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Assessment of Graduated Compression Stockings: Variation in Fabric Properties Among Different Sizes

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Background. Graduated compression stockings (GCS), one of the essential compression therapy modalities, have been widely used for the prophylaxis and treatment of varicose veins, swelling, deep vein thrombosis, lymphedema, etc., by providing controlled pressure on the lower leg extremities (Sachdeva et al., 2018; Liu et al., 2007). GCS, when fitted and used properly, increase blood flow velocity, and may reduce coagulability, leading to reduced risk of venous thrombosis (Muñoz-Figueroa & Ojo, 2015). These types of stockings are developed in various lengths, generally called 'thigh-length' and 'knee-length', and allow for mobility and some aesthetic expression, but sizing is available in limited standardized choices, often leading to uncomfortable and inefficient pressure on the legs (Mota et al., 2020). The pressures are determined and specified by the manufacturer, based on laboratory measurements, but there is no single standard used worldwide, causing confusion among healthcare providers and patients. In general, low compression refers to pressure on the leg of less than 20mmHg, medium compression is 20-30mmHg; and high compression is greater than 30 mmHg (Wienert et al., 2008). Knee-length GCS have been found to be more efficient than thigh-length, and many patients need to wear the GCS for four to six weeks after hospital discharge (Winslow & Brosz, 2008). The researchers agree that there is some evidence that high compression knee-length GCS may be more efficacious than those with moderate compression (Ziaja et al., 2011). However, the designation of pressure depends on the GCS sizing system.

Medical providers rely on the manufacturer specifications in recommending appropriate sizing and compression level GCS. The overall pressure applied to the legs is affected by factors such as the elasticity and stiffness of GCS material, the size and shape of the wearer's legs, and the movements and activities of the wearer (Lim &Davies, 2007; Liu et al., 2006). In most of the existing studies relating to GCS, the emphasis was placed on how the elasticity property (or stretch ability) of stocking fabric affects the pressure magnitudes or the efficacy of compression treatment (Liu et al., 2006). Few studies investigated the variations of material attributes of GCS between ankle to calf regions, which considerably alter the corresponding pressure gradient distributions. Therefore, the purpose of this study was to investigate the physical properties of one size range (S-XXL) of a commercial brand of medical grade GCS and determine how does the material properties change between sock sizes between ankle and calf areas. Understanding these differences could help GCS manufacturers improve their sizing design process, resulting in more consistent pressure properties across sock sizes, and better therapeutic and recovery patient experience.

Method. One pair of a complete size range (S-XXL) of knee-length medical grade GCS were purchased from a reputed domestic manufacturer. The medium compression GCS were made of 90%bamboo 10%spandex, with a pressure range of 20-30mmHg, knitted on Lonati 240N circular sock machine. Yarns used for knitting were 30/1 natural color bamboo plaited with 40/1/70/34 white spandex, and 420D 1/70/34 white spandex for welt/body/foot. After knitting, the socks were board size finished to set the shape and shrink the spandex.

Fabric swatches for testing were cut directly from each sock of each size, after splitting all socks along the back heel from welt to toes. The two levels of interest, the calf and ankle, were marked on all socks, then air permeability, fabric thickness, weight, and density measurements were performed in the marked areas. For elongation till breakage measurements, the sock pair size S was divided into

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five rectangular strips 160mm long, between top of calf and bottom of ankle areas, and the resulting width (50mm) was used to cut the same width strips from all other sock sizes. All assessments were conducted in a laboratory with strictly controlled environmental temperature, and fabric swatches were conditioned for 24 hrs at (21 ± 1) ºC and relatively humidity of (65 ±2) % (ASTM D1776 – 04). ASTM and AATCC standard methods were used for all textile testing. SPSS software and ANOVA were used to evaluate the effect of 'SockSize' and Level ('Ankle' and 'Calf') on all dependent variables. For all statistical analyses, $p < 0.05$ was considered significant.

Results and discussion. Mean weight for all fabrics was 4.78mm (SD=0.1). There were significant differences in fabric thickness among the different sock levels, with thickness increasing from sizes S to M to L, but then decreasing for XL and significantly increasing to XXL. All sizes were thicker at Calf than Ankle levels, a fact explained by the 3D geometry of increased knit stitch loops at Calf level versus Ankle level. The main effect of Level was statistically significant for fabric density (Mean= 857, SD= 131.2), but the main effect of SockSize and the interaction effect between SockSize and Level were not statistically significant. The mean density was consistently higher at the Ankle level than Calf for all sizes, but sizes XL and XXL had much lower density at Ankle than Calf level. Since the sock yarns are plaited with spandex, a lower fabric density at Calf level for XL and XXL suggest a lower spandex content in this area, which would lead to lower pressures on the leg compared with the other sizes.

Mean elongation was 319.5% (SD= 17.16) and mean force was 31.17N (SD=2.92). No significant effect of SockSize on elongation was found, but a significant effect of SockSize on the Force used to achieve the elongation till breakage was reported. The adjusted R-square suggested that SockSize accounts for approximately 68% of the variance in the breaking force. Force gradually decreased from size S to size XXL, a fact that can be explained by the lower yarn content of larger sizes as suggested by the lower densities (mean fabric density decreased from sizes S to XXL). The interaction between SockSize and Level had a significant effect on air permeability. There was no significant effect within the Ankle level, but there was a significant effect within the Calf level. The following pairwise mean differences in air permeability values were found to be significant at the Calf level: XXL and all sizes, XL and M, XL and L. Mean air permeability values were higher at Calf versus Ankle level for all sizes except XXL. This fact can be explained by the use of larger knit stitch loop sizes at Calf to achieve increased sock diameter versus at Ankle levels. There was much more variation in air permeability at Calf level across sizes than Ankle level. Higher air permeability can also be explained by the larger knit stitch loops at Calf levels, which help achieve lower pressures on the Calf versus at Ankle, a desired property of GCS. However, the Calf pressures should be consistent between sizes, and these findings show that, based on the inconsistent variations of density, thickness, breaking force and air permeability, the pressures can be predicted as inconsistent for sizes XL and XXL versus the smaller sizes, S, M and L.

Significance. The results of this study highlight the inconsistent fabric properties across a size range of medical grade GCS, with the larger sizes having potentially lower pressures on the leg than the smaller sizes. A follow up study will be conducted on verifying the pressures on the leg of this size range, aiming at improving medical recommendations of GCS for patients seeking faster post-surgery recovery or prophylactic treatment of lower leg circulatory problems. This study adds to the scientific body of knowledge regarding the GCS and their material properties, broadening the researchers' expertise on compressive apparel and functional apparel design.

References

ASTM (2004) ASTM D1776-04. Standard Practice for Conditioning and Testing Textiles. *American Society for Testing and Materials*, Pennsylvania.

Liu, R., Kwok, Y. L., Li, Y., Lao, T. T., & Zhang, X. (2007). Quantitative assessment of relationship between pressure performances and material mechanical properties of medical graduated compression stockings. *Journal of Applied Polymer Science*, *104*(1), 601-610.

Lim, C. S., & Davies, A. H. (2014). Graduated compression stockings. *Canadian Medical Association Journal*, *186*(10), E391-E398.

Mota, G. R., Simim, M. A. D. M., Dos Santos, I. A., Sasaki, J. E., & Marocolo, M. (2020). Effects of wearing compression stockings on exercise performance and associated indicators: a systematic review. *Journal of Sports Medicine*, 29-42.

Muñoz-Figueroa, G. P., & Ojo, O. (2015). Venous thromboembolism: use of graduated compression stockings. *British Journal of Nursing, 24(*13), 680-685.

Sachdeva, A., Dalton, M., & Lees, T. (2018). Graduated compression stockings for prevention of deep vein thrombosis. *Cochrane Database of Systematic Reviews*, (11).

Wienert, V., Gerlach, H., Gallenkemper, G., Kahle, B., Marshall, M., Rabe, E., ... & Zabel, M. (2008). Medical compression stocking (MCS). *Journal der Deutschen Dermatologischen Gesellschaft, 6*(5), 410-415.

Winslow, E. H., & Brosz, D. L. (2008). Graduated compression stockings in hospitalized postoperative patients: correctness of usage and size. *The American Journal of Nursing*, *108*(9), 40-50.

Ziaja, D., Kocełak, P., Chudek, J., & Ziaja, K. (2011). Compliance with compression stockings in patients with chronic venous disorders. *Phlebology*, *26*(8), 353-360.