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REVIEW ARTICLES

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The calf muscle pump revisited

Katherine J. Williams, MBBS, MA (Cantab), MRCS,[a] Olufemi Ayekoloye,[b] Hayley M. Moore, MBBS, MA (Cantab), MRCS,[a] and Alun H. Davies, BM, BCh, MA (Cantab), FRCS, DM (Oxon), FHEA,[a] *London, United Kingdom*

Background: **Chronic venous disease (CVD) defines the spectrum of manifestations of venous disease that originate as a result of ambulatory venous hypertension. Thus far, the role of the calf muscle pump in the development and potentiation of CVD has been overlooked and understated in the clinical setting, with much greater emphasis placed on reflux and obstruction. The aim of this review is to explore the level of significance that calf muscle pump function or dysfunction bears on the development and potentiation of CVD.**
Methods: **EMBASE and MEDLINE databases were searched with keywords *"calf"* AND *"muscle"* AND *"pump"* AND *"venous"* AND *"insufficiency"* AND *("lower limb*"* OR *"leg*"),* screened for cross-sectional and longitudinal studies relating to chronic venous insufficiency, highlighting the role of the calf muscle pump in CVD and the extent to which the calf muscle pump is impaired in these cases. This resulted in the inclusion of 10 studies.**
Results: **Compared with healthy subjects, patients with CVD have a reduced ejection fraction (15.9%; $P < .001$) and an increased venous filling index (4.66 mL/s; $P < .001$), indicating impairment in calf muscle pump ejection ability as well as poor venous competence. Calf muscle pump dysfunction is present in 55% of patients with CVD in the literature, but this did not reach significance on meta-analysis. Isotonic exercise programs in patients with active and healed ulcers have been shown to increase calf muscle pump function but not venous competence.**
Discussion: **Calf muscle pump failure is a therapeutic target in the treatment of CVD. Evidence suggests that isotonic exercise treatment may be an effective method of increasing the hemodynamic performance of the calf muscle pump.**
Conclusions: **This review emphasizes the requirement for more attention to be placed on the treatment of calf muscle pump failure in cases of CVD by use of exercise treatment programs or other methods, which may be of clinical importance in managing symptomatic disease. To establish this in routine clinical practice, these results would need to be replicated in appropriate clinical trials. It would also be logical to look at other modifiable muscle pumps, such as the thigh and foot, and to explore the potential benefit of electrical devices acting on the leg (eg, electrical muscular or neuromuscular stimulation), especially for those patients in whom exercise capacity is limited. (J Vasc Surg: Venous and Lym Dis 2014;2:329-34.)**

The venous anatomy of the lower extremity consists of a complex network of thin-walled, high-capacitance veins in which the maintenance of appropriate venous return depends on the interaction of an effective pumping mechanism, a pressure gradient, and competent venous valves.[1]

From the Academic Section of Vascular Surgery, Imperial College London[a]; and the Imperial College Medical School.[b]

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Reprint requests: Prof Alun H. Davies, Academic Section of Vascular Surgery, Charing Cross Hospital (4th Floor), W6 8RF, London, England (e-mail: a.h.davies@imperial.ac.uk).

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The calf muscle pump. Venous return from the lower extremities is vitally dependent on the action of the foot, calf, and thigh muscle pumps, with approximately 90% of venous return attributed to these muscle structures during ambulation.[2] Among these, the calf muscle pump plays the most pivotal role, reflected in the fact that it has the largest capacitance and generates the highest pressure, with an ejection fraction (EF) of approximately 65% in healthy subjects. In comparison, the thigh muscle pump has a significantly lower EF of approximately 15%.[2] During ambulation, Alimi et al[3] showed a pressure increase of 92% in the deep posterior compartment of the calf, 104% in the superficial posterior compartment, and 18% in the anterior tibial compartment. This was associated with a rise in venous pressures of 63% in the popliteal vein and 32% in the great saphenous vein. Eberhart et al[4] showed that on contraction of the calf, an increase in pressure of up to 250 mm Hg is observed in the posterior fascial compartment. On calf relaxation, the resting venous pressure falls to between 15 and 30 mm Hg, at which point the function of the bicuspid valves becomes vital to prevent retrograde flow.[4] Dysfunction or impairment of either the valvular or musculoskeletal components of the calf muscle pump may

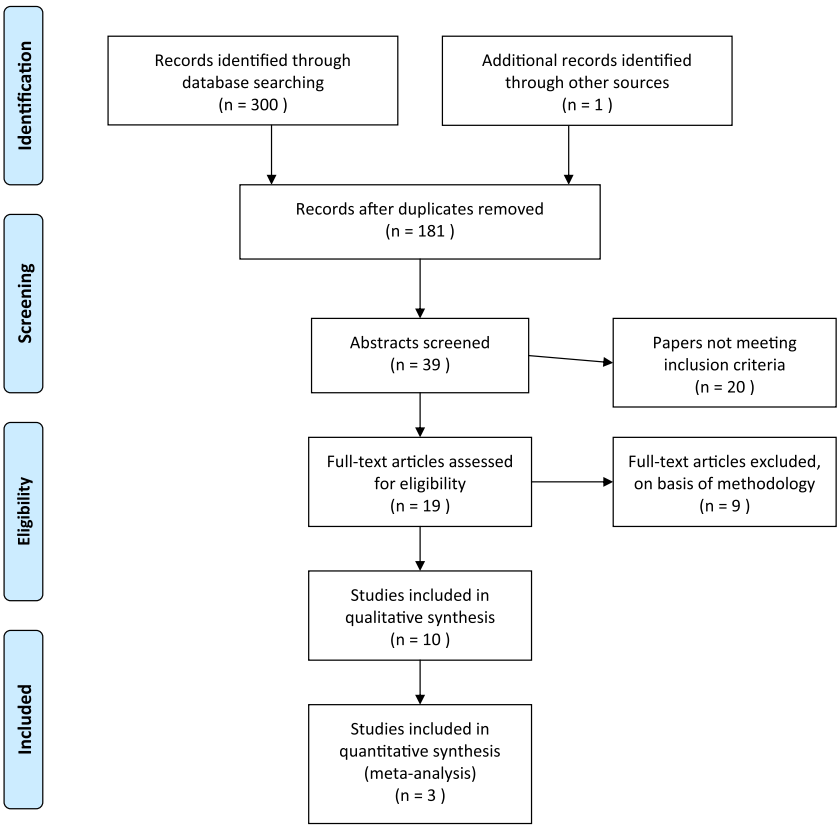

Fig 1. PRISMA diagram of systematic review.

be a major mechanism for the development of venous incompetence and can lead to several manifestations of chronic venous disease (CVD).[4]

Venous dysfunction and pathophysiology. CVD defines the spectrum of manifestations of venous disease that result from ambulatory venous hypertension. Valvular competence, venous obstruction, and calf muscle pump function determine ambulatory venous pressure; therefore, dysfunction of one or more of these can lead to CVD with varying degrees of severity. An effective calf muscle pump in the presence of valvular dysfunction or obstruction plays a compensatory role and may thereby go some way to offset CVD.[4] On the other hand, failure of the peripheral pump caused by musculofascial weakness, loss of joint motion, valvular failure, or outflow obstruction has been reported to be associated with dysfunction of the peripheral venous system.[5] Valvular incompetence and venous reflux are associated with a rapid refill time after muscle contraction; this is due to refill occurring not only by inflow from the superficial system but also by pathologic retrograde venous flow.[2,4] Reflux generates abnormal pressure characteristics, and as there is no reduction in pressure after ambulation, this further potentiates the accelerated refill time.

Venous obstruction results in resistance to the outflow of blood, that in turn causes elevated venous pressures during calf muscle contraction, as well as minimal (if any) reduction in resting pressure after contraction. This has the potential to result in ambulatory venous hypertension and thus the pathogenesis and potentiation of CVD. The pathologic effects of chronic venous hypertension are observed in the skin and subcutaneous tissues and are manifested in the form of edema, pigmentation, fibrosis, and ulceration.[4] The annual cost of venous ulcers in the United Kingdom is estimated to be between £400 and £600 million.[6] Conventionally, severity of CVD is evaluated by both the Clinical, Etiologic, Anatomic, and Pathologic (CEAP) classification and venous severity or quality of life scores.[7]

Aims. The primary aim of this study was to evaluate the relationship between calf muscle pump function and the onset and progression of CVD, using the available literature.

METHODS

Search strategy. By use of the OVID portal to gain access to the archives of MEDLINE and EMBASE (EMBASE Classic and EMBASE plus), articles from 1946 to the present were searched with the keywords "*calf*" AND "*muscle*" AND "*pump*" AND "*venous*" AND "*insufficiency*" AND ("*lower limb**" OR "*leg**").

Inclusion criteria. Cross-sectional and longitudinal studies in humans relating to CVD, highlighting or quantifying the role or impairment of the calf muscle pump in its etiology, onset, or progression, were included.

Exclusion criteria. Articles reporting case studies, reviews, and letters of any form, whether or not they