Stiffness of compression devices

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This issue of *Veins and Lymphatics* collects papers coming from the *International Compression Club (ICC) Meeting on Stiffness of Compression Devices*, which took place in Vienna on May 2012.

Several studies have demonstrated that the stiffness of compression products plays a major role for their hemodynamic efficacy. According to the European Committee for Standardization (CEN), *stiffness* is defined as the pressure increase produced by medical compression hosiery (MCH) per 1 cm of increase in leg circumference.[1] In other words stiffness could be defined as the ability of the bandage/stockings to oppose the muscle expansion during contraction.

Measurements of stiffness are performed in textile laboratories using different extensometers. However, up to now pressure ranges are declared only for compression stockings; no pressure ranges can be declared for bandages as the exerted pressure depends on the stretch applied to the bandages, number of layers and leg configuration. Information concerning stiffness is not given either for elastic stockings or for bandages.

In vivo experiments have offered useful surrogate data. The leg circumference increases when moving from the supine to the standing position and during muscle activities.[2-4]

To assess stiffness according to CEN definition, it would be necessary to measure the increase of compression pressure and of leg circumference simultaneously, requiring a pressure measurement device and a strain gauge plethysmograph. In order to simplify the stiffness calculation it has been proposed to assume that the increase of leg-circumference, moving from lying to standing position, is always 1 cm. In this case the so-called static stiffness index (SSI) could simply be calculated by subtracting the supine from the standing pressure.[5] A comparison between the two measuring systems of stiffness (the first including the measurement of the leg circumference increase and the second just calculating SSI) was performed showing the same sensitivity and specificity in distinguishing between elastic and inelastic systems.[2] The conclusion of this comparison clarified that SSI is an effective method to calculate stiffness and that more complex measurements do not give more information.

Nevertheless the assessment of stiffness *in vivo*, as recommended in a previous consensus meeting of the ICC,[6] came under some criticism. Despite the fact that SSI is basically able to differentiate the elastic properties of MCH, a great variability among different patients could be a major issue. This variability depends on the fact that some other variables play a role in SSI calculation in addition to elastic properties of material: the leg position during measurements, the configuration and consistency at the measuring site of the leg, the individual muscle strength, the presence of fat and others.[7]

A new standardized method to measure the stiffness on a mannequin leg was reported[8] which presents the advantages to be simple, highly reproducible, easily available and cheap. If this method will be widely adopted, it would also be possible to avoid that every company producing MCH measure stiffness with different systems thereby increasing the confusion. In order to differentiate between measurement *in vivo* and in laboratory (lab) the so called *in vitro* measurement, it was proposed to name the *in vitro* calculation not anymore stiffness *in vitro,* but resistance.[9] Regarding the measuring site on the leg, the B1 point described in the ICC consensus paper[6] was brilliantly confirmed as the most suitable site for stiffness measurement.[10]

Stiffness, together with pressure and hysteresis,[11] is an important parameter for effectiveness combined with comfort of MCH. Neumann's paper rises two important points.[11] One is the relevance of another indicator of stiffness the so-called dynamic stiffness index (DSI) requiring complex measuring systems. Nevertheless, an excellent correlation between SSI and DSI could be shown by using this lab equipment[12] but also *in vivo* during muscle exercise.[2,13] This supports the idea that *in vivo* testing is a valuable tool for assessing the elastic properties especially in connection with clinical effectiveness of compression devices. The second point is the importance of the hysteresis of different compression materials. Hysteresis can be measured only in the lab and remains something *obscure* for the clinicians whereas they should receive full information by companies on this parameter.

An ideal compression device should exert a low, comfortable pressure during rest, with a strong or very strong pressure[14] during standing and working in order to counteract ambulatory venous hypertension (effective). Such a device would have a very high SSI but, unfortunately, it doesn't exist yet. Inelastic material presenting high stiffness comes close to an ideal compression device;[15] especially when pressure decreases after some hours from application in the supine position, the difference between standing and supine pressure is very high exerting an effective massaging effect on the leg during walking and improving significantly the hemodynamic impairment of chronic venous insufficiency. Elastic material, exerting a sustained pressure, not very different between supine and standing position or during muscle exercise, shows a small improvement on the impaired venous hemodynamics which is always significantly smaller than that from inelastic material.[16,17]

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Actually stiff materials exerting strong or very strong pressure showed to be clinically effective in ulcer treatment[16,18,19] when a significant impact on venous hemodynamics is very important and also in lymphoedema.[20]

Pressure and stiffness can be critically reduced in some areas of the leg with concave rather than convex shape as this is the case in the retro-malleolar space. Unfortunately this is a critical area where often venous ulcers occur. It has been shown that in this region the pressure as well as stiffness can be close to zero as the pressure doesn't increase in standing position or during muscle activity. Pressure and stiffness in these areas can be significantly increased by applying local compression straps[21] which greatly improve the clinical outcome.[22] An increase of pressure and stiffness can be achieved also at thigh level by means of eccentric devices, which are able to compress the thigh veins otherwise difficult to compress.[23] In this region higher pressure and stiffness leads to better outcome following surgical or endovascular procedures on the great saphenous vein.[24,25]

In conclusion it is important to realize that stiffness can be mainly considered as a surrogate indicator of comfort and effectiveness. The higher the stiffness the greater comfort and effectiveness in improving the clinical outcomes. Stiffness is very high only with inelastic material, or multilayer systems and can be enhanced by straps applied in a fan distribution or by eccentric compression devices in the leg segment that need to be treated.

In vivo measurement techniques must be better defined in order to minimize the variability; a parallel match with the lab assessments is a mandatory target for future researches. Only in this way the stiffness effective value will scientifically demonstrate to correspond to the great impact that already empirically presents in our everyday clinical practice.

References

1. European Committee for Standardization (CEN). Non active medical devices. Working Group 2 ENV 12718: European Pre-standard 'Medical Compression Hosiery.' CEN TC 205. Brussels: CEN; 2001.
2. Mosti G, Mattaliano V. Simultaneous changes of leg circumference and interface pressure under different compression bandages. Eur J Vasc Endovasc Surg 2007;33:476-82.
3. Stolk R, Wengen Van Der-Franken CPM, Neumann HAM. A method for measuring the dynamic behaviour of medical compression hosiery during walking. Dermatol Surg 2004;30:729-36.
4. Wienert V, Hansen R. Anmessen von medizinischen kompressionsstrümpfen am liegenden oder am stehenden patienten? Phlebologie 1992;21:236-8.
5. Partsch H. The static stiffness index: a simple method to assess the elastic property of compression material in vivo. Dermatol Surg 2005;31:625-30.
6. Partsch H, Clark M, Bassez S, et al. Measurement of lower leg compression in vivo: reccommendations for the performance of measurements of interface pressure and stiffness. Dermatol Surg 2006;32:224-33.
7. Schuren J, Bichel J. Sub-bandage dynamics: stiffness unraveled. Veins and Lymphatics 2013;2:e2.
8. Hirai M, Partsch H. The Mannequin-leg: a new instrument to assess stiffness of compression materials. Veins and Lymphatics 2013;2:e3.
9. Cornu-Thénard A, Benigni J-P, Uhl J-F. Terminology: resistance or stiffness for medical compression stockings? Veins and Lymphatics 2013;2:e4.
10. Uhl J-F, Benigni J-P, Cornu-Thénard A. Where should be stiffness measured in vivo? Veins and Lymphatics 2013;2:e5.
11. Neumann HAM. Elasticity, hysteresis and stiffness: the magic triangle. Veins and Lymphatics 2013;2:e6.
12. van der Wegen-Franken K, Tank B, Neumann M. Correlation between the static and dynamic stiffness indices of medical elastic compression stockings. Dermatol Surg 2008;34:1477-85.
13. Mosti G, Mattaliano V, Partsch H. Inelastic compression increases venous ejection fraction more than elastic bandages in patients with superficial venous reflux. Phlebology 2008;23:287-94.
14. Partsch H, Clark M, Mosti G, et al. Classification of compression bandages: practical aspects. Dermatol Surg 2008;34:600-9.
15. Andriessen A, Abel M. Experimental study on efficacy of compression systems with a high static stiffness index for treatment of venous ulcer patients. Veins and Lymphatics 2013;2:e8.
16. Mosti G. Relevance of stiffness of compression material on venous hemodynamics and edema. Veins and Lymphatics 2013;2:e9.
17. Bender DJ, Fronek H, Arkans E. Quantified hemodynamics of compression garments. Veins and Lymphatics 2013;2:e10.
18. Wong IK, Andriessen A, Lee DT, et al. Randomized controlled trial comparing treatment outcome of two compression bandaging systems and standard care without compression in patients with venous leg ulcers. J Vasc Surg 2012;55:1376-85.
19. Mosti G, Crespi A, Mattaliano V. Comparison between a new, two-component compression system with zinc paste bandages for leg ulcer healing: a prospective, multicenter, randomized, controlled trial monitoring sub-bandage pressures. Wounds 2011;23:126-34.
20. Schingale F-J, Partsch H. Alginate hydrocolloid impregnated zinc paste bandages-an alternative in the management of lymphoedema? Veins and Lymphatics 2013;2:e11.
21. Hopkins A, Worboys F, Partsch H. The use of strapping to increase local pressure: reporting of a sub-bandage pressure study. Veins and Lymphatics 2013;2:e12.
22. Hopkins A, Worboys F, Bull R, Farrelly I. Compression strapping: the development of a novel compression technique to enhance compression therapy and healing for 'hard-to-heal' leg ulcers. Int Wound J 2011;8:474-83.
23. Partsch H, Mosti G, Mosti F. Narrowing of leg veins under compression demonstrated by magnetic resonance imaging (MRI). Int Angiol 2010;29:408-10.
24. Mosti G, Mattaliano V, Arleo S, Partsch H. Thigh compression after great saphenous surgery is more effective with high pressure. Int Angiol 2009;28:274-80.
25. Lugli M, Cogo A, Guerzoni S, et al. Effects of eccentric compression by a crossed-tape technique after endovenous laser ablation of the great saphenous vein: a randomized study. Phlebology 2009;24:151-6.