Brief Report

Elasticity, hysteresis and stiffness: the magic triangle

H.A. Martino Neumann

Department of Dermatology, Erasmus MC University Medical Center, Rotterdam, The Netherlands

Abstract

The use of external compression on the human leg is still a cornerstone in the treatment of venous diseases. The most important question to answer is: how will compression perform on the human leg?

Introduction

First of all the applied compression generated by a device as a medical elastic compression stocking (MECS), bandage or whatever is used, exerts its pressure on the surface of the leg, *e.g.* the skin. Normally this is expressed as interface pressure and the shape of the leg pressure differences are depending on Laplace low. Second step is the transmission of this interface pressure into the tissue as the subcutaneous fat, muscles, and veins. This process depends on Pascal law. The third item is the pressure changes during walking depending on the circumference chances of the leg (Laplace law) and, fourth, the durability of the pressure in time, which depends on the quality of the device.

For a long time research was focused on interface pressure, usually under static conditions and pressure course in time.[1]

The quality of compression capacity of a given device is depending on the characteristics of the used materials. All used materials for medical compression therapy have three major characteristics: i) *elasticity*, which is the capacity to return to the original shape and size after the material has been stretched. The pressure/elasticity relation under static condition on the leg is influenced by Laplace law; ii) *stiffness or elasticity coefficient*; this term is defined as the increase in pressure after a certain given elongation. For MECS the Centre Européenne de Normalisation uses the increase of the normal tension at the B1 level with 1 cm expressed in hpa. Stiffness is depending on elasticity in static condition; iii) *hysteresis*, which reflects the inborn resistance of material as result of internal friction hysteresis, can be visualized in a force/elongation curve (Figure 1A). By increasing the speed to perform such a fair elongation curve the angle towards the x-axis will move. So hysteresis is influenced by the speed of movements (Figure 1B).[2]

These three characteristics works all together in compression therapy (Figure 2). As normally compression is only expressed as interface pressure we are not informed about the contribution of stiffness, hysteresis and changes during walking. In fact we only know the resting pressure which is far away from the reality of a walking patient with a compression device as a MECS. To overcome this problem we defined the dynamic stiffness index

Correspondence: H.A. Martino Neumann, Dermatologie en Venereologie, Erasmus MC University Medical Center, Rotterdam, The Netherlands.
E-mail: h.neumann@erasmusmc.nl

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(DSI).[3] Analyzing the differences between static and dynamic compression it turns out that hysteresis is the most important factor. Our triangle can be changed from static (Figure 2) into dynamic (Figure 3) where hysteresis plays the main role.

As pressure diminishes in time static compression will become ineffective during the day. However DSI remains in the same time (Figure 4).[4] For MECS, DSI is independent from compression pressure (class) and manufacturing differences as round- and flat knitted.[5] The clinical implication of DSI is that low

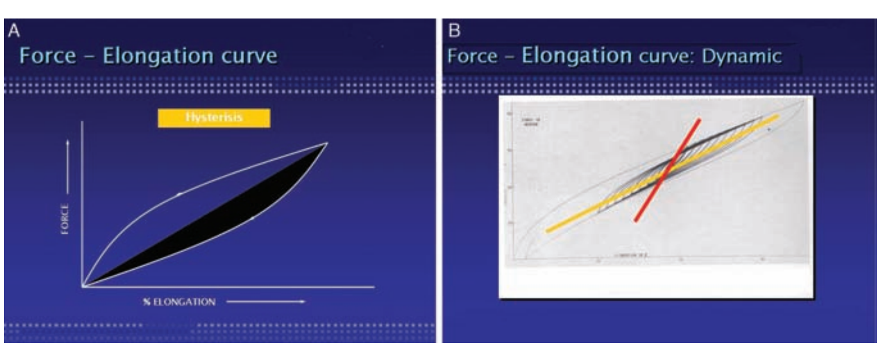

Figure 1. A) *Hysteresis curve* of an elastic fabric: X-axis represents stretch, y-axis the applied force; B) force elongation curve of elastic knitwear. The elongation increments are progressively made larger. The steepness of the initially small cycle is diminished with the increased amplitude (modified from Stolk and Salz, 1988[2] with permission).

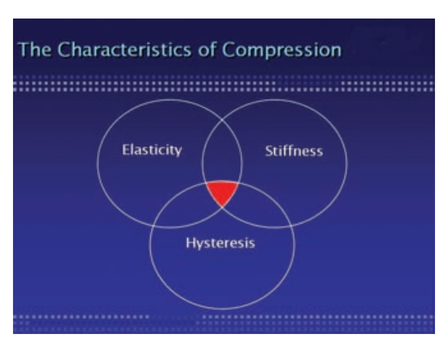

Figure 2. The magic triangle, static.

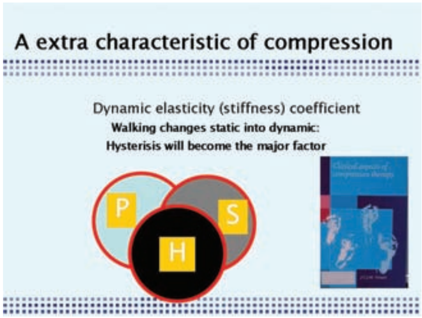

Figure 3. Dynamic relation between pressure, stiffness and hysteresis.

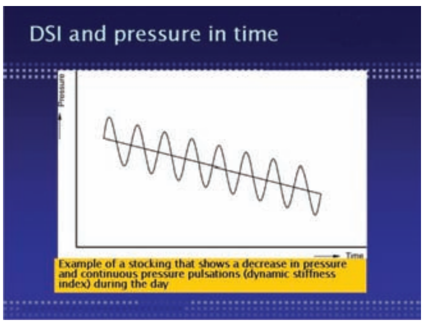

Figure 4. In spite of decreasing pressure of a stocking, stiffness is maintained (modified from Van der Wegen *et al.*, 2009[4] with permission).

compression and high DSI can be very efficient for ambulatory patients and have the same effect as high compression with low DSI. To combine compression and DSI the physician can prescribe the optimal device, *e.g.* MECS for the patient. As logical consequence the higher changes of interface pressure during walking will be transferred to the tissue resulting in a high massage effect and by this the effects of Laplace and Pascal law comes together.

Conclusions

In order to optimize venous function with compression therapy, three key-points should be considered: i) *hysteresis*, mainly influenced by the type of knitwear determines the efficacy of compression force elongation relation; ii) the quality of compression (Laplace law) defined by DSI; iii) the final effect of compression (Pascal law) defined by the composition of the subcutaneous tissue. For daily practice: DSI is the most important characteristic of compression.

References

1. Veraart JCJM, Daamen E, Neumann HAM. Short stretch versus elastic bandages: effect of time and walking. Phlebology 1997;26:19-24.
2. Stolk R, Salz P. A quick pressure-determining device for medical stockings based on the determination of the counter-pressure of air- filled leg-segments. Swiss Med 1988;10:91-6.
3. Stolk R, van der Wegen-Franken CPM, Neumann HAM. A method for measuring the dynamic behaviour of medical compression hosiery during walking. Dermatol Surg 2004;30:729-73.
4. Van der Wegen CPM, Tank B, Nijsten T, Neumann HAM. Changes in the pressure and the dynamic stiffness index of medical elastic compression stockings after having been worn for eight hours: a pilot study. Phlebology 2009;24:31-7.
5. Van der Wegen-Franken CPM, Tank B, Neumann HAM. Correlation between the static and dynamic stiffness indices of medical elastic compression stockings. Dermatol Surg 2008;34:1477-85.