Efficacy of Sport Stockings can be Improved

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Abstract

**Background:** Convincing data on the hemodynamic efficiency of conventional sport stockings are lacking.

**Aim:** To discuss possible innovations concerning the material and the pressure exerted on the venous calf pump function to stimulate producers to develop types of compression devices for sports people which are in accordance with new hemodynamical insights.

**Methods:** Based on measurements of the calf pump function characterizing the most important driving power for the venous drainage against gravity up to the heart, some options for improvement are discussed. Main points are higher pressure over the calf and use of non-yielding compression material.

**Results:** It is demonstrated that higher compression pressure over the calf without increasing the pressure during muscle relaxation is essential to increase the ejection fraction of the calf pump. This may be achieved by applying stiff Velcro-bands or patches around the calf which do not give way when the muscles contract. A pressure gradient from distal to proximal may be neglected and even foot-sparing compression devices can be considered. The resulting fluctuations of compression pressure during movement exert a massaging effect squeezing out venous blood from the calf much more efficiently compared to the effect of elastic, yielding stocking material.

**Conclusions:** Development of stiff compression material is recommended for future studies validating performance and physiological parameters during exercise. Potential improvement of physiological parameters and of performance enabled by this new concept need to be demonstrated in future studies.

**ABBREVIATIONS**

EF: Ejection Fraction; SSI: Static Stiffness Index; WPA: Walking Pressure Amplitude

**INTRODUCTION**

Knee high compression stockings were recommended to improve performance in several sport disciplines. It was assumed that graduated compression of the lower leg would improve venous drainage, thereby increasing venous return to the heart and accelerating the clearance of waste products from the microcirculation. However, objective proof for these effects is sparse and still a matter of debate [1-3].

An essential target of compression devices applied to the lower leg is to achieve an increase of expelled blood volume during exercise. When calf muscles contract, the veins within the muscle are compressed and venous blood is expelled which increases venous return to the heart and accelerates removal of metabolic waste products [4,5].

Which leg segments should be compressed?

The largest venous pools are located at mid-calf level. Squeezing out this area will mobilize more blood volume than can be shifted from the distal leg by compressing the ankle region. This concept led to the recommendation of using "anti-gradient" or "reverse gradient" stocking, also called "progressive stockings", which provide higher pressures over the calf than over the distal leg compared to conventional graduate elastic compression stockings [6]. Actually we were able to demonstrate that in patients with chronic venous insufficiency compression of the calf is more important than a pressure gradient [7]. For sport stockings positive effects, especially concerning subjective feelings of the wearer including the ease of donning and doffing have been reported. However, no advantage concerning objective parameters compared with conventional graduated sport stockings could be demonstrated [3].

One example for such a "progressive sport stocking" is the Booster BV-sport stocking developed in France based on pioneer

Which compression pressures could achieve maximal effects?

It could be shown that 20 mmHg compression stockings lead only to a minor reduction of leg vein calibers in the upright position, and that the increase of expelled volume which depends on the exerted pressure is rather small [8]. Based on vein imaging using ultrasound and MRI we know that for compressing of the lower leg veins usually external pressures of more than 50-70 mm Hg in the standing position are necessary, which is much more than the pressures achieved by sport stockings [9,10]. Pressures reported for the Booster stocking - go up to 27 mmHg over the calf area and are lower over the ankle [3]. An example is shown in Figure (1).

The intravenous pressures measured at calf level correspond to the height of the blood column between the measuring point and the right heart and are around 50-70 mmHg during standing.

An external pressure which should empty such a vein should therefore exceed this intravenous pressure value.

Deep, sub fascial compartment pressures in a healthy population are around 50 mmHg during standing and go up to about 160 mm Hg in the muscle contraction phase during walking and 250 mmHg during running [5]. These pressure peaks will certainly close the veins intermittently for the short phases of muscle contraction and shift blood out from the pumping chamber. The deciding role of external compression which adds to the compartment pressure. Would be to prolong this squeezing effect and to prevent immediate refilling of the pumping chamber as shown in Figure (1). The anti-gradient stocking model shows an increase of interface pressure from 18 to 28 mmHg over the calf and from 14 to 18 mmHg proximal to the ankle region and pressure fluctuations can be seen during dorsiflexions and walking. However, while these pressures may narrow superficial and deep veins in the lying position they are too weak to narrow calf veins during standing, walking or running substantially.

The use of elastic compression textiles is limited by the fact that pressures of over 50 mmHg will be hardly tolerated on the leg because of painful constricting sensations at rest. What is needed is a compression which is well tolerated during rest but increases automatically its pressure when the individual gets up and starts moving (Figures 2-4).

How can we achieve higher compression pressures during standing, walking and running?

Amazingly in many publications on sport stockings the exerted pressure is a point of consideration but the possible...
Significant correlation between Walking Pressure Amplitudes (WPA) and percent change of ejection fraction (EF). Compared to no compression in healthy persons.

The fact that compression with inelastic material is hemodynamically more effective than with elastic textiles is well documented for patients suffering from venous insufficiency. Measurements of venous pressure in a foot vein were able to show that in severe stages of chronic venous insufficiency the pathophysiologically deciding parameter of ambulatory venous hypertension can be reduced, in contrast to compression stockings exerting the same pressure[12]. In such patients inelastic material is also more effective to reduce venous refluxes[13] and to increase the ejection fraction of the calf pump[14]. However, a potential influence of inelastic compression in healthy sports people on the calf muscle pump function had not been investigated previously.

The ejection fraction of the calf pump can be measured applying a strain gauge plethysmograph around the calf. [15]. By elevating the leg in the lying position veins are emptied and a minimal calf volume will be registered. By standing up veins are filled and the volume registration will come to a maximal plateau after some minutes. The measured leg volume difference between the filled and the empty vein position corresponds to the “venous volume”. Then the test person starts to walk and the volume decrease during a standardized walking exercise reflects the blood volume ejected by the calf pump. The ejection fraction [EF] is the proportion of expelled volume in relation to the venous volume.: In healthy individuals EF is between 60 and 70%[14], which means that during walking 60-70% of the blood volume in the calf will be pumped up into the proximal veins. Placing the strain gauge proximal to a lower leg cast, Poelkens et al showed reduced EF-values due to the fixation of the ankle joint impeding the function of the venous calf pump. However, there was an increase of EF when water filled pads were positioned between the calf and the cast, depending on the pressure in the pads achieved by variable filling.[15] Together with Giovanni Mosti we have used this method in several studies searching for an optimal improvement of the venous pumping function in patients with venous insufficiency by different compression devices. As an example—we were able to demonstrate superior improvement of EF with anti-graduate stockings and bandages[7,16].

Increasing the efficiency of the venous calf pump by inelastic compression in healthy sports people. In a recent study on healthy people sport stockings [CEP®, medi Bayreuth] without and with Velcro bands wrapped over the calf with different strength were compared [17]. Figure 2 shows the interface pressure readings in one example demonstrating increasing differences between the supine and the standing position: While there is only a very slight pressure increase by standing up under a conventional sport stocking, pressure rises to 40 mmHg when light straps are wrapped over and to 62,5 mmHg under strongly applied Velcro wraps. There is also an increase of the pressure amplitudes during movement.

The resulting changes of EF in a group of. 12 healthy sports people are summarized in Figure 3: There was a mild, not significant increase of EF under conventional sport stockings, but a highly significant augmentation when Velcro bands were ‘wrapped over the calf, under mild pressure and even more so under strong pressure.

This increase of EF by inelastic material can be explained by an intermittent narrowing of the veins in the compressed calf region during muscle systole without producing ‘high pressures during muscle diastole which could prevent refilling of the pumping chamber.

**Stiffness is the key for boosting venous drainage**

The difference between lying and standing pressure has been termed static stiffness index (SSI) and characterizes the elastic property of a compression product[18]. Measured on the distal leg SSI-values exceeding 10 mmHg characterize stiff products. The standing pressure can be taken as a snapshot of the pressure course during walking and there is an excellent correlation with the peak values.[14] The magnitude of the pressure fluctuations during walking, “Walking pressure amplitudes (WPA)”, characterize the massaging effect which occurs during exercise, leading to an intermittent compression of the veins. As shown in Figure 4 there is a significant correlation between WPA and the percent increase of EF investigated in normal individuals with compression materials of different stiffness.
Concerning practical application wrapping the calf region by an inelastic Velcro band could be handled by the sports people themselves and the tightness during application could left to their personal feelings.

CONFLICT OF INTEREST

Sport stockings and Velcro straps were provided by medi Bayreuth.

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