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Prevalence of ankle equinus and correlation with foot plantar pressures in people with diabetes

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ABSTRACT

Background: An association between equinus and plantar pressure may be important for people with diabetes, as elevated plantar pressure has been linked with foot ulcer development. To determine the prevalence of equinus in community dwelling people with diabetes and to examine any association between presence of equinus and forefoot plantar pressures.

Methods: Barefoot (Tekscan HR Mat™) and in-shoe (Novel Pedar-X®) plantar pressure variables, non-weight bearing ankle range of motion and neuropathy status were assessed in 136 adults with diabetes (52.2% male; 47.8% with neuropathy; mean (standard deviation) age and diabetes duration: 68.4 (11.5) and 14.6 (11.1) years respectively).

Findings: Equinus, when measured as ≤5° dorsiflexion, was present in 66.9% of the cohort. There was a significant correlation between an equinus and barefoot ($r = 0.247$, $p = 0.004$) and in-shoe forefoot pressure time integrals ($r = 0.214$, $p = 0.012$) and in-shoe forefoot alternate pressure time integrals ($r = 0.246$, $p = 0.004$). Significantly more males ($p < 0.01$) and people with neuropathy ($p = 0.02$) or higher glycated haemoglobin levels ($p < 0.01$) presented with an equinus.

Interpretation: Community dwelling adults with diabetes have a high rate of ankle equinus which is associated with increased forefoot pressure time integrals and a two-fold increased risk of high in-shoe peak pressures. Clinical assessment of an ankle equinus may be a useful screening tool to identify adults at increased risk of diabetic foot complications.

1. Introduction

An ankle equinus has been described as reduced sagittal plane range of motion at the ankle joint, such that the minimum of 10° of dorsiflexion of the foot required for normal gait cannot be achieved (Root et al., 1977). However there is no definitive definition of equinus in the literature. In addition to < 10°, authors have also used ≤5° (DiGiovanni et al., 2002; Orendurff et al., 2006; Van Gils and Roeder, 2002) or ≤0° (Frykberg et al., 2012; Lavery et al., 2002; Lin et al., 1996) of dorsiflexion to indicate equinus. This lack of consensus may partly explain why the reported prevalence of equinus in populations with diabetes is so varied, ranging from 10.3% to 37.2% in urban populations (Frykberg et al., 2012; Lavery et al., 2002), and from 72.4% to 91% in populations with a history of ulcer, amputation or neuropathy (Boffeli et al., 2002; Van Gils and Roeder, 2002).

An equinus may result from diabetes, aging, bony block, neurological abnormalities such as cerebral palsy and stroke, soft tissue contracture as a result of prolonged inactivity or wearing high heel shoes (DiGiovanni et al., 2002). An equinus is more common in people with diabetes than in the general population and this may be due to the underlying metabolic changes occurring with the disease (Frykberg et al., 2012). It is believed that chronic hyperglycaemia promotes non-enzymatic glycosylation of proteins, resulting in excessive advanced glycation end product (AGE) formation and abnormal collagen cross links (Somai and Vogelgesang, 2011). These changes lead to structural abnormalities, resulting in thickening and decreased elasticity in peri-articular structures such as joint capsules, ligaments and tendons, including the Achilles tendon (Grant et al., 1997). The higher prevalence of equinus reported in populations with a history of neuropathy and foot complications could be expected as hyperglycaemia and AGE formation have been implicated in the development of both conditions (Singh et al., 2014).

An equinus has been reported to contribute to conditions such as metatarsalgia, chronic heel pain, forefoot nerve entrapment, toe

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deformity and diabetes related foot ulcers (Barrett and Jarvis, 2005; Cheuy et al., 2016; DiGiovanni et al., 2002; Irving et al., 2006; Lin et al., 1996). Elevated plantar pressures, particularly forefoot pressures, resulting from an equinus are proposed as one of the underlying mechanisms for development of foot ulcer. However, studies investigating the link between equinus and elevated plantar pressures have had variable outcomes (Christensen and Albert, 1994; Guldemond et al., 2008; Lavery et al., 2002; Orendurff et al., 2006; Payne et al., 2002). The potential contribution of ankle equinus to high plantar pressure may be of particular importance in people with diabetes. Elevated plantar pressures have been associated both prospectively and retrospectively with increased risk of foot ulcer (Frykberg et al., 1998; Lavery et al., 1998; Veves et al., 1992). While assessment of plantar pressure has been suggested as a tool for earlier identification of increased ulcer risk, the equipment is expensive and not readily available in clinical practice (Patry et al., 2013).

Ankle dorsiflexion range of motion testing is easy to perform in a clinical situation, and, if associated with increased plantar pressure, may be a simple screening tool to identify people at increased risk of foot ulcer in diabetes cohorts. However, the majority of previous studies investigating a link between equinus and plantar pressures have tested ankle dorsiflexion using a goniometer and manual force applied by an examiner. Serious concerns have been raised about the reliability and validity of this method, and it is recommended that patient and foot position, and direction and magnitude of force should be standardised (Gatt and Chockalingam, 2011; Van Gheluwe et al., 2002). Only two studies investigating ankle dorsiflexion and plantar pressures ($n = 27$ and $n = 10$) have measured ankle dorsiflexion using a method meeting these requirements (Orendurff et al., 2006; Rao et al., 2006). Therefore, the primary aims of this study were 1) to determine the prevalence of equinus in community dwelling people with diabetes using a standardised measurement method, and, 2) to examine any association between presence of equinus and forefoot plantar pressures in this population.

2. Methods

2.1. Participants

Ethics approval was granted by the University of Newcastle Human Research Ethics Committee and written informed consent was obtained from all participants. Participants were recruited from the University of Newcastle Podiatry Clinic at Wyong Hospital, NSW Australia and from newspaper advertisements in local newspapers, between June 2016 and October 2017. Inclusion criteria were adults, 18 years of age and over, able to speak and read basic English, and a diagnosis of either type 1 or type 2 diabetes. Exclusion criteria were existing foot ulcer affecting plantar pressure measurement, any previous lower limb amputation, any surgery to the foot or lower limb involving fixation of a joint, any neurological condition that may affect the lower limb other than loss of sensation due to diabetes, inability to walk 8 m unaided, or current pregnancy.

2.2. Procedures

All data were collected at one testing session at the University of Newcastle Podiatry Clinic, Wyong Hospital, NSW, Australia. Testing was conducted on the participants' dominant leg only to maintain independence of data (Menz, 2004). Dominance was determined by asking the participant which foot they would kick a football with. Details of chronic medical conditions and medications, glycated haemoglobin, and duration of diabetes were obtained from medical history supplied by the participant's general practitioner (83.1%) or by self-report where data from the general practitioner was not provided.

Non-weight bearing ankle joint range of motion was measured using a modified Lidcombe template, which has been shown to have excellent

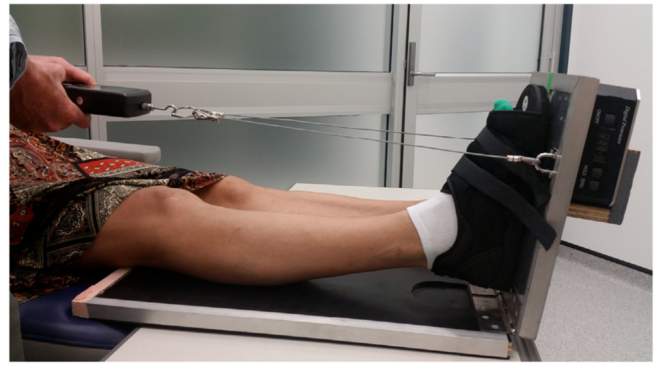

Fig. 1. Lidcombe template.

reliability in adolescents (ICC = 0.99) and in adults with diabetes (ICC = 0.89–0.94) (Scharfbillig and Scutter, 2004; Searle et al., 2018). The template consisted of a 300 mm solid foot plate hinged to a solid base plate with a digital protractor (Bear Digital Protractor 82201B-00, China) fixed to the back of the foot plate to allow the degree of dorsiflexion to be measured. (Fig. 1) A digital force gauge (FGD-200, Starr Instruments, Melbourne, Australia) was attached to the front of the foot plate at a distance of 200 mm from the hinge attachment. Participants were required to lay reclined with their knees extended on an examination table with the base plate of the device placed under the dominant leg. Participants were advised against actively dorsiflexing their ankle, flexing their knee or resisting the applied force during the examination. A standardised force of 80.4 N was applied to the base plate, by means of the examiner pulling on the strain gauge. This amount of force is the most commonly used as it is believed to best replicate the forces experienced during gait (Charles et al., 2010). The force was maintained only as long as required for the other investigator to read the degree of dorsiflexion (approximately 1 s). The test was completed three times, with 10 s rest between tests, and the average score was documented as the test result. For this trial an equinus was defined as $\leq 5^\circ$ of non-weight bearing dorsiflexion as there is evidence that this degree of restriction may contribute to increased plantar pressures. Forefoot pressures have been shown to be higher in people with diabetes where ankle dorsiflexion is $< 5^\circ$ (Orendurff et al., 2006), and ankle dorsiflexion $< 5^\circ$ or insensitivity are suggested as predisposing factors for development of a plantar ulcer (Mueller et al., 1989).

Neuropathy status was assessed using a monofilament and a neurothesiometer which are reliable tests for measuring foot sensation (Smieja et al., 1999; van Deursen et al., 2001). Four points on the plantar surface of the dominant foot (1st, 3rd and 5th metatarsal heads and the distal hallux) were tested with a 10 g Semmes-Weinstein monofilament. An abnormal test was noted if the participant failed to identify the monofilament at one or more test sites (Boulton et al., 2008). A neurothesiometer (Horwell, Bailey Instruments, Manchester, UK) was used to detect the vibration perception threshold (VPT) at the pulp of the hallux. Three readings were taken and the average used in analysis. A VPT value of > 25 V was regarded as abnormal (Boulton et al., 2008). Participants were assessed as neuropathic if they recorded one or more abnormal test results.

Foot pressure testing was conducted barefoot and in-shoe. Assessment of both conditions allowed determination of whether appropriate footwear could offset any increases in plantar pressures resulting from an ankle equinus. The Novel Pedar-X ® system, (Novel GmbH, Munich, Germany) used to measure in-shoe plantar pressures utilises 1.9 mm thick flexible insoles containing 99 capacitive sensors sampling at a frequency of 100 Hz, and has been shown to be a reliable and valid measurement system (Arts and Bus, 2011). All insoles were calibrated according to manufacturer's instruction with the Trublu1® device prior to the commencement of the study. Participants were required to walk along a flat twelve metre walkway at their normal