CASE STUDY

Changes in pedal plantar pressure variability and contact time following massage therapy:
A case study of a client with diabetic neuropathy

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Summary

Objective: This study was conducted to examine changes in plantar foot pressure variability, and foot contact time in a client with diabetic neuropathy, following a single massage therapy treatment focused on the lower limbs.

Method: The research was a pre-test post-test case study, in which plantar foot pressure measurements were taken at baseline, and immediately following massage therapy treatment. The participant was purposefully selected from the client pool at Sutherland-Chan School of Massage Therapy, where the research was conducted.

Intervention: The intervention involved a single massage therapy treatment of 80 min duration, focused on the lower limbs. The techniques applied followed principles as outlined in the standards of practice of the College of Massage Therapists of Ontario, and included Swedish and myofascial techniques, passive stretching, trigger point treatment and mobilization of the joints of the lower limb distal to the knee. Additionally, preparatory hydrotherapy was applied. All techniques were modified in relation to the client’s clinical needs and presentation.

Outcome measures: Outcome measures were coefficients of variation for mean peak pressures (MPP) for the full foot, the first metatarsophalangeal joint and the hallux; coefficients of variation for the mean value pressure picture (MVP), also for the full foot, the first metatarsophalangeal joint and the hallux; and foot contact time.

Results: A significant increase in the variability of MPP and MVP (greater than 5%) below the hallux was noted. Additionally, there was a significant decrease in contact time ($t(7) = 58.207; p < 0.001$) following treatment. Other comparisons were not statistically significant.
Conclusion: The results suggest that the massage therapy intervention utilized increased the variability of pressure below the hallux of a participant with diabetic neuropathy, and also affected gait positively in terms of velocity and fluidity. Although this single case study is a preliminary investigation of the role, massage therapy may play in the management of clients with diabetic neuropathy, the results reflect a potential to improve mobility and reduce the incidence of neuropathic ulceration in the diabetic population.

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Introduction

Diabetes mellitus is a chronic and life-threatening disease, affecting approximately 5–10% of the population in the United States (Reiber, 1993). In Canada, the prevalence is similar in that approximately 5% of the population (one and a half million people) have been diagnosed with diabetes (Tan and MacLean, 1995), with a projected increase of some seven hundred thousand people by the year 2010 (Tan et al., 1997).

Costs relating to the treatment of diabetes are high. In the United Kingdom, conservative estimates place diabetes-related inpatient costs alone to be in excess of 220 million pounds (Laing et al., 1991). In the United States, the total cost of caring for people with diabetes has been estimated to be as high as 14% of health care expenditures, or approximately 105 billion US dollars (Rubin et al., 1994), and in Canada statistics similar to those relating to the United States can be anticipated (Meltzer et al., 1998).

Many people with diabetes will develop foot problems (Reiber, 1993), and 15% will develop foot ulceration during their lifetime (Palumbo and Melton, 1995). Thus, diabetic complications involving pedal lesions are the most common of all the potential sequellae associated with the disease (Reiber, 1993), and account for approximately 20% of hospital admissions in the North American (diabetic) population (Bild et al., 1989; Reiber, 1993; Frykberg and Veves, 1996).

The clinical end point commonly associated with pedal ulceration is amputation (Reiber et al., 1992; Boyko and Lipsky, 1995; Frykberg and Veves, 1996), and up to 85% of these are preceded by ulceration (Reiber et al., 1995). In the United States, amputation in people with diabetes accounts for greater than one half of all lower extremity amputations (Reiber et al., 1995), the equivalent figure with respect to the United Kingdom being between 20% and 45% (Connor, 1987). The impact of amputation is compounded by the fact that 9–13% of amputees will undergo subsequent ipsilateral amputation within 1 year of the initial procedure (Miller, 1985), and 30–50% undergo contralateral amputation within 1–3 years (Bodily and Burgess, 1983). Additionally, inhospital mortality rates for diabetic amputees have been reported at 10%, this figure being higher than in the general diabetic population (Nelson et al., 1988), and the 5 year mortality rate following amputation is 50–75% (Laing et al., 1991).

The role of sensory neuropathy and elevated or altered plantar pressure in the causation of diabetic ulceration has been recognized for some time (Duckworth et al., 1985; Boulton, 1992; Masson, 1992; Veves et al., 1993). More recently, Boulton (2004) noted that repetitive stress in the neuropathic foot played a major role in maintaining wound chronicity, thus reinforcing the need to manage plantar pressures effectively. Additionally, the relationship between deformity, plantar pressure and callus formation as a prelude to ulceration has been reported (Cavanagh et al., 2000). Cavanagh et al. (2000) also indicate that prophylactic surgical treatment of deformity results in a high incidence of Charcot fractures, thus highlighting the importance of more conservative approaches to the control of plantar pressure variables. However, although it is well established that an increase in absolute pressure has the potential to result in ulceration, it is unclear as to the functional predisposition that ultimately results in this pressure increase. Despite the efforts of the scientific community over the past years, the normal plantar pressure pattern remains elusive (Akhlaghi et al., 1994). This has led to an increasing awareness that the concept of normality needs to be reframed so as to focus on normal variability of plantar pressure patterns. It may be that absence of pathology can be associated not with a normal pressure pattern, but with sufficiently broad plantar pressure variability.

This theory is supported when the time-dependent visco-elastic properties of biological tissue are
considered, in that the yield point will be reached more quickly with repeated strain (deformation caused by stress). Therefore, it can be argued that failure thresholds would be reached more readily with decreased inter-footstep variability, ultimately leading to tissue ulceration.

Another factor implicated in the development of abnormal plantar pressures is limited joint mobility (Shinabarger, 1987; Masson et al., 1989; Birke et al., 1991; Fernando et al., 1991; Veves et al., 1993; Bennett et al., 1996), which has been found in up to 45% of adults with type 2 diabetes (Fitzcharles et al., 1984) and 30% of children with type 1 diabetes (Rosenbloom et al., 1981). This is thought to be related to glycosylation of collagen, leading to thickening and reduced flexibility of soft tissue structures (Brownlee et al., 1984; Crisp and Heathcote, 1984).

Given the negative effects of neuropathy, limited joint mobility and plantar pressure in the diabetic population, interventions focused on reducing the effect of these factors may reduce the risk for ulceration and amputation.

Massage therapy is one of the oldest healing modalities (Kahn, 2002) and has been shown to effect a variety of systems and tissues. Overviews of these effects have been presented by a number of authors (Field, 1998; Rich, 2002; Yates, 1994), and more specifically, it is theorized that massage effects connective tissue in ways that would improve joint mobility, and therefore, increase the variability of plantar pressures in a population at risk for neuropathic ulceration. This theory relates to the stretching and mobilization of connective tissue that has become short, tight or adhered, and clinical experience shows that massage will improve both tissue flexibility and mobility.

If the mobility and flexibility of the tissues of the foot and lower leg can be improved in the diabetic population, then it is reasonable to hypothesize that limitation of range of motion would be reduced. Consequently, the variability of plantar pressures would be increased, thus reducing the risk for ulceration and amputation. It is this theory on which the present study is based, the primary intent being to determine if a defined massage therapy intervention results in an increase in the inter-footstep variability of mean peak pressures (MPP) and mean value pressure picture (MVP).

The pressure measurement system utilized in the research was the Emed pedar pressure measurement system, which has been reviewed elsewhere by one of the authors (Finch, 1999). This system utilizes a sensor matrix in the form of an insole (2 mm thick) that is placed into the subject’s footwear (Kernozek et al., 1996), the thickness being a product of the force sensor technology (capacitance measurement) on which the system is based (Schaff, 1993; McPoil et al., 1995; Kernozek et al., 1996).

The equipment was made available by the Michener Institute for Applied Health Sciences in Toronto, for which the authors are most grateful.

Research aims

The aim of the research was to examine the changes in variability of MPP and MVP in a client with diabetic sensory neuropathy, following a single massage therapy treatment focused on the lower limbs. It was hypothesized that treatment would result in an increase in pressure variability below discrete areas of the foot, and increased speed and fluidity of gait.

Method

Design

The research undertaken was a pre-test post-test single case study focused on determining changes in plantar foot pressure variability (MPP and MVP) following a single massage therapy treatment focused on the lower limbs.

Participant

The client presented as a clinically well Caucasian male aged 72, with a relevant medical history of type 2 diabetes (10 years duration), hypertension, peripheral diabetic neuropathy, elevated cholesterol, anxiety and depression.

Blood pressure, cholesterol, anxiety and depression were satisfactorily controlled with Terazosine hydrochloride (5 mg), Lipitor (10 mg), Buspirone hydrochloride (10 mg) and Effexor (150 mg), respectively.

Diabetes was controlled by a combination of diet, exercise and drug therapy, the latter consisting of Avandia (4 mg od), Glyburide (5 mg od) and Metformin (500 mg bid). The client reported a usual blood sugar of 7.8, and no recent history of hypoglycemic episode.

Renal disease was denied, as were intermittent claudication and other symptoms related to peripheral vascular impairment, although the client did report occasional night cramps affecting the calf muscles. Physical examination of the lower limbs revealed anhydrotic skin, palpable, although diminished, dorsalis pedis, anterior tibial and
posterior tibial pulses, a capillary refill time within normal limits and normal skin appendages.

The clinical impression of the client’s vascular status was within normal limits in the context of his overall presentation. He was therefore at low risk for pedal complications resulting from peripheral vascular disease, including ischemic breakdown.

The patient reported symptoms related to peripheral sensory neuropathy, which included paresthesia and numbness in a classic stocking distribution. Physical examination revealed erratic response to light touch and loss of protective sensation and vibration based on use of a research grade 10g monofilament and a 128Hz tuning fork.

Range of motion testing revealed moderate reduction in the mobility of the talocrural and pedal joints generally, including the subtalar and midtarsal joints, the first metatarsal ray and the first metatarsophalangeal joint. The combination of reduced range of pedal joint motion combined with sensory neuropathy placed the client in a moderately high-risk category for neuropathic ulceration. As such, the study inclusion criteria of a medically stable client with adequate peripheral circulation who presented with risk factors associated with neuropathic ulceration had been met.

**Procedures**

The client was initially identified as a potential participant in the research study through purposive sampling. This involved the selection of the participant on the basis of subjective judgment that his presentation was aligned with the focus of the research. The participant was not known, and had not been treated, by any of the researchers prior to the purposive sampling process.

Once identified as a potential participant, the study was explained by a member of the research team and the client attended the clinic for an appointment. After the client’s suitability for the study had been determined, the research was fully discussed and informed consent obtained.

Foot pressure measurements were then taken using the Emed pedar in-shoe system in accordance with accepted protocol. This involved placing the correctly sized pressure-sensing insoles in the subject’s shoes, and after connecting the system, the participant was instructed to walk back and forth along a 40ft walkway at his normal, comfortable walking speed for an acclimatization period of 5 min. After acclimatization, pressure data were collected during two data collection runs, the system being reset in between. Prior to enrolling the participant it had been decided to analyze the data related to the left foot. The two data collection runs resulted in data being available for a total of eight left footsteps, which were then saved and the pressure equipment removed from the participant.

After the pre-intervention data collection was completed, the intervention phase of the study began, details of which can be found in the following section.

After the treatment had been delivered, the participant dressed and pressure data were collected in the same fashion as during pre-intervention data collection. Approximately 15 min elapsed between completion of the treatment and data collection, after which the participant was monitored for a period of 10 min to ensure that no adverse effects were experienced.

**Massage intervention**

The intervention was performed by a member of the school’s faculty, who was educated in Ontario and had 10 years broad-based clinical experience in hospital, multi-disciplinary and solo practice environments.

Appropriate draping and pillowing were performed throughout, and the techniques utilized were applied in accordance with standard clinical practices in Ontario. Consistently, preparatory hydrotherapy was applied prior to the application of manual techniques, and was modified in relation to the participant’s neuropathic status. This resulted in regional hydrocollator application being reduced to 10 min, and six rather than three towels being used to wrap the pack.

Initially, the participant was treated in the prone position and Swedish techniques, trigger point release, myofascial techniques and passive stretching were applied to the right thigh, lower leg (posterior and peroneal compartments) and foot. Additionally, mobilization of the talocrural, subtalar, midtarsal, metatarsal ray, first metatarsophalangeal, distal tibiofibular and proximal tibiofibular joints was performed. The same combination of techniques was then applied to the left leg.

Turning the participant into a supine position, Swedish techniques, trigger point release, myofascial techniques and passive stretching were applied to the left leg. Additionally, mobilization of the talocrural, subtalar, midtarsal, metatarsal ray, first metatarsophalangeal, distal tibiofibular and proximal tibiofibular joints was performed. The same combination of techniques was then applied to the right leg.

The total treatment time was 80 min, half of this being spent with the participant in the prone position and half supine. Of the 80 min, approximately 48 min were devoted to the application of
Swedish and trigger point techniques, and passive stretching, 15 min to myofascial techniques and 12 min to joint mobilizations.

**Outcome measures**

The outcome measures for the study were contact time, and the variability of MPP and MVP (expressed as the coefficient of variation) for the full foot, the first metatarsophalangeal joint and the hallux.

**Data analysis**

Contact time data for the eight pre-intervention footsteps were compared with data for the eight post-intervention footsteps using a paired *t*-test, the alpha requirement being set at *p* < 0.05. Coefficients of variation were calculated for the MPP and MVP and were visually compared. The a priori determined percentage difference required in order to suggest significance was 5%, based on external expert opinion (Thomson, 2006).

**Results**

As indicated in Table 1, when comparing pre- and post-intervention foot contact time, a significant difference was noted (*t*(7) = 58.207, *p* < 0.001). This objective finding was reinforced by the subjective observation of the participant’s gait, which was faster, more relaxed and more fluid.

As indicated in Table 2, visual comparison of pre- to post-intervention coefficients of variation, revealed a generalized increase in the variability of MPP and MVP, for the full foot, first metatarsophalangeal joint and hallux. The a priori requirement for these differences to be deemed significant was 5%. Thus, the results indicate that MPP and MVP variability for the hallux were significantly increased.

**Discussion**

When considering the implications of this study it should be remembered that the results are based on data collected from a single subject, and therefore, definitive conclusions should not be drawn. This being said, the findings are encouraging in that the influence of a massage therapy intervention on the gait of a participant with diabetic neuropathy is noteworthy, although the relative importance of each of the treatment components is not known.

The results speak directly to a slight increase in variability of MPP and MVP generally, and increases of above 5% for the hallux. Indirectly, this likely reflects an increase in the range of motion of the joints of the foot and lower limb. The combination of increased pressure variability and increased range of joint motion is suggestive of potentially reduced risk for diabetic neuropathic ulceration.

It is interesting to speculate that if these results are supported by larger scale controlled studies, this may lead to a better understanding of the role of massage therapy in the management of diabetic neuropathy.

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<tr>
<th>Table 1</th>
<th>Comparison of pre-post intervention foot contact time</th>
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<tr>
<td>Mean pre-intervention contact time (s)</td>
<td>Mean post-intervention contact time (s)</td>
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<td>0.6</td>
<td>0.38</td>
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<th>Table 2</th>
<th>Variability of pressure characteristics expressed as coefficient of variation (CV)</th>
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<tr>
<td>Parameter</td>
<td>Pre-intervention CV</td>
</tr>
<tr>
<td>Full foot</td>
<td>MPP</td>
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<td></td>
<td>MVP</td>
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<td>1ST mpj</td>
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<td>Hallux</td>
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massage therapy may find an important place in the prevention of neuropathic ulceration in the diabetic population. This could be achieved through screening of foot pressures and the timely introduction of massage therapy to the patient’s management plan. Such an approach is aligned with the inter-professional care of people with diabetes, and has the potential to improve clinical outcomes and reduce the economic burden on the health care system.

Conclusion

The results suggest that the massage therapy intervention utilized affected the gait of a client with diabetic neuropathy positively, in terms of velocity and fluidity, and the variability of pressure under the weight-bearing surface of the hallux. Although this single case study is a preliminary investigation, the results reflect a potential to improve mobility, and reduce the incidence of neuropathic ulceration in the diabetic population.

Limitations

As with any single case study, the ability to extrapolate findings and draw conclusions is limited. Although the results are suggestive, the changes noted cannot definitively be attributed to the intervention tested. Additionally, the participant was a long-time recipient of massage therapy, and therefore, undoubtedly represents a sub group of the neuropathic diabetic population. However, although the participant was “massage friendly” and had reported positive response to treatment in the past, he had never specifically noted any changes in gait.

Certain technical issues necessitated that the researchers limit the focus of the study to the pressure characteristics noted in the results section of this paper. In future research, it is hoped that the focus will be broadened to include such variables as pressure time integral and center of pressure. Additionally, more recently described variables such as the peak pressure gradient (Mueller et al., 2005) will also be important to consider.

Future research

On the basis of this study, further work is being planned to investigate more rigorously the effect of massage therapy on plantar foot pressures and the gait of clients with diabetic neuropathy. Beyond this, research focused on the effects of massage therapy on the incidence and healing of neuropathic ulceration could potentially lead to improved clinical outcomes related to diabetic clients with peripheral neuropathy.

In addition to the above, research investigating exercise and home care regimens would inform treatment planning, as would information related to the relative importance of the different treatment components in achieving the desired clinical outcomes.

Author’s contributions

PF: Conceived the idea and research question, designed and organized the work, collected and analyzed the data, wrote and edited the manuscript.
AB: Assisted with the development of the massage therapy protocol, assisted with data collection and provided feedback on the manuscript.
FM: Assisted with the development of the massage therapy protocol, delivered clinical treatment to the participant and provided feedback on the manuscript.
PB: Assisted with the development of the massage therapy protocol, assisted with data collection and provided feedback on the manuscript.

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References

Changes in pedal plantar pressure variability and contact time


