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Haemodynamic Performance of Low Strength Below Knee Graduated Elastic Compression Stockings in Health, Venous Disease, and Lymphoedema☆

C.R. Lattimer [a,b,c,*], **E. Kalodiki** [a,b], **M. Azzam** [a], **G. Geroulakos** [a,b,c]

[a] Josef Pflug Vascular Laboratory, Ealing Hospital, Middlesex, UK
[b] Department of Surgery and Cancer, Imperial College, London, UK
[c] West London Vascular and Interventional Centre, Northwick Park Hospital, Harrow, UK

WHAT THIS PAPER ADDS

The compression profile of graduated elastic stockings is defined by the manufacturer using bench tests. However, these do not necessarily quantify their action in assisting venous return. This study compared the haemodynamic performance of compression stockings in patients with varicose veins, post-thrombotic syndrome, and lymphoedema against healthy legs, with and without stockings of two different compression strengths. The results indicate that stockings behave differently depending on a patient's disease profile. This may help to explain why not all patients improve from off-the-shelf compression. Routine in vivo performance testing may complement existing bench tests and help select patients who benefit.

Objective: To test the in vivo haemodynamic performance of graduated elastic compression (GEC) stockings using air-plethysmography (APG) in healthy volunteers (controls) and patients with varicose veins (VVs), post-thrombotic syndrome (PTS), or lymphoedema. Responsiveness data were used to determine which group benefited the most from GEC.

Methods: There were 12 patients per group compared using no compression, knee-length Class 1 (18–21 mmHg) compression, and Class 2 (23–32 mmHg) compression. Stocking/leg interface pressures (mmHg) were measured supine in two places using an air-sensor transducer. Stocking performance parameters, investigated before and after GEC, included the standard APG tests (working venous volume [wVV], venous filling index [VFI], venous drainage index [VDI], ejection fraction [EF]) and the occlusion plethysmography tests (incremental pressure causing the maximal increase in calf volume [IPMIV], outflow fraction [OF]). Results were expressed as median and interquartile range.

Results: Significant graduated compression was achieved in all four groups with higher interface pressures at the ankle. Only the VVs patients had a significant reduction in their wVV (without: 133 [109–146] vs. class1: 93 [74–113] mL) and the VFI (without: 4.6 [3–7.1] vs. class1: 3.1 [1.9–5] mL/s), both at $p < .05$. The IPMIV improved significantly in all groups except in the PTS group ($p < .05$). The OF improved only in the controls (without: 43 [38–51] vs. class1: 50 [48–53] %) and the VVs patients (without: 47 [39–58] vs. class1: 56 [50–64] %), both at $p < .05$. There were no significant differences in the VDI or the EF with GEC. Compression dose-response relationships were not observed.

Conclusion: Patients with varicose veins improved the most, whereas those with PTS improved the least. Performance seemed to depend more on disease pathophysiology than compression strength. However, the lack of responsiveness to compression strength may be related to the low external pressures used. Stocking performance tests may have value in selecting those patients who benefit most from compression.

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* Corresponding author. Josef Pflug Vascular Laboratory, 7th Floor Ealing Hospital, Uxbridge Road, Southall, Middlesex, UB1 3HW, UK.

E-mail address: c.lattimer09@imperial.ac.uk (C.R. Lattimer).

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INTRODUCTION

Compression strength and type of graduated elastic compression (GEC) stockings required for a patient are determined by a physician using measuring charts. Although this tradition is satisfactory for most patients, it has become clear that not all legs benefit from GEC. This may be because GEC stockings are rarely assessed haemodynamically during wear, thereby preventing the most suitable stocking being prescribed for that patient.

The in vivo haemodynamic performance of a stocking in augmenting venous return can be measured with several provocation manoeuvres using air-plethysmography (APG). A test is performed first without a stocking and then repeated with GEC so any differences can be compared. Each APG manoeuvre provides selective information on how a stocking performs. These parameters, when combined, are termed stocking performance tests.

Pathological venous insufficiency, defined as insufficient venous drainage, results from pooling, reflux, obstruction, venous wall scarring, and muscle pump dysfunction; alone or in combination. These may be quantified by APG using the working venous volume (wVV), the venous filling index (VFI), the venous drainage index (VDI), the incremental pressure causing the maximal increase in calf volume (IPMIV) and outflow fraction (OF), and the ejection fraction (EF), respectively.

A standardised study investigating the effects of GEC stockings using the same apparatus with the same tests under the same conditions in four different groups of participants is lacking in the literature. The aim of this study was to investigate patients with varicose veins, post-thrombotic syndrome (PTS), or lymphoedema, and healthy controls using GEC stocking performance testing.

MATERIALS AND METHODS

Study design

This was a single centre prospective study comparing the effect of GEC stockings on four groups of participants/legs ($n = 12$/group). Patients with varicose veins, PTS, or lymphoedema were recruited from the vascular outpatients department. Healthy participants were recruited from colleagues and healthcare workers. Below the knee Class 1 (ccl 1: 18—21 mmHg) and Class 2 (ccl 2: 23—32 mmHg) stockings (VenoTrain, Bauerfeind AG, Zeulenroda, Germany) were used as the intervention. Stocking size was selected using the measuring chart recommended by the manufacturer. Stocking-leg interface pressure was measured supine, 5 cm above, and 2 cm posterior to the medial malleolus (gaiter point), and over the medial border of the soleus muscle at the level of the inferior border of the medial gastrocnemius muscle (soleal point) using the PicoPress transducer (Microlab Elettronica, Nicolò PD, Italy). The haemodynamic performance of the leg before and during wear was measured using APG (ACI Medical LLC, San Marcos, CA, USA) in response to standard provocation manoeuvres.

The study was approved by the NRES Committee London-Harrow, REC reference, 13/LO/1863, and is registered on a public database (www.controlled-trials.com), reference, ISRCTN: 45952875.

Participants

The control group denied any symptoms of venous disease and had no evidence of venous or lymphatic disorder on clinical examination. The presence of venous symptoms, varicose veins, and saphenous reflux >0.5 seconds on duplex[1] defined the VVs group. The PTS group was defined based on a history of deep vein thrombosis (DVT) >6 months, venous symptoms, and the presence of obstruction, wall thickening and/or reflux on duplex. Lymphoedema was defined from the clinical features of dermal thickening, a positive Stemmer's sign,[2] and delayed tracer uptake on lymphoscintigraphy.[3] A lymphoedema group was included because they are a common treatment group with GEC and to determine the effect of this compression in optimising venous physiology. Having two groups without CVI and two groups with CVI seems a good balance for the study. Care was taken to ensure that there was no overlap between the groups.

Gravitational tests

These were described using APG and reported in 1964.[4] The wVV in mL was established by measuring the change in calf volume from a position of leg elevation to a position of dependency (Fig. 1A). Initially, the calf is drained with the individual supine on an examination couch and by elevating the leg about 70° from horizontal. The knee is slightly flexed to prevent physiological popliteal vein compression.[5] Once a baseline is reached the individual is asked to stand bearing their weight on the other leg and just touching the floor with the toes of the test leg. Support is provided using an orthopaedic frame. When the tracing on the monitor reaches a plateau, this signifies maximum dependent volume. The wVV is calculated by subtracting the baseline drainage volume from the plateau at maximal volume. The term wVV is preferred to the "venous volume" because it recognises that the leg has a residual volume of venous blood which remains un-drained.

The VFI (mL/s) is calculated from elevation to dependency and is a measure of the rate of calf filling, as described previously.[6] The VDI (mL/s) is the opposite manoeuvre from dependency to elevation (Fig. 1A). It measures the rate of venous emptying and is an index of venous obstruction.[7]

Occlusion plethysmography tests

Venous occlusion plethysmography (VOP) tests are measured supine with the individual's heel resting on a block to make room for the air sensor cuff around the calf. It is an advance on earlier methods of VOP using segmental water chambers.[8] Proximal thigh compression (graduated venous occlusion) was achieved using the VenaPulse pump from the same manufacturer as the APG apparatus. This has been validated to provide sustained compression at preselected pressures with a quick deflation mechanism.[9] This was attached to an 18-cm wide thigh-cuff with dual band velcro straps (CC17 Contoured Thigh Cuff, Hokanson, D. E. Hokanson, Inc., Bellevue, WA, USA).

The thigh-cuff was placed around the mid-thigh, inflated in 10 mmHg steps to 80 mmHg, and the corresponding increases in calf volume were recorded using APG (Fig. 1B). The step causing the maximal increase in incremental