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Review

Association between ankle equinus and plantar pressures in people with diabetes. A systematic review and meta-analysis

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ABSTRACT

Background: Diabetes is one of the most common chronic diseases in the world and is associated with a life-time risk of foot ulcer of 12–25%. Diabetes related restriction in ankle joint range of dorsiflexion is proposed to contribute to elevated plantar pressures implicated in the development of foot ulcers.
Methods: A systematic search of EBSCO Megafile Premier (containing MEDLINE, CINAHL, SPORTSdiscus and Academic Search Complete) and The Cochrane Library was conducted to 23rd November 2016. Two authors independently reviewed and selected relevant studies. Meta-analysis of study data were conducted where possible.
Findings: Fifteen studies met the inclusion criteria. Three studies were eligible to be included in the meta-analysis which found that equinus has a significant, but small, effect on increased plantar pressures (ES $= 0.26$, CI 95% 0.11 to 0.41, $p = 0.001$). Of the remaining studies, eight found evidence of an association between limited ankle dorsiflexion and increased plantar pressures while four studies found no relationship.
Interpretation: Limited ankle joint dorsiflexion may be an important factor in elevating plantar pressures, independent of neuropathy. Limited ankle dorsiflexion and increased plantar pressures were found in all the studies where the sample population had a history of neuropathic foot ulceration. In contrast, the same association was not found in those studies where the population had neuropathy and no history of foot ulcer. Routine screening for limited ankle dorsiflexion range of motion in the diabetic population would allow for early provision of conservative treatment options to reduce plantar pressures and lessen ulcer risk.

1. Introduction

Diabetes is one of the most common chronic diseases in the world, affecting 9% of the population in 2014 (World Health Organization, 2015), and is associated with a life-time risk of foot ulcer of 12–25% (Cavanagh et al., 2005). Diabetic foot ulcers lead to high morbidity, increased associated healthcare costs and are estimated to precede lower extremity amputations in 75–85% of cases (Boulton et al., 2005). Foot ulcer development has been associated both prospectively and retrospectively with elevated plantar pressures in people with diabetes (Boulton et al., 1983; Veves et al., 1992). It is well established that factors such as peripheral neuropathy (Caselli et al., 2002), foot deformity (Mueller et al., 2003a) and limited joint mobility in the foot (Fernando et al., 1991) contribute to elevated plantar pressures.

Ankle equinus has emerged as a possible contributory factor to increased plantar pressures (Amemiya et al., 2014; Lavery et al., 2002), and may play a significant role in the development of pressure related foot ulcers (Boffeli et al., 2002; Francia et al., 2013). Limited ankle joint dorsiflexion, or equinus, acts to restrict the forward progression of the tibia over the foot during stance phase. This is proposed to result in gait compensations such as an early heel lift, excessive subtalar joint pronation and associated midtarsal joint pronation (Michaud, 2011). It is hypothesised that these changes lead to prolonged weight bearing at the forefoot and increased plantar pressures which subsequently contribute to the development of pressure ulceration (Aronow et al., 2006; Mueller et al., 1989).

Prevalence of equinus in the general population is not well documented, with most reports being observational or anecdotal (Charles et al., 2010; DiGiovanni et al., 2002). Prevalence of equinus in an urban population with diabetes is variable, ranging from 10.3% to 37.2%, a threefold increase in risk compared to a group without diabetes (Frykberg et al., 2012; Lavery et al., 2002). The higher prevalence of equinus in people with diabetes is thought to be, in part, due to the non-enzymatic glycosylation of soft tissues resulting in structural abnormalities and thickening of the Achilles tendon leading to increased tendon stiffness and reduced joint mobility (Giacomozzi et al., 2005; Grant et al., 1997).

Given the increasing burden of diabetic foot complications, it is important that risk factors for foot ulcer development and subsequent amputation are identified and managed. If ankle equinus is found to

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contribute to high plantar pressures then it could present an opportunity for earlier clinical detection of patients at risk of pressure-related foot ulcer and, may also provide additional preventative treatment options for these patients (Francia et al., 2013). Therefore, the aim of this review is to systematically evaluate the current literature to determine if, for people with diabetes, there is an association between equinus and high plantar pressures, and to evaluate study findings by meta-analysis where possible.

2. Methods

An electronic database search of EBSCO Megafile Premier (containing MEDLINE, CINAHL, SPORTSDiscus and Academic Search Complete), EMBASE, and The Cochrane Library was conducted from their inception to 23rd November 2016. The search strategy used for the EBSCO database used the following terms:

- #1 Diabet* and ((Pressure or loading or function) and (plantar or foot or forefoot or peak))
- #2 Ankle or dorsiflex* or DF
- #3 Equinus or contracture or LJM or "joint mobility" or "joint motion" or "joint stiffness" or "range of motion" or ROM or orthop* or flexibility
- #4 1&2&3

No language, publication date or publication status restrictions were used. Reference lists of included studies, clinical guidelines and review articles were also searched.

Published reports including prospective cohorts, case series and observational studies were eligible for this review. Included studies were required to investigate ankle dorsiflexion range of motion and plantar pressures in people with diabetes. Studies were excluded if the individuals had current plantar foot ulcers preventing foot pressure measurement or neurologically induced limited ankle joint range of motion (such as stroke or cerebral palsy). Studies were also excluded if they reported ground reaction forces or joint moments only, or if ankle joint range of motion was reported as a combination of plantarflexion and dorsiflexion only and data specific for dorsiflexion range of motion could not be provided. One reviewer conducted the electronic searches (AS). Titles and abstracts were independently assessed by two reviewers (AS and VC). Disagreements were resolved by consensus and a third reviewer where necessary (MS).

An assessment of the methodological quality of the included studies was conducted using the Observational Study Appraisal Checklist designed by Health Evidence Bulletins – Wales, which is designed for critical appraisal of observational studies (Weightman et al., 2004). This tool was selected as it allows use of one set of questions for all included studies, includes a small number of key domains, is a simple checklist rather than a scale and was developed using a variety of literature sources (Sanderson et al., 2007). Methodological quality of the studies was assessed according to four key domains: domain A (aims and outcomes of study), domain B (population, bias and follow up), domain C (results, statistical methods and conclusions), and domain D (external validity).

Data from each trial were extracted from the available text. Meta-analysis was performed to compare plantar pressures in people with and without equinus where possible. Studies were included in the meta-analysis if data for equinus and non-equinus groups were reported separately. For the purpose of the meta-analysis equinus was defined as less than or equal to zero degrees of ankle dorsiflexion (Lavery et al., 2002). Where the data provided was not reported in equinus and non-equinus groups, the corresponding author of the trial was contacted via email and the relevant data requested. All data analyses were performed using STATA version 12.1 software. A random effects model was used as it is considered more suitable for combining the results of studies that may not be functionally equivalent and allows for a more generalised inference of effect size (Hedges and Vevea, 1998). Effect sizes were calculated as Cohen's d and then converted to Hedge's g (Hedges and Olkin, 1985) which provided a less biased estimate of the treatment effect (Borenstein et al., 2009). An effect size of greater than or equal to 0.8 was considered to represent a large clinical effect, 0.5 a moderate effect and 0.2 a small effect (Cohen, 1988). Statistical heterogeneity between studies was assessed by use of the I^2 statistic and a value of >50% was considered to indicate significant heterogeneity (Higgins et al., 2003).

3. Results

The initial database search resulted in a total of 386 citations of which 47 were appropriate for full review (Fig. 1). After review, 15 studies were included (Table 1) and 32 were rejected on the basis of exclusion criteria (Supplementary Table 1). The 15 studies, with sample sizes from 10 to 1666 people, included a total of 2544 participants with an age range of 45 to 80 years of age and duration of diabetes of between 1 and 31 years. Twelve of these studies measured ankle joint dorsiflexion with a goniometer, two with custom devices that allowed standardised torques to be applied at the ankle joint, and one described using a musculoskeletal exam to identify equinus. Five studies measured plantar pressures in shoe while the other ten used a barefoot pressure platform. Details of individual studies are included in Table 1.

Methodological quality of the studies is detailed in Supplementary Table 2. All of the studies provided detailed information for study population, aims, outcomes, study method and follow up. The least favourably ranked questions were those regarding whether the population studied was appropriate, the presence of selection bias and if the results could be applied more widely. With regard to the population studied, three studies did not randomly select case-controls (Amemiya et al., 2014; Bennett et al., 1996; Birke et al., 1995), one did not have matched case controls (McPoil et al., 2001) and one did not provide details of the population (Orendurff et al., 2006). None of the studies reported blinding the investigators. Seven (Amemiya et al., 2014; Armstrong et al., 1999; Cerrahoglu et al., 2016; Christensen and Albert, 1994; McPoil et al., 2001; Sacco et al., 2009; Wrobel et al., 2003) of the 15 studies reviewed specific populations that could make comparison

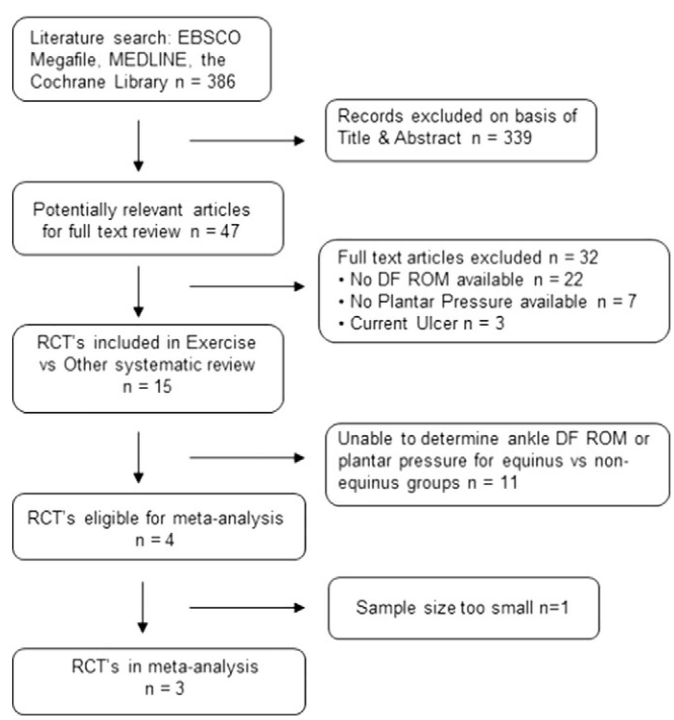

Fig. 1. Flow diagram of systematic review inclusion or exclusion.