of the ankle via its effects on the series and elastic components of the muscle-tendon unit (Kovaleski et al., 2008; Krause et al., 2011). The changes

reported for NWB DF-ROM within this study beyond the minimal detectable change values may therefore be due to the mobilisation causing a relaxation in the gastro-soleus complex. Due to the adoption of a bent knee position during the WBLT, a relaxation in these muscles would not affect WB DF-ROM. In addition the applied force during WB DF-ROM is greater than during NWB, as well as more closely reflecting the physiological torque during gait (Baumbach et al., 2014). It is therefore likely that not all subjects reached end-range motion during NWB DF-ROM resulting in the observed differences in DF-ROM between NWB and WB. A further explanation for this discrepancy may be due to the asymptomatic population used within the study. Symptomless individuals must possess at least 10^0 of ankle DF-ROM in order to walk, descend stairs or kneel (Crosbie et al., 1999), whilst at least 20^0 is needed for running (Yamaguchi et al., 2009). Indeed, the baseline characteristics of the participants were analogous to normative ranges in healthy adults (Hoch & McKeon, 2011b). Individuals who have sustained lateral ankle sprains often have DF-ROMs below 0^0 (Soucie et al., 2011), due to the propensity of the talus towards anteriorly subluxation following ligament disruption (Denegar et al., 2002). As such, symptomatic populations possess a larger range in which improvements can occur than asymptomatic groups.

The current research adds clarity to the comparison between mobilisation treatment duration and improvements in ROM for asymptomatic individuals in the absence of pain. The results show that during a single session grade IV mobilisation of 30 seconds an increase in NWB DF-ROM can be gained. In

addition, as the treatment duration is increased, significantly greater improvements in NWB DF-ROM are produced. From a clinical perspective an understanding of how treatment dose can affect the attainment of ROM improvement is integral to successful clinical practice. The current research suggests that treatment doses of 2 minutes will confer the greatest improvement in NWB DF-ROM when utilised on asymptomatic individuals. Further research within this area should focus upon a comparison between single treatment durations and repeated doses to highlight whether equivalent doses confer disparate or comparable results, as well as investigating the effects of treatment duration on symptomatic individuals with DF-ROM restriction. As the current study limited the treatment dose to a maximum of 2 minutes, the effect of longer treatment durations should also be a focus of study to identify whether significant improvements in ROM are continually produced as the treatment duration increases, or whether there is a point at which increasing the treatment duration confers no significant improvement over shorter treatment times.

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