Offloading of diabetic foot ulcers: The role of the physiotherapist as part of a multidisciplinary team

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Effective diabetic foot ulcer (DFU) offloading, which is the ability to reduce pressure forces over the wound site, is the key to managing patients with DFUs (Botros et al, 2010; RNAO, 2013). Failure to provide intensive offloading to patients with DFUs can lead to further trauma, infection, and ultimately amputation. Protection of the wound and foot is essential as the wound heals. As part of the multidisciplinary healthcare team, physiotherapists are able to assess patients with DFUs and offer strategies to manage offloading while mobilizing. This paper is a narrative review of key studies supporting the physiotherapist role for offloading of DFUs using gait aids and gait patterns which reduce peak plantar pressures (PPP) while ambulating.

Foot plantar pressure is the pressure field that acts between the foot and the support surface during every day locomotor activities (Razak et al, 2013). Pecoraro et al (1990) investigated the effects of foot plantar pressures, over a 30-month period, by following 80 patients with diabetes mellitus (DM) who had a lower limb amputation due to a diabetic foot ulcer (DFU). The investigators used a synthesis of various objective and subjective data to define causal pathways that led to the amputation. They concluded that patients with DM and peripheral neuropathy (PN) are at high risk for plantar ulcers over the metatarsal heads due to excessive pressure and insensate skin. The causal sequence of minor trauma, cutaneous ulceration, and wound-healing failure applied to 72% of the amputations, often with the additional association of infection and gangrene. An episode involving minor trauma that caused cutaneous injury, such as increased plantar pressures in inappropriate footwear, preceded 69 of 80 amputations which they felt was an identifiable and potentially preventable event.

Assessing the peak plantar pressures (PPP) using in-shoe insole pressure sensors is often used as a surrogate measure for studying the risk of skin breakdown (Cavanagh et al, 1997; Ahroni et al, 1999), and elevated plantar pressure is a significant risk factor for foot complications (Lavery et al, 2003).

Minimizing PPP in at risk populations could prevent the need for future amputations. Many strategies are used with the DFU population for the management of PPP with the goal of DFU healing. Among these is the use of specialized footwear, which is commonly referred to in the literature as foot wear for “pressure redistribution” and to increase the area of weight bearing. Total contact casting (TCC) and removable walkers are very effective in reducing PPP at sites of ulceration and high plantar pressure in the diabetic neuropathic foot. Offloading shoes also reduce peak pressure significantly, but not as much as TCC and removable walkers, which is likely to contribute to the lesser clinical effectiveness of these devices (Bus et al, 2008). Although effective, TCC and removable walkers can be expensive for patients and their families, and may be limited in availability depending on the services and professional support in the patients’ local community.

Although there is no clear percentage of effective offloading that is needed to avoid skin damage and maximize wound healing in DFU (Beuker et al, 2005), it can be presumed that the maximal amount of offloading would be of most benefit.
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Predicting plantar pressures

In a study by Cavanagh et al (1997) the team took radiographic images of the feet of 50 healthy subjects to identify what measurements could be utilized as predictors of PPP. They found that only 31% of the heel and 38% of the first metatarsal head PPP variance could be explained by the measurements of foot structure derived from the radiographs. Soft tissue thickness and arch height were found to be the best predictors of increased pressure. Given that foot anatomy can only account for approximately 40% of pressure differences, their findings implied that dynamics of gait exert the major influence on plantar pressure during walking.

As well, Mueller et al (2003) examined forefoot structure as a predictor of PPP during walking, and compared 20 people with DM and PN to 20 people without DM. Measures of foot structure were taken from three dimensional images. They found that hammer toe deformity, soft tissue thickness, hallux valgus, and forefoot arthropathy accounted for 47–71% of the PPP variance in the DM group and 52–83% of the variance in the control group.

Given this wide margin, the source of PPP are multifactorial. Gait aids and gait patterns need to be considered along with foot deformity when evaluating risk for DFU in DM patients.

Gait patterns and their effect on plantar pressures

The assessment of gait in a person with diabetes is recommended to establish a person’s risk of falling, abnormal weight bearing and alterations in gait pattern. Assessment of gait can also be utilized to determine changes in plantar pressures while walking.

The effect of walking cadences on in-shoe plantar pressures in eight able-bodied subjects was evaluated by Zhu et al (1995). With increasing cadence, mean pressure-time integral continuously decreased (45% at 120 steps/minute), mean foot to floor contact durations continuously decreased (64% at 120 steps/minute), and mean peak plantar pressures increased (119% at 120 steps/minute). These percentages were compared to the subjects at a cadence speed of 70 steps/minute. The results showed that the greater the walking speed, the greater the PPP.

The authors then challenged whether decreased PPP with gait aids are due to the device itself or the decrease in cadence of patients using these devices.

Given that patients using TCC and other therapeutic footwear would also likely have a decrease in cadence, it is difficult to attribute decreased PPP to the footwear alone. Encouraging patients to slow their gait speed while walking may result in decreased PPP and decrease their risk of minor trauma.

Zhu et al (1991) also studied gait patterns in 10 healthy males, and reported the effect of shuffling gait patterns on plantar pressures. PPPs decreased at the first and second metatarsal heads and the hallux by up to 57.8% and 63.2% respectively. Again, the question of whether the pressure change was due to less of a push off versus decreased walking speed could not be determined. The risk of friction and shear causing cutaneous injury with shuffle type gait was also not addressed, but needs to be a clinical consideration with this gait pattern.

Gait patterns in patients with DM and PN were studied in comparison to healthy subjects (Mueller et al, 1994). Limited plantar flexion muscle torque secondary to peripheral neuropathy was found in the group with DM. The authors suggest that emphasizing hip pull-off for patients may decrease pressure under the metatarsal heads.

Mueller et al (1994) tested this hypothesis with seven male subjects who had diabetes mellitus and peripheral neuropathy. They were asked to emphasize a hip pull-off gait pattern by decreasing their push-off at the ankle, pull their legs forward from the hips, and shorten their steps but not slow their walking speed. Compared to normal ankle push-off, the hip pull-off pattern showed a 27% decrease in forefoot peak plantar pressures and a 24% increase in heel peak plantar pressures.

It was recognized that further studies would need to be conducted to determine if this increase in heel pressure is more of a risk for patients than the benefit of decreased forefoot pressure. Though this is a small study, it reminds us that when pressure is decreased in one segment of the foot it is potentially increased in a secondary segment which would then be at increased risk for breakdown due to high plantar pressures.

“Step to” pattern of gait was researched by Brown and Mueller (1998) in 10 healthy subjects and one subject who lived with DM and PN. The researchers compared “step to” gait with and without a cane and “step through” gait with and without a cane in both groups. Peak plantar pressures decreased 53% in the
forefoot and increased 14% in the heel with “step to” gait regardless of whether the cane was used or not.

These results were compared with results from the PN subject, who had an 87% decrease in forefoot pressures and 46% increase in heel pressures with “step to” gait when compared to “step through” gait. “Step through” with the cane decreased the peak plantar pressure on the forefoot by 84% and increased peak plantar pressure on the heel by 39%.

The authors concluded that the cane did not significantly reduce pressure in the healthy subject’s forefeet or the heels using the step to pattern, but there was a decrease in plantar pressures with use of a cane in the patient with DM and PN. This was attributed to the ineffective use of the cane by healthy subjects. Literature on the use of gait aids and their effect on PPP are discussed in the following section.

**Gait aids and their effect on plantar pressures**

In order to explore gait aids and their effect on plantar pressure, Youdas et al (2005) studied 10 healthy subjects to determine if subjects can offload target amounts of weight using a wheeled walker, cane, crutches and forearm crutches. Subjects were trained by a physiotherapist to offload the right lower extremity by 50% using an assistive device and a bathroom scale for feedback on weight reduction. Vertical ground reaction force was measured by using forceplates while subjects walked at a self-selected speed using a three-point partial weight-bearing pattern.

The authors found that the axillary crutches were most effective in consistently decreasing weightbearing to 50% of body weight. Forearm crutches achieved 56% offloading, wheeled walker 36%, and the straight cane 24%. This study concluded that even though patients are taught to offload their lower extremity with a gait aid, the amount of offloading may also depend on the gait aid provided in order to achieve consistent offloading.

Nordic pole walking has become more popular in recent years as a means of low risk and highly practical aerobic exercise. Patients with DM and PN are asked to decrease plantar pressures for DFU prevention, but it is important for overall health and glucose management to keep an active lifestyle.

Pérez-Soriano et al (2001) recognized the need for a safe aerobic exercise for patients with DM and PN, and researched the option of using Nordic pole walking for this population. Fifty healthy subjects were recruited and the plantar pressures of experienced pole walkers and inexperienced pole walkers with and without use of the Nordic poles were evaluated. Participants walked along a 12 metre walkway at the participants preferred speed and a speed 20% faster. Their findings showed that Nordic walking experience significantly modified the plantar pressure pattern, reducing the load on the second and third metatarsals by approximately 50%; 45% on the medial metatarsal, and 40% on the second and third metatarsal heads not only during Nordic walking but also during normal walking.

Despite the greater speeds in Nordic walking, there was no significant increase in heel and first toe plantar pressures which has been recorded by previous studies when cadence is increased. They did find an increase in medial heel pressures in the experienced group with Nordic walking of 25% for the preferred speed and 23% for the fast speed which was statistically significant.

Given their findings, the authors suggest that Nordic walking could be beneficial prophylactically for patient populations who are at risk for forefoot ulcers such as the diabetic neuropathic foot. As walkers gain more experience with pole walking, they also modified their pressure pattern during walking without poles and reduced pressure on the metatarsals by 30–50%.

Lee et al (2011) recognized that foot pressure is widely used for the evaluation of gait and studied the fluctuating changes of foot pressure with normal, two-point, and four-point crutch walking in healthy volunteers. PPP parameters were collected using a force plate during gait with or without a crutch. The regional plantar forefoot pressure significantly decreased during two-point and four-point crutch (67.36 +/- 4.61 kPa; 63.82 +/- 4.51 kPa respectively) walking compared with normal gait (79.73 +/- 4.08 kPa). However, the regional plantar foot pressure of the midfoot and the rearfoot were not altered by gait type.

Healthy subjects were also tested and compared with ipsilateral and contralateral cane use for peak vertical plantar force (Aragaki et al, 2009). The researchers collected data using a force plate from subjects walking in three different conditions relative to their PPP parameters.
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to a randomly assigned limb: contralateral cane, ipsilateral cane and no cane. Their results showed that compared to walking unaided, there was a 7% decrease in peak plantar vertical force with ipsilateral cane use and an 11% decrease with contralateral cane use. The authors concluded that both ipsilateral and contralateral cane use reduced peak plantar vertical pressures, but also decreased cadence by 13% which they believe was due to inexperienced cane users.

Clinical implications

While physiotherapists have traditionally been referred to for ambulatory aids and recommended alterations in gait patterns in the treatment of the orthopedic population to aid the healing of a bone or soft tissue injury in the foot, they are not typically referred to for equipment and weightbearing strategies in the DFU population. Physiotherapy assessment as part of the multidisciplinary team plan of care is imperative in the effective treatment of patients with diabetic foot ulcers, including developing tailored teaching plans related to effective ways to decrease offloading and assist in healing (Bakker and Schaper, 2012). Many approaches have been used to adapt footwear to decrease plantar pressures in the DFU population and such adaptations are able to reduce forefront pressures by 37%–85% (Beuker et al, 2005). The above literature review shows that it is not only foot deformity and peripheral neuropathy that accounts for high peak plantar pressures leading to minor trauma, but also gait pattern, which therefore should be assessed.

Gait aids can be used in isolation or in combination with therapeutic footwear to maximize offloading for patients who cannot comply with specialized footwear due to adherence, financial restraints, or contraindications. Combining multiple strategies for the offloading of DFUs will maximize healing. Physiotherapists need to be aware of their role in care of patients with DFU to augment offloading with recommendations related to gait, mobility and safe physical activity for overall health and safe glucose management.

Conclusion

The physiotherapist is a key member of the multidisciplinary team caring for patients with diabetes who may be in need of foot offloading. This narrative review of the literature supports the importance of the physiotherapist role in maximizing offloading interventions through attention to gait aids and gait training. Further research is needed to assess the long term effects of altered gait pattern on the musculoskeletal system. Offloading of the heel is also noted to be much more challenging than offloading of the forefoot. A number of studies commented on the increase in heel pressures with the decrease of forefoot pressures. A risk benefit analysis is clinically indicated for all DFU patients. The majority of studies found calculated the effects of gait patterns and gait aids on healthy volunteers. Further research in the DFU population is warranted.

References


