

Understanding the relationships between the calf muscle pump, ankle range of motion and healing for adults with venous leg ulcers: a review of the literature

O'Brien JA, Edwards HE, Finlayson KJ & Kerr G

Abstract

Exercise offers the potential to improve circulation, wound healing outcomes, and functional and emotional wellbeing for adults experiencing venous leg ulceration. Individuals with chronic leg ulcers typically have multiple comorbidities such as arthritis, asthma, chronic obstructive airways disease, cardiac disease or neuromuscular disorders, which would also benefit from regular exercise.

The aim of this review is to highlight the relationships between the calf muscle pump and venous return and range of ankle motion for adults with venous leg ulcers. The effect of exercise will also be considered in relation to the healing rates for adults experiencing venous leg ulceration.

The findings suggest there is evidence that exercises which engage the calf muscle pump improve venous return. Ankle range of motion, which is crucial for complete activation of the calf muscle pump, can also be improved with simple, home-based exercise programs. However, observational studies still report that venous leg ulcer patients are less physically active than age-matched controls. Therefore, the behavioural reasons for not exercising must be considered. Only two studies, both underpowered, have assessed the effect of exercise on the healing rates of venous leg ulcers.

In conclusion, exercise is feasible with this patient population. However, future studies with larger sample sizes are needed to provide stronger evidence to support the therapeutic benefit of exercise as an adjunct therapy in wound care.

Keywords: venous leg ulcers, exercise, calf muscle pump, range of ankle motion, literature review.

Introduction

Venous leg ulcers affect 1–3% of the population aged over 60 years^{1,2} and this incidence is expected to increase with an ageing population³. Patients with venous leg ulcers report multiple comorbidities⁴ and are more likely to be sedentary than age-matched controls⁵. An increase in physical activity may have an impact on reducing the burden of chronic disease and improving functional aspects of patients' lives whilst potentially improving the healing rates of venous leg ulcers.

Regular exercise is an important aspect in the prevention of the growing global burden of chronic disease⁶. The benefits of regular exercise in older adults are extensive: reducing the risk of cardiovascular disease, thromboembolic stroke, hypertension, type 2 diabetes, osteoporosis, obesity, colon cancer, breast cancer, anxiety and depression⁷. Of particular importance to older adults is that there is substantial evidence that physical activity reduces the risk of falls and injuries from falls, prevents or mitigates functional limitations and is an effective therapy for many chronic diseases⁸.

Through exercise training it is possible for older adults to improve their strength, cardiorespiratory fitness and their ability to live independently^{9,10}. The 2009 position stand of the American College of Sports Medicine is simple: all adults should avoid inactivity, and some physical activity is better than none¹¹.

Physiological factors reported to influence the general wound healing process include circulation, exercise, nutrition and the ageing process. The circulatory system is required to provide an adequate flow of oxygen and nutrients to damaged tissue and removal of toxic waste products for wound healing to occur¹². Deficiencies in either the arterial supply or flow of venous return are known to result in the development of leg ulcers and impair wound healing¹³. Exercise may be of particular benefit to patients with venous leg ulcers as the presence of venous insufficiency and the subsequent venous hypertension may lead to calf muscle changes such as muscle fibre atrophy¹⁴, abnormal gait¹⁵ and reduced strength and functioning of the calf muscle^{16,17}.

The aim of this paper is twofold:

- a) to review the literature on the relationship between the physiological aspects of the calf muscle pump and range of ankle motion in terms of mobility patterns for adults with venous leg ulcers; and
- b) to review the current evidence on the relationship between exercise and wound healing.

A search of the literature was conducted from 1980 to March 2012 using the keyword search terms of venous, chronic venous insufficiency, leg, ulcer* and exercise* and/or physical activity and calf muscle pump and ankle range of motion. Databases searched were Medline, Cinahl, PsycINFO, Academic Search Elite, EJS E-Journals, Biological Abstracts, Sport Discus, Current Contents, ProQuest health databases, the Cochrane Library Databases, ScienceDirect, and Web of Science.

The role of the calf muscle pump

Although, several theories exist that aim to explain the mechanisms that lead from venous disease to venous ulcers¹⁸⁻²², the pathogenic steps leading from venous

hypertension to ulceration are still largely unknown. However, it is agreed that venous hypertension is a fundamental part of this process^{23,24} and, therefore, the mainstay of treatment of venous leg ulceration aims to reverse venous hypertension through multilayer compression bandages.

Numerous observational studies have reported that patients with chronic venous insufficiency (CVI) have an inefficient calf muscle pump^{17,25-27}. Christopoulos *et al.*²⁶ conducted a large prospective design where 30 normal limbs, 110 limbs with primary varicose veins, 34 limbs with reflux in the deep veins but without occlusion, and 31 limbs with deep venous occlusion, with or without reflux, were studied. The authors concluded that an increase in the incidence of ulceration occurred with increasing values of reflux and decreasing values of the calf muscle pump ejection fraction. Araki *et al.*²⁵ clinically evaluated 69 limbs with CVI and concluded that venous insufficiency is essential but not enough to cause venous ulceration and a deficiency of the calf muscle pump is significant to the severity of venous ulceration. Similarly in a study by Yang *et al.*¹⁷ 49 patients with recently healed venous ulcers (49 limbs) were observed to have a significant impairment of the calf muscle pump function compared with healthy age and sex-matched controls. It is of clinical significance to note that over 70% of patients who present with a venous leg ulcer have an impaired calf muscle pump²⁸.

The calf muscle pump is the primary mechanism to return blood from the lower limbs to the heart. During exercise, the calf muscles (gastrocnemius and soleus) contract and compress the intramuscular and deep veins, raising venous pressure and propelling blood in the deep venous system to flow toward the heart, while the one-way valve function prevents reflux, thereby preventing blood from pooling^{16,29,30}. When the gastrocnemius and soleus muscles contract, they expel more than 60% of venous blood into the large popliteal vein²⁴.

The efficiency of the calf muscle pump is dependent upon ankle joint mobility and the competency of the veins¹⁶. There are several pumps in the leg from the foot to the upper thigh^{31,32} which synchronise during walking. Dorsiflexion of the foot before weight-bearing empties the distal calf pump; weight-bearing empties the foot pump; and plantar flexion following weight-bearing empties the proximal calf pump³¹. Therefore, the moving ankle joint and the competency of the veins work together, helping the calf muscles to pump venous blood back up to the heart¹⁶. It is likely that calf muscle pump haemodynamic performance is directly related to the strength of the calf muscle contraction; the stronger the contraction, the greater volume of blood emptied from the venous sinuses as a result. It is hypothesised that a reduction in calf muscle bulk through atrophy could result in a decrease in venous return, eventually leading to CVI³³.

There is varied level of evidence to support the effect of exercise on improving calf muscle pump function by engaging

Jane A O'Brien* RN, ESSAM AEP, MAppSci
(Research)

PhD Candidate, Senior Research Assistant, School of Nursing, Institute of Health and Biomedical Innovation, Queensland University of Technology Brisbane, QLD, Australia

Tel +61 7 3138 6419

Fax +61 7 3138 6030

Email j3.obrien@qut.edu

Helen E Edwards RN, PhD

Head, School of Nursing, Institute of Health and Biomedical Innovation, Queensland University of Technology, Brisbane, QLD, Australia

Kathleen J Finlayson RN, PhD

Postdoctoral Research Fellow, School of Nursing Institute of Health and Biomedical Innovation Queensland University of Technology Brisbane, QLD, Australia

Graham Kerr PhD

Professor, School of Exercise and Nutrition Institute of Health and Biomedical Innovation Queensland University of Technology Brisbane, QLD, Australia

* Corresponding author

in simple lower limb exercises such as lifting and lowering of the heels (tip-toe exercises)^{17,28,34,37}. Air plethysmography has been used in the following studies as it provides a non-invasive, reliable method for determination of the calf muscle pump function, venous reflux and obstruction^{35,38}. Significant changes in ejection fraction (EF; percentage), which measures the capacity of the outflow of the calf muscle pump has been observed^{17,28,34,35,37}. Residual volume fraction (RVF; percentage), which measures the residual calf volume after maximal muscle contraction using tip-toe exercise has also been observed to improve significantly^{17,28,35,37}. Venous filling index (VFI) (in millilitres per second) is an estimate of the amount of venous reflux and typically has not been observed to change after exercise therapy^{17,28,34,35,37}.

The duration of these exercise programs has ranged from seven days²⁸, six weeks¹⁷ to 12 weeks^{34,37} and six³⁵ months and have been supervised^{28,36}, home-based^{17,34,37} or a combination of both³⁵. The majority of these studies have been prospective in design^{17,28} with few randomised controlled trials (RCTs)^{34,35,37}. Sample sizes have been typically small, making the evaluation of the effectiveness of the trials difficult.

The calf muscle pumps plays a crucial role in the pathogenesis of venous ulceration²⁵. Evidence above highlights how the effect of a simple exercise program can improve the efficiency of this pump^{17,28,34,35,37}. It has been suggested the stretch of the calf muscles due to weight bearing and dorsiflexion of the upper ankle joint are the key mechanisms by which blood is ejected into the veins³¹. Therefore, it is necessary to understand the biomechanical components that contribute to the dysfunction of the calf muscle pump such as reduced ankle range of motion (ROM) and calf muscle wasting³⁹.

Relationship between ankle ROM and calf muscle pump activation

Ankle ROM is dependent on the integrated functioning of nerve, muscle, tendon, capsule, ligament and cartilage⁴⁰. Thus ankle ROM may be altered by conditions that affect the functional capability of any of these components such as stroke, neuropathy, trauma, arthritis and inactivity⁴⁰.

Normal ankle ROM is the combination of plantar flexion and dorsiflexion, and is approximately 57 +/- -2 degrees. In patients with active ulceration, ankle ROM is restricted^{5,39-42} and has been shown to be as little as 21 +/- -4 degrees⁴⁰. It is understood that ankle ROM decreases with age⁴³⁻⁴⁷; however, this alone does not explain the difference observed; as those patients with open leg ulceration still have significantly lower ankle ROM when age-matched to controls⁵. Poor ankle ROM has been associated with poor calf muscle pump function⁴⁰, indicating the importance of improving calf muscle pump function through improving ankle ROM. Back *et al.*⁴⁰ assessed 32 limbs on the basis of varying clinical presentations. The authors demonstrated that ankle ROM in actively ulcerated limbs was significantly worse than ROM in non-ulcerated

limbs with CVI. Good ankle ROM is an important factor for leg ulcer healing^{41,42,48} and it is likely that restricted ankle movement contributes to calf muscle pump failure in patients with venous leg ulceration¹⁷. The 24-week healing rate has been noted to be significantly reduced in patients with poor ankle mobility: 13% for patients with ankle mobility <35 degrees, compared with 60% for patients with ankle mobility >35 degrees⁴⁸.

Ankle ROM is probably compromised by long-term layered compression bandaging. It has, therefore, been suggested that patients in compression bandaging should, therefore, be instructed to exercise to counteract the associated immobilisation^{5,39}. Pain associated with chronic leg ulceration may be a possible cause for a decrease in voluntary ankle flexion and extension. However, only one study has considered this and it was not shown to be a significant factor⁴⁰. It is acknowledged that inactivity is a likely contributor to decreased ROM in patients with CVI⁴⁸. Lengthy inactivity may also be an important factor in ankle stiffness, since oedema and compression devices may discourage or restrict the patient from exercising⁵. Prolonged inactivity and bed rest can lead to muscle atrophy, contracture and degenerative joint disease²⁷. One of the muscles particularly affected by resting of the leg is the tibialis anterior, which acts as a dorsiflexor of the ankle⁴⁰. It is expected that exercises designed to improve ankle ROM will improve calf muscle pump function and thereby improve healing rates of venous leg ulcers.

Although only a couple of studies have measured change in ankle ROM after an exercise intervention with ankle stretches in adults with venous leg ulceration, all have demonstrated significant improvements after 12 weeks^{37,39,49}. Only two of these studies were RCTs^{37,49}; however, all of the studies had small sample sizes but were able to demonstrate significant improvements in ankle ROM. The exclusion criteria in two of the studies^{39,49} could, however, be considered to be too limiting to the profile of venous leg ulcers patients and, therefore, it must be questioned how generalisable some of the findings are.

The overall significance of the degree of ankle ROM is that for normal walking motion to occur dorsiflexion past the 90 degree "neutral" position is required⁴⁰ for calf muscle pump activation. What is becoming increasingly accepted is that patients with venous leg ulcers may not have a normal walking motion; instead they tend to shuffle their feet when they walk. One study has shown over 60% of limbs had a negative dorsiflexion, which would indicate walking patterns to be out of the normal range⁴⁰. In challenging this assumption, another study proposed the idea that venous leg ulcer patients walk too slowly to optimally enhance blood flow¹⁵.

It is reasonably intuitive to assume that leg ulcer healing is more favourable in mobile patients, yet studies report decreased general mobility of these patients^{3,50,51} and that

they are more dependent on walking aids and transportation than age-matched controls⁵. In one study, one-quarter of all patients engaged in walking outdoors only once a week or less⁵⁰. Similarly another study reported that leg exercises were conducted by only one-third of the patients⁵¹. A recent survey and retrospective chart review showed only 35% of patients reported undertaking daily ankle exercises, while 44% elevated their legs above the level of their heart for 30 minutes or more at least five days/week⁵².

The above studies included a variety of observational study designs and self-reported data^{5,50-52}, which may be considered a limitation to the research. It is unclear whether there is an association between mobility patterns and healing. One study indicated poor mobility as an important factor for delayed healing of venous ulceration⁵³, whereas another large study found no association between mobility and healing⁵⁴. There is only one study to date that has measured mobility patterns with this patient population using an objective measure⁵⁵ and interestingly they found the time spent mobilising did not differ significantly between leg ulcer patients and matched controls. The authors concluded that it was instead the rate of stepping and the number of steps that differed significantly – with ulcer patients taking fewer steps in the same period of time than the control group⁵⁵. This reinforces the concept that venous leg ulcer patients may not be optimising use of the calf muscle pump function to a level which may assist ulcer healing.

Until recently studies which have reported mobility patterns have utilised cross-sectional designs; however, a recently published randomised trial demonstrates the effectiveness of a nurse-led intervention on enhancing walking behaviour and conducting leg exercises by enhancing a patient's self-efficacy toward these activities⁵⁶. There were 16% (95% CI: 6–21%;

$p < 0.01$) more patients in the intervention group versus the control group who had 10-minute walks on at least five days of the week, and 32% (95% CI: 20–44%; $p < 0.01$) more patients in the intervention group who conducted their leg exercises over the 18-month study period. This study highlights that tailoring advice on physical activity is effective in this group of patients. These results were in line with the authors' expectations from previous findings⁵¹ that the majority of patients would be highly motivated to enhance physical activity behaviours if they knew this would improve wound healing or to prevent recurrence of leg ulcers.

Contrary to venous leg ulcer patients being reported as stating that maintaining their level of independence, that is their ability to walk and accomplish everyday tasks^{57,58}, is of utmost concern to them, they are frequently reported as being less mobile than age-matched controls^{3,50,51}. It is, therefore, important to understand why these patients are not as mobile as it seems they would like to be. According to one review⁴, low levels of physical activity for venous leg ulcer patients are caused by pain, cumbersome compression bandaging, wound exudate, oedematous legs, older age and the need to wear larger shoes. This review fails to acknowledge fear of injury; lack of time due to time-consuming ulcer care and/or care of family members; and insufficient or contradictory advice from caregivers regarding physical activity or exercise⁵⁹. Interestingly, another study specifically explored the concept of fear of movement and associated avoidance behaviours and concluded that fear-avoidance beliefs were a better predictor of low levels of physical activity in these patients than pain⁶⁰.

Suggestions for improving physical activity levels include influencing knowledge, beliefs and self-efficacy⁵⁹. In addition, it is imperative that the patient's individual physical

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limitations, pain, adequate foot-wear and social support be taken into account⁵⁹ and fear-avoidance beliefs need to be discussed⁶⁰. Home-based exercises could be implemented so the patient can tailor them to suit their lifestyle. Consistent advice given from health professionals is needed to encourage venous leg ulcers patients; for example, including information that exercise may improve their healing rates and to inform them of other benefits of exercise such as improved mood, quality of sleep and weight control^{9,10}.

With respect to walking technique, practitioners should address the need for adequate footwear⁵ and instruct patients in proper gait patterns by emphasising heel-toe walking, and that an adequate push-off phase is necessary to effectively engage the calf muscle pump function²⁵.

Impact of exercise on wound healing in patients with venous leg ulcers

The general guidelines recommended for patients with venous leg ulcers is regular walking and ankle exercises and this is based on the expected benefits from improved venous return⁶¹. Practitioners and patients are concerned not with the mechanisms for improvement but with the clinical effect on healing or preventing recurrence.

However, few studies have considered healing as a primary outcome. An RCT on 28 healthy older adults examined the effect of a three-month exercise program on wound healing⁶². One month post-recruitment, participants underwent an experimental wound procedure and it was observed that those in the intervention group healed at a significantly faster rate. The authors postulated that exercise may contribute to increased blood flow to the skin and increased skin oxygen tension, thereby enhancing wound rates.

However, this phenomenon has not been observed in chronic wounds. Two recent pilot studies, both of which have been RCTs^{34,37}, have investigated the impact of 12-week, home-based exercise programs. Both studies utilised an intervention group who performed heel raises in addition to compression therapy, versus a usual care group who were also in compression therapy. The first of these was a nurse-led study in which 40 participants were randomised and stratified by ulcer size and duration³⁴. Changes in ulcer parameters (change in area, percentage change area) were measured. These authors did not observe a gain in calf muscle pump efficiency or difference in healing between groups over time; however, it was noted that adherence to the exercise regime was high at 81%. While the other study³⁷ had a small sample size (n=11), it concluded that the exercise protocol was feasible, well adhered to and significant changes in calf muscle pump efficiency (increase in EF $p=0.05$; decrease RVF $p=0.04$) and ankle ROM were observed ($p=0.01$). However, the difference observed between groups in healing outcomes was not statistically significant due to the limited power of the study and it was concluded that a larger sample size is

required to ascertain if exercise improves the healing rates of venous leg ulcers.

Conclusion

Efficient venous return from the lower limbs depends primarily on the activation of the calf muscle pump. Therefore, exercise has the potential to be both a preventative measure and an adjunct form of therapy. Current evidence suggests that tailored, individualised exercise programs designed to increase the strength of the calf muscle pump through resistance training is not only feasible and well adhered to by patients but is also effective in improving the calf muscle pump function^{17,28,34,35,37} and ankle ROM^{37,39,49}.

Only two trials have been undertaken in this area which have not had the power to determine the effect of exercise programs on healing; however, they demonstrated resistance training was feasible and well adhered to. This area urgently needs future exercise intervention trials with adequate sample sizes to determine the effect of exercise on healing and other aspects such as functional and emotional wellbeing outcomes for adults with venous leg ulcers.

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