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Risk of plantar ulceration in diabetic patients with single-leg amputation

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Abstract

Background. There is a disconcerting rate of bilateral limb loss in patients with diabetes. Therefore, this study aimed to explore plantar loading of the surviving foot following unilateral trans-tibial amputation within a wider context of daily walking activity to investigate the precise risk to the surviving limb.

Methods. Twenty-one subjects with diabetic neuropathy and trans-tibial amputation were matched for weight; height; age and gender with 21 control subjects with diabetic neuropathy without history of plantar ulceration. Gait parameters, in-shoe plantar pressure distribution and daily walking (using the step activity monitor) were recorded. *Student's t*-tests were used to compare groups (α-level: 0.05).

Findings. The trans-tibial amputations group walked almost 30% slower compared to controls ($P < 0.01$), with reduced cadence ($P < 0.01$), and shorter strides ($P < 0.01$). Despite walking slower, the surviving foot showed higher mean peak plantar pressures in the trans-tibial amputations group over the heel ($P < 0.001$) however there was no significant difference over the I–II and lateral III–IV–V metatarso-phalangeal regions. Pressure time integral was higher over the heel ($P < 0.00$), I–II ($P < 0.01$) and III–IV–V metatarso-phalangeal ($P < 0.05$) in the trans-tibial amputations group. The amputee group walked less steps per day ($P < 0.01$).

Interpretation. Adaptations in gait and level of walking activity affect plantar pressure distribution and ultimately the risk of ulceration to the surviving foot. Therefore rehabilitation measures should consider implications for plantar loading and the potential risk of ulceration to the surviving foot.

Keywords: Surviving foot; Plantar ulceration; Diabetic neuropathy; Trans-tibial amputation; Physiotherapy

1. Introduction

Individuals with diabetes mellitus (DM) have a fifteen fold higher rate of lower extremity amputation than those without diabetes (Most and Sinnock, 1983). 6–30% of the amputee population undergo contra-lateral lower extremity amputation within 1–3 years of their initial amputation (Reiber, 1996) and a patient with DM with single limb amputation has a 50% (Hoar, 1962) to 66% (Goldner, 1960) incidence of contra-lateral lower extremity amputation within 5 years. Despite the disconcerting rate of contra-lateral limb loss, this problem appears to be addressed inadequately by the rehabilitation care systems owing to the limited evidence in this area (Broomhead et al., 2003). Data from objective gait analysis of the contra-lateral limb following unilateral lower extremity amputation appear to confirm the clinical impression that unilateral amputees are more stable and accept increased pressure on their remaining contra-lateral "limb-at-risk" during walking compared to the

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amputated side (Pinzur et al., 1991). However, the exact relationship between the contributing factors related to walking leading to further plantar tissue injury remains unclear.

There has been some work completed on the loading of the contra-lateral limb in below-knee amputees. Pinzur et al. (1991) studied the impact of trans-tibial amputations (TTA) on the loading of contra-lateral foot in patients with peripheral vascular insufficiency and concluded that risk of contra-lateral LEA is related to systemic peripheral vascular insufficiency or local factors and not increased loading of the remaining contra-lateral "limb-at-risk". Powers et al. (1994) and Snyder et al. (1995) investigated the influence of prosthetic foot design on the loading of the in-tact limb in cases of traumatic and dysvascular TTA, respectively. They recorded greater vertical loading force to the sound limb and concluded that prosthetic foot design can have an effect on the magnitude of vertical forces experienced by the limb. Despite the high incidence of contra-lateral lower extremity amputation in diabetic patients, to our knowledge only two studies have directly addressed the issue of plantar loading of the surviving foot in this patient population. Veves et al. (1992) studied peak plantar pressures over the surviving foot of subjects with unilateral major lower extremity amputation with DM compared to subjects with lower extremity amputation without DM; subjects with diabetic peripheral neuropathy (DMPN) and non-diabetic control subjects. They demonstrated higher foot pressures over the remaining foot of the diabetic amputees and concluded that amputation itself does not increase pressures under the remaining foot but attributed the increased levels to DMPN. However, in the light of evidence in the literature on the relationship between gait velocity and plantar pressures their report is not very clear regarding the consideration of walking speed in the interpretation of plantar pressure distribution. Peak pressures are known to rise with increasing gait velocity (Burnfield et al., 2004). Hayden et al. (2000) studied the effect of various prosthetic feet on the pattern of plantar pressure distribution on the sound limb of unilateral trans-tibial diabetic amputees during walking. They concluded that the type of prosthetic foot used did not significantly affect peak plantar pressures on the surviving foot, except the heel region.

The influence of level of weight bearing activity on the mechanical trauma accumulated by plantar tissues among individuals with diabetes has been identified (Cavanagh et al., 1996). However, the impact of daily weight-bearing activity on the potential risk of plantar ulceration resulting from cumulative plantar stress to the surviving foot has not been studied. Maluf and Mueller (2003) have studied daily weight-bearing activity and cumulative plantar tissue stress in subjects with DMPN. Their findings suggest that plantar tissues may be more susceptible to injury at relatively low levels of cumulative stress following an initial episode of skin breakdown. However, no studies to our knowledge have investigated the impact of daily walking activity on the surviving foot of diabetic people following unilateral amputations though walking is a commonly encountered essential weight bearing activity of daily life.

Therefore though the literature has addressed the issue of weight bearing on the contra-lateral foot following unilateral lower extremity amputations, further investigation to explore plantar loading of the surviving foot within a wider context of daily walking activity is lacking. Walking is an essential weight-bearing activity of daily life. Considering the disconcerting rate of contra-lateral limb amputations in diabetic people it is essential to explore the contribution of daily walking activity to the plantar loading of the contra-lateral foot. The authors believe that this might help to guide the focus of rehabilitation services in the direction of safeguarding the surviving foot. Our objectives were to compare the differences in the gait characteristics and daily walking activity and their respective influence on plantar loading between the subjects with DMPN and unilateral TTA and subjects with DMPN without history of plantar ulceration.

2. Methods

2.1. Subjects

Following written, informed consent, 21 subjects with DMPN and unilateral TTA were matched on marginal distributions of weight; height; age and gender with 21 control subjects with DMPN without history of plantar ulceration. Semmes–Weinstein monofilaments were used to confirm the neuropathy status (Kumar et al., 1991). Neuropathy was considered present if the 5.07 (10 g) Semmes–Weinstein monofilament (loss of protective sensation) was not perceived in at least one of these four plantar areas tested (Hallux; Ist metatarsal head; Vth metatarsal head and heel). Five to ten trials were performed at each site (Diamond et al., 1989) and the subject needed to perceive 80% of the trials to be graded as the sensation present over that site. The site was scored 1 in case of presence of sensation and 0 in case of absence of the sensation. The sum of the scores over the four sites was used to present the final sensory score over the entire foot.

2.2. Selection criteria

Subjects within the age range of 40–75 yrs, living independently in the community with visual acuity of minimum 20/40 in the better eye (pre-requisite to obtain