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THE EFFECT OF COMPRESSION STOCKING ON LEGS` GEOMETRY CHANGES WITHIN DIFFERENT MOVEMENT

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Abstract: *In this study, the changes in leg size and shape as well as pressure at different sites of a lower leg were investigated using advanced tools such as the Move4D scan system and Texsens pressure measuring device. The effect of the class of compression stocking, wearing time, and movement type was analyzed for a few volunteers. It is the basis for the high-accuracy ready-to-wear compression stocking development based on the concept of personalization.*

Keywords: *compression stocking, 4D body scanning, lower leg, body size and shape, dynamic position*

1 INTRODUCTION

The demand for compression clothing and rehabilitation goods increases every year. Today`s market for compression products is not limited to medical applications. They are widely used in sports and everyday life. With the improvement of human needs and the development of technology, more and more attentions are paid to the comfort and quality of the products used. Particular emphasis in this matter is on the items and products that can help maintain health levels.
Simultaneously ensuring the necessary functional properties, namely the pressure level at different areas, and high levels of comfort of the compression clothing is problematic within the mass production of the products of standard sizes. On the other side, the emerging technologies in the textile industry as 4D scanning [1], 3D design [2], and CAD systems enable manufacturers to produce bespoke textiles on demand.
Investigation of the geometry changes of body legs with compression stocking in the static position [3] showed that 3-4D scanning allows the quick estimation of the compression clothes functionality and it can be a promising means for assessing the dimensional changes of the body parts.
This research aims to study the changes in sizes and shapes of the lower legs within the wearing time of compression stockings and different activities as well as changes in pressure that occurred at the same time. The research results are the basis for the development of a tool for high-accuracy ready-to-wear compression garment design.

2 MATERIALS AND METHODS

Conventional 40 den stockings and two classes of compression stockings (I CCl and II CCl) of size 3 [4] of the same manufacturer were used. The persons did their usual ruining activity between measurements.
The MOVE 4D system from Valencia Polytechnic University at ITM TU Dresden was used for the investigation of the changes in the size and shape of the lower legs. Two following movements were performed: stepping and bending over. The scanning time for each movement was 4 seconds with a frequency of 15 frames per sec (Fig. 1). Scans were made for the control leg and within stocking wearing: just after putting on stockings (0 hour) and after wearing time of 1 and 4 hours.

a b

Figure 1 Example of a scan captions during stepping: a – without stockings' b – with II class stockings

The slicing of the legs scans and data transfer were done by ParaView 5.11.0, and MeshLab 2022.02 was used for the planar section, area and circumference measurements. The left and right legs were studied separately.
The texsens force and pressure measuring device developed by novel.de were used for pressure investigation. Measurement time was 60 sec (1 min) with 0.02 sec frequency. The measurements were done at different levels just after putting on stockings (0 hour) and after the first and fourth hours of wearing during all activities.

3 RESULTS AND DISCUSSION

The research was conducted in a few steps. Firstly, the leg shapes and sizes of the three volunteers as well as their changes over time were studied in static position. The values of existing changes at three levels were calculated and analyzed. The volunteers' legs despite the same recommended stocking size differ in both the leg`s shape and the swelling level. Then, the effect of compression stocking was studied in a static position. It was found that I CCl stocking fits for the second volunteer and II CCl stocking fits for the others. After that, the lower legs` sizes within the wearing time of compression stockings and different activities (stepping and bending over) as well as occurred pressure were measured and analyzed.

3.1 Lower leg`s size

An example of measurements is presented in Figure 2. The differences in the left and right legs are observed. The right leg is thicker by 1 cm in circumference. The changes in legs` size during bend-over are within 1 cm for the right leg and 0.7 cm for the left leg. Both legs are swelling but the right leg swells more which is clear when comparing the control leg with the leg after 4 hours.

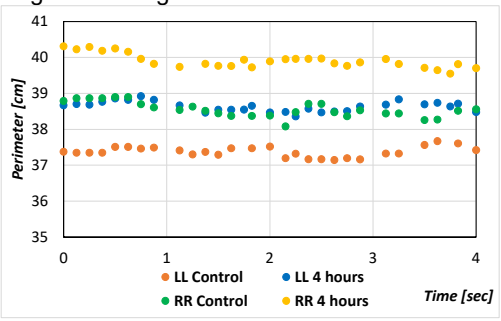


Figure 2 Legs circumference for the second volunteer within bending over

The research results for changes in the leg`s area at 30 cm level for one of the volunteers are presented in Table 1. The leg size and shape change not only over time but during different activities as well.

Table 1 Left leg area (mean value) at 30 cm site for the first volunteer

Acti-vity	Time	I Class		II Class	
		S [cm²]	Δ [%]	S [cm²]	Δ [%]
Static posi-tion	control	117	-	125	-
	0 hour	117	0	116	-7.6
	1 hour	124	5.5	121	-3.4
	4 hours	125	6.8	120	-4.3
Step	control	119	-	121	-
	0 hour	118	-1.1	116	-4.2
	1 hour	124	3.7	121	-0.3
	4 hours	127	5.9	122	0.7
Bend over	control	117	-	122	-
	0 hour	116	-1.3	115	-5.7
	1 hour	121	3.8	119	-2.5
	4 hours	122	4.3	121	-0.8

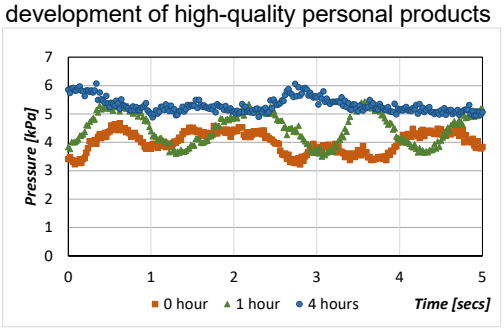
The 4D scanning data gives a possibility for a quick comparison of the legs. The evaluation can be done not only by leg circumference and area at certain sites but by the cross-sectional contours as well.

3.2 Pressure value

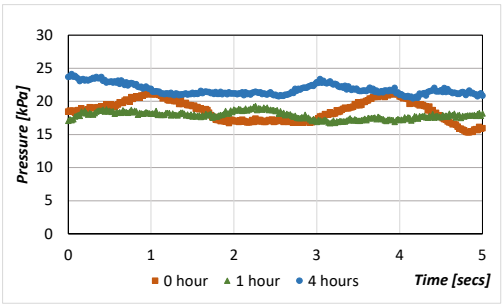
The change in the leg`s size leads to changes in stocking pressure on a lower limb. As we can see in Figure 3.a the pressure during bend over with 1 CCl stocking was from 3.2 to 4.5 kPa just after stocking wearing and in the 3.9-5.2 kPa range within 1 hour of wearing. The pressure rose to 5-6 kPa (over 50% increase) after 4 hours of wearing due to leg swelling.

The II CCl stocking with a higher level (17-22kPa) of delivered pressure keeps it more stable (Figure 3.b). The changes in pressure during bend over just after stocking wearing was within 5 kPa but after 1 hour of wearing it was only 2 kPa with similar mean values. After 4 hours of wearing the pressure goes up but an increase is not more than 20%.

The plots in Figures 2 and 3 show similarity in tendencies thus 4D scan data can be used for the evaluation of compression stocking performance for certain persons and future development of high-quality personal products



a



b

Figure 3 Pressure at 30 cm level within bending over for compression stockings: a – I CCl; b – II CCl

4 CONCLUSION

The conducted research has shown a correlation between the leg size (circumferences and areas) and the pressure level delivered by compression stockings. The study results for three volunteers with stockings of two compression classes within wearing time and different activity is the basis for future customization of compression stocking for individual body geometry.

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