Journal of Electromyography and Kinesiology 25 (2015) 973–981

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

The effects of ankle supports on gait in adults: A randomized cross-over study

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ARTICLE INFO

Article history:
Received 26 February 2015
Received in revised form 8 August 2015
Accepted 12 August 2015

Keywords:
Gait analysis
Physical therapy
Rehabilitation
Ankle
Ankle brace
Ankle support

ABSTRACT

We aimed to compare the effects of different ankle supports used after ankle injury/surgery on temporo-spatial gait characteristics. We conducted a randomized cross-over study including adult participants with no previous lower limb or neurological pathology, who underwent gait analysis on an electronic walkway in three different ankle supports, Tubigrip®, a stirrup brace and a walker boot. The 18 participants were an average age of 42 (SD 13, range 24–62) years and 14 (88%) were female. Compared to Tubigrip®, gait in the walker boot was slower (−0.19 m/s, 95%CI −0.23 to −0.16, $P < 0.001$), step length asymmetry was 10% (95%CI 9–12, $P < 0.001$) worse, single support time asymmetry was 5% (95%CI 3–7, $P < 0.001$) worse and participants also adopted a wider step width (4.1 cm, 95%CI 3.7–4.5, $P < 0.001$). There were no important differences in gait between the Tubigrip® and stirrup brace. The findings of this study suggest that there is a limit to the degree of normal walking characteristics in a walker boot in the absence of lower limb impairment. Further research is required to directly compare the effects of these ankle supports in clinical populations.

1. Introduction

Ankle supports are routinely issued to patients after acute ankle injuries and surgery (Lin et al., 2010). The rationale for ankle support use is to limit joint range of motion, aid pain relief, control loading of the injured tissues and facilitate weight bearing and rehabilitation of walking (Kerkhoffs et al., 2002). The types of ankle support described in the literature as being used for acute severe ankle sprain (Lamb et al., 2009) and after surgery for ankle fracture (DiStasio et al., 1994) vary greatly in their design. The primary differences in the designs are the extent and direction of mechanical limitation to ankle joint motion. For example, patients may be advised to use Tubigrip® (an elasticated tubular bandage that does not aim to prevent joint motion), a stirrup brace or a type of removable walker boot. There is uncertainty about the optimal design even though they are used at the same stage of clinical management. In cadaver models of complete lateral ligament tear, ankle stirrup braces have been shown to mechanically limit inversion (Omori et al., 2004). Stirrup braces have also been found to restrict ankle range of motion in all directions, but principally inversion, *in vivo* (Eils et al., 2002). Previous studies have investigated the effect of fixed-angle walker boots, which aim to limit ankle motion in all planes, on plantar pressures in healthy adults (DiLiberto et al., 2007; North et al., 2012). These studies provide information about asymmetry and distribution of load within the feet but not about gross gait asymmetry (Perry and Burnfield, 2010).

One of the main aims of the initial phase of rehabilitation after ankle injury and/or surgery is to optimize the recovery of a normalized walking gait pattern for a timely restoration of ambulatory function and balance (Karlsson, 2007). After ankle injury the main disturbance in walking gait that presents is asymmetry (Becker et al., 1995) due to unilateral impairments including pain, inability to weight bear, limited joint range of motion, diminished proprioception and muscle atrophy and weakness (Hupperets et al., 2009; Lin et al., 2009; O'Connor et al., 2013; Stevens et al., 2004). Optimization of gait symmetry is important as it results in efficient bipedal locomotion (Perry and Burnfield, 2010). Symmetry reduces energy expenditure, aids balance control and distributes mechanical load on the musculoskeletal system evenly between the lower limbs (Whittle et al., 2012).

There are currently no studies directly comparing the effects of different types of ankle supports on walking quality in either

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http://dx.doi.org/10.1016/j.jelekin.2015.08.004
1050-6411/

healthy adults or in clinical populations. In order to understand the trade-offs between offering ankle supports that aim to stabilize the ankle joint by limiting range of motion and the impact on gait, a comparison of Tubigrip® with stirrup braces and walker boots in healthy adults is required. The wide heterogeneity in injury presentation complicate the interpretation of experiments in clinical populations. Understanding the impact of different supports on normal gait, would help to integrate and target clinical trials and interventions in a phased approach to developing effective supports. We aimed to compare the effects of ankle supports on gait characteristics in healthy adults without ankle impairments.

2. Materials and methods

2.1. Study overview and design

The design was a randomized three-treatment, three-period, cross-over trial. A cross-over trial is ideal for gait analysis where between-individual variation can be higher than within-individuals (Perry and Burnfield, 2010). The within-subject design controlled for important influences on gait such as age and gender, as each participant acted as their own control. A cross-over trial was deemed appropriate as the mechanical effects of applying the ankle support were expected to have an immediate impact on walking in healthy participants (Richards et al., 2014). It was considered unlikely that carry-over effects would be problematic between interventions. The effect of mechanical limitations to ankle range of motion from an ankle support would immediately be eliminated on removal.

2.2. Setting

The study took place from February to May 2012 in a research laboratory within a university hospital in the UK. Approval was obtained from the Central University Research Ethics Committee.

2.3. Participants

Potential participants were issued a participant information sheet and, if willing to participate, gave written informed consent prior to study registration and randomization. Eligible participants were healthy volunteers who were aged 18 years or over, able to give informed consent and understand verbal instructions and walk a minimum of 10 m unaided. The participants were not entered into the study if they had any medical history of neurological disorders or previous serious lower limb disorders, injury or surgery.

2.4. Interventions

The ankle supports tested are shown in Fig. 1. The standard intervention was Tubigrip® (Mölnycke Health Care, Sweden), which is an elasticated compressive tubular bandage applied in a double layer from the level of the tibial tuberosity to the metatarsophalangeal joints. The ankle ‘stirrup’ brace (protect.Ankle air foam, Medi, Germany) is formed by two rigid plastic strips with an inner lining on the medial and lateral sides of the lower leg and ankle complex. The stirrup fastens to the leg with Velcro straps. The stirrup primarily limits motion in the frontal plane (inversion and eversion). In line with clinical practice and guidelines for temporo-spatial gait analysis (Kressig et al., 2006), participants wore their own normal footwear with the support for the gait analysis. The removable below-knee walker boot (Jura Walker Fixed, Promedics, UK) is formed by an internal liner and an external plastic sole, with rigid vertical struts medially and laterally, a rocker bottom sole and Velcro fastening straps. The sole of the design of walker boot shown is approximately 4 cm in depth in the mid-section. The walker boot is designed to limit motion at the ankle in all planes. The participant wore each ankle support on their right foot and their normal footwear on the left foot. The supports were applied according to manufacturer guidelines by the lead investigator, an experienced physical therapist.

2.5. Baseline assessments

Data were collected on the participants’ age, gender and current lower limb function, using the Lower Extremity Functional Scale (LEFS) (Binkley et al., 1999). The LEFS is a self-report questionnaire consisting of 20 items with a maximum score of 80, indicating a high functional level.

2.6. Randomization

There was a need to control for order-effects (Field and Hole, 2003; Senn, 2002) as it was feasible that participants could respond differently to the first, second and third supports as they became more familiar with the tests, but also potentially develop fatigue with more ambulation. To deal with a potential systematic order-effect, a Latin square design was utilized (Senn, 2002). These sequences ensured an even number of participants were tested in each support first, second or third. The allocation concealment method used was based on strategies recommended by Schulz and Grimes (2002). A layer of aluminum foil was inserted into the pre-prepared envelopes containing an allocation card. Independently prepared sequentially numbered, opaque, sealed envelopes were opened once the participant information had been written on the front, with carbon paper inside transferring information onto the assignment card.

2.7. Gait analysis procedures

In accordance with international testing standards for gait analysis (Kressig et al., 2006) we aimed to ensure participants achieved a steady state of walking velocity while walking across the mat by participants walking 2.5 m before and continuing 2 m beyond the active sensors (Lindemann et al., 2008). The testing was performed in controlled well-lit conditions in a research laboratory, with limited sources of audio-visual distraction and with standardized instructions given to participants. The participants walked 9.4 m over the electronic walkway system for each test (with an active length of sensors in the mid-section of 4.88 m).

One preliminary trial of walking over the electronic walkway, back and forth, was conducted at the participant’s preferred walking speed in their own footwear prior to commencing the test procedures. Once allocation was revealed, the first ankle support was applied. Participants walked back and forth across an electronic walkway at preferred walking speed, followed by measurements at slow walking speed and then fast walking speed. Therefore, 2 walks were recorded at each speed, 6 walks in total for each ankle support tested. There was a rest period for a minimum of 3 min before testing the second and third ankle supports with the same protocol.

2.8. Instrumentation

All data were measured using the GAITRite® electronic walkway (CIR Systems, Peekskill, NY, USA). Gait data were collected by the GAITRite® system on a connected laptop and were stored on the system’s software in an integrated database (GAITRite® v3.8E). The GAITRite® system has an internal algorithm to calculate velocity, step length, single support time and step width. Concurrent