EFFECT OF MULTIPLE USE ON THE DURABILITY OF COMPRESSION SOCKS

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Abstract: *Compression socks are widely used for medical purposes. The socks are classified as three pressure classes with different sizes according to circumference of leg. These socks are daily worn for complete and due to hygiene issues it's washed every day as well. The research work shows the effect of washing and multiple wearing on the durability of compression socks. There is significant decrease of pressure in terms multiple wearing and there was insignificant difference from the washing cycles. The results are beneficial for the patient who regularly uses the compression socks.*

Keywords: *socks, compression socks, pressure.*

1 INTRODUCTION

Compression socks are the widely used textile garment for pressure exertion on the lower part of the leg. It is used to reduce venous hyper pressure [1].

Working principle is lowering of pressure exertion from ankle to calf portion of the leg. The pressure exertion value should be highest at the ankle that must gradually decrease along the direction of the leg. This varying degree of compression pressure propagate and regulate blood flow, keep the muscles in-line at the right position to mitigate the injury risk, gives relief to many of chronic venous disease patients and used for therapeutic purposes [2, 3].

The intensity of compression pressure used for various diseases is categorized as moderate up to (20-30 mmHg) and firm compression (30-40 mmHg). This extent of pressure is decided and recommended to treat circulatory and vascular medical conditions as well for tired, sore, swollen, or aching legs [4-7].

Textile durability is the measure of textile ability to resist mechanical and chemical influences, that they are exposed during their manufacturing and subsequent using. It is determined by the length of time that a textile is able to maintain its innate characteristic, like strength, dimension and appearance, in use. This time may vary depending on the environment, the amount and degree of use and the user's judgment about the durability. Interpretation of textile durability has considerably changed over years. For example, hundred years ago, textiles were relatively expensive, so they were intensively used and repaired. Nowadays, textiles are much cheaper and customer more often prefers a buy of a new product than a repair of old one, which substantially influences the durability [8].

Performance and characteristics of textile materials are determined by their manufacture, i.e. the type of used fibers, yarn, fabric structure and finishing treatments. Generally, knitted textiles are less stable in use than woven textiles. This is caused by the fact they are produced from low twist yarns, and have a slack construction. So, knitted fabrics tend to deform easily under a fairly low degree of tension [12-16].

Devices used for measuring interface pressure

The most commonly used device for measuring compression pressure in industry is HATRA, which is required for measuring MCS (medical compression socks) by British standards, and HOSY device, required by German standard RAL GZ 387 [9-11].

HATRA device, with two metal bars, simulates a simplified leg shape onto the stockings are stretched. Moveable is just the top bar while the lower bar is fixed and has two curved attachments that are used to simulate calf or thigh. Holders for the top edge of stockings are also available in different sizes (i.e. thigh-high length, knee-high length, etc.). After the garment is placed on the leg form, a measurement is made by simultaneously stretching the stocking both length and width ways on the dimensions which simulate its wearing. The measurement head force element is brought into contact with the stocking at the place marked for measuring. When pressed against the material, the device counts pressure acting on the sensor [9-11].

The *HOSY* utilizes system of twenty tensile tester devices, where each is 5 cm wide. The measured stocking of any shape is clamped in these tester devices and measure without destroying. Upper gripping system is fixed, while the lower gripping system is moveable, and stretches clamped stocking at the specified length to the specified width, simulating its wearing. When it is stretched to the destined dimension, the force needed to stretch the stocking in the circumferential direction is measured. Based on these values an amount of applied pressure on the body is determined. In addition to interface pressure, it can measure elongation, tensile force, and residual pressure [9-11].

MST (medical stocking tester) consists of a flat, air-filled sleeve, connected to the pressure sensor. This sleeve is inserted between measured stocking and the leg or a leg form. Due to its low profile, there are no bulges on the stocking which would result in an inaccurate measurement, and the pressure can be registered at different height levels. The MST has been developed over the years, and while the earlier versions used a wooden leg form required to be changed to test different sized stockings, the current version can be used for quality control in production or laboratory environments, as well as on patients in the hospital environment [9-11].

Kikuhime device represents one of the easiest methods to measure compression pressure of MCS directly on the body. It is a portable monitoring device, consists of an oval polyurethane balloon sensor containing a 3 mm thick foam sheet, and this is connected to a syringe and a measuring unit. When is the sensor placed between the leg and the compression stockings, the transducer monitors the pressure experienced by the balloon and the pressure value is converted to mmHg and shown on the digital display [9-11].

Dimensional stability of textiles is the ability to keep its original dimensions during and after the manufacturing process and when it is in use by the customer. Knitted textiles can exhibit either reversible or irreversible shrinkage (i.e. dimensional decrease) or, growth (i.e. dimensional increase). Several factors affecting the change in dimensions of a knitted fabric exist: fiber characteristics, stitch length, machine gauge, yarn twist, yarn count, knitting tension, type of machine, type of needle, type of fabric, the method of relaxation procedure, the method of washing, finishing, drying, etc. Not all of those factors have such a major influence on fabric shrinkage, but the most responsible is the relaxation of internal stress imposed on the yarn during the knitting process [8].

Knitted fabrics have more than any other textiles tendency to dimensional instability and spontaneous changes. Already, in the knitting process is a fabric in unstable shape. When knitted textile is drawn-off, it shrinks in wales direction and the geometrical parameters are changed. After taking-off from the machine and removing strain, a fabric gets into a dry relaxation (relatively stable shape). After laundering, especially after multiple laundering is a fabric most approaching the state of complete relaxation (state with minimum of internal deformation energy and with the lowest tendency to change dimensions). Subsequent drying process must be without any mechanical stresses, it means lying, because when a knit is hanging, there is a tension leads again to the deformation and dimensional changes.

2 MATERIALS AND METHODS

The samples of socks are selected according to pressure classes, following is the detail of the standard pressure class of medical compression socks.

Table 1 Compression classes according RAL GZ 387

Compression class	Compression intensity	Compression in kPa[1)]	Compression in mmHg[2)]
I	Low	2.4 to 2.8	18 to 21
II	Moderate	3.1 to 4.3	23 to 32
III	High	4.5 to 6.1	34 to 46

1) 1 kPa = 7.5 mmHg; 2) 1 mmHg = 0.133 kPa

Three socks with similar composition and material are selected for Class 1, 2, and 3 for the standard leg circumference of 23-26 cm. the details are mentioned in Table 2.

The standard wooden leg with circumference of 24 cm from the Swiss company is selected for the experiment all the measurements of pressure are done on the ankle position.

Table 2 Specifications of MCS samples

Sample identification	Compression class	Structure	Composition	Manufacturer (Country)	Circumference [cm]
AI	CCLI/Light	Rib	60% polyamide, 40% elastane	Varitex (Netherlands)	23 - 26
BII	CCLII/Medium	Plain/Single Jersey	60% polyamide, 40% elastane	Varitex (Netherlands)	23 - 26
CIII	CCLIII/High	Plain/Single Jersey	60% Tactel/polyamide, 40% Lycra/elastane	Aries (Czech Republic)	23 - 26

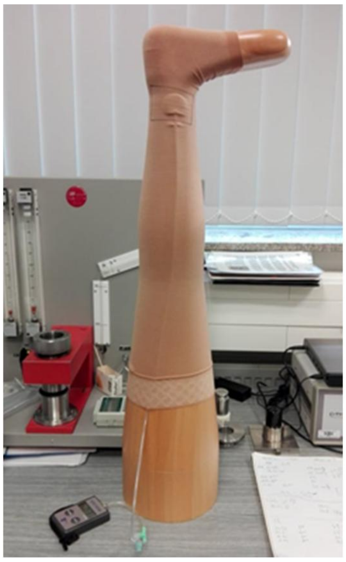

Figure 1 Placement of the pressure sensor on leg

Fabric thickness is measured as the perpendicular distance between the two fabric surfaces under a specified applied pressure. For fabric thickness determination SDL M034A device was used. The measuring was done according the standard ČSN EN ISO 5084 (80 0844). The standard specifies applied pressure 1 000 Pa, size of the pressure head 20 cm^2 and sample load 200 g. Measurement, the same as results, are recorded by computer. Ten measurements of material thickness were performed on each sock. Further properties of the socks are listed in Table 3.

Compression Pressure Measurement

Pressure measurement of socks was performed at the ankle level, the point where the Achilles tendon changes into the calf muscles. As literature shows, this is the area of socks that has to keep the biggest pressure and has to withstand largest differences in the circumference during its wearing. Pressure measurements were performed with using a standardized leg. For measuring the pressure exerted by stocking on the surface of wooden leg a Kikuhime device was used. To measure with Kikuhime, it needs to be calibrated after turning on, and then insert sensor between the surface of plastic leg and stocking.

Table 3 List of stitch density and thickness of socks

Sample identification	Wale density [Loops/cm]	Course density [Loops/cm]	Stitch density [Loops/cm^2]	Thickness [mm]
AI	28	22	616	0.94
BII	23.8	21.8	518.84	0.76
CIII	26.6	21	558.6	0.63

3 RESULTS AND DISCUSSION

All the samples were tested firstly for the compression after application, after 24; 28 and 48 hours respectively to observe the effect of the compression pressure on the wearing time.

Table 4 Mean compression pressure of socks

Pressure	AI	BII	CIII
	CCL I	*CCL II*	*CCL III*
mmHg	26.60	40.50	54.60
kPa	3.54	5.39	7.26

Figures 2-4 show that there is decrease of the compression pressure of medical socks after worn on the leg for 48 hours.

Table 5 Compression pressure of socks after long term usage

Sample identification	Pressure at cB [mmHg]					Total of pressure drop [mmHg]
	after application	*after 4 hours*	*after 24 hours*	*after 28 hours*	*after 48 hours*	
AI	26.67	23.00	18.00	17.00	13.67	13.00
BII	40.67	38.67	32.00	30.33	26.33	14.33
CIII	54.00	48.67	37.67	36.33	29.67	24.33

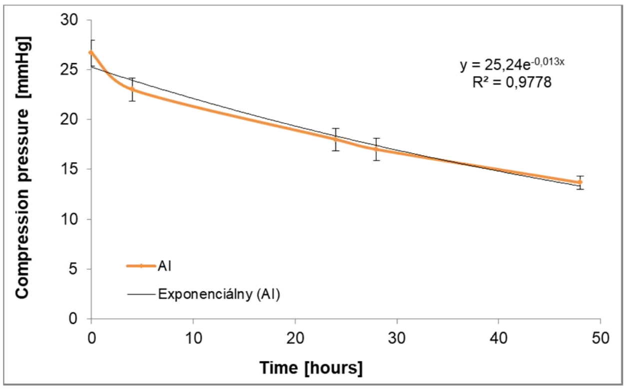

Figure 2 Decrease of compression pressure with time of wearing for Class 1

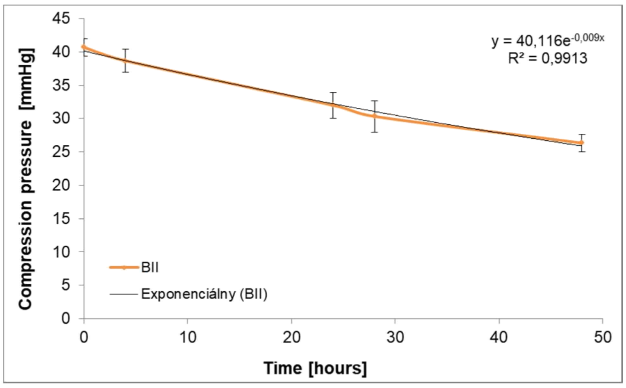

Figure 3 Decrease of compression pressure with time of wearing for Class 2

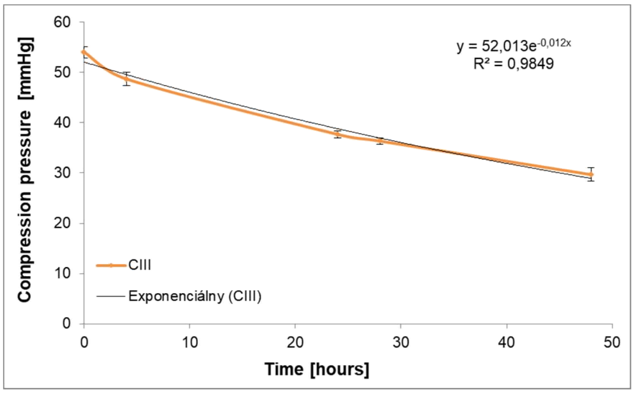

Figure 4 Decrease of compression pressure with time of wearing for Class 3

This shows that the pressure is lost by nearly 10-25% which is very crucial for the medical patients. This loss of pressure is majorly due to the relaxation of the knitted structure with time. Either the socks should be replaced after 6-8 hours or worn out and should be given some time to come back to its original structure.

Secondly the original all socks and the socks worn for 12 hours are tested for the load elongation, the curve shows that the each Class of compression socks are able to be extended even at lower force. The experiments are performed only on the course side as in compression socks the overall decrease of the socks radius causes the pressure and the role of the warps is very limited. Only a portion of the curve at identical force level is shown to compare the extension lines, which gives a realistic idea of socks on a real leg.

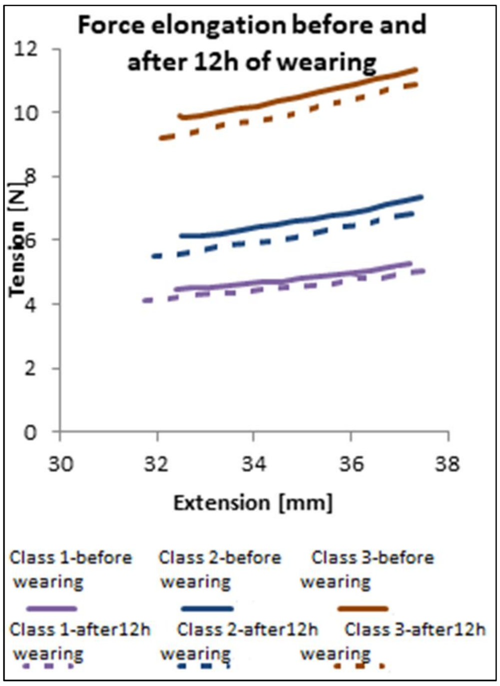

Figure 5 Force extension curve before and after 12 h of wearing

The percentage decrease of compression pressure after wearing is shown in Table 6.

Table 6 Percentage pressure degradation in 48 hours

Sample identification	Pressure decrease [%]			
	after 4 hours	*after 24 hours*	*after 28 hours*	*after 48 hours*
AI	13.75	32.50	36.25	48.75
BII	4.92	21.31	25.41	35.25
CIII	9.88	30.25	32.72	45.06

The socks were also hand washed to see the effect of washing on the compression pressure. The temperature of water was 35°C and the results in Table 7 shows a minor increase in compression pressure, which can be due to the contraction of knitted structure after washing. The effect is found to be insignificant.

Table 7 Pressure at ankle level after hand washing

Sample identification	AI	BII	CIII
Compression class	CCL I	CCL II	CCL III
Mean [mmHg] before washing	26.60	40.60	54.20
SD [mmHg]	0.97	1.84	1.23
Mean [mmHg] after washing	25.8	41.12	53.73
SD [mmHg]	0.87	1.5	1.7

The Table 7 is very essential to understand the insignificant different in compression pressure after hand washing, the compression socks are quite often washed to protect the patients form any bacterial infection. The producer recommends the hand wash but it is generally seen that most of the patient prefer to machine wash. In further research the effect of machine wash at different temperature will be analyzed.

3.1 Dimensional change

The exact original dimensions in a square form were indicated by textile marker pen on each sample of socks at the location of ankle level. The size of marked square was 50x50 mm. After the samples were washed and air-dried, the dimensions of the marked square were measured again to determine the change in dimensions. Table 8 shows the dimensions in course and wale directions before and after the M samples were washed, where D_{NW} are dimensions of marked square before washing, D_{HW} are dimensions after HW. Measurements were taken to the nearest 0.5 mm of the lines that were marked off.

Table 8 Dimensional change after different types of laundering

Sample identification	D_{NW}			D_{AHW}		
	course x wale [mm]			course x wale [mm]		
AI	50	x	50	50	x	48.5
BII	50	x	50	49	x	50
CIII	50	x	50	49	x	49.5

Dimensional changes expressed in [%], were calculated according the literature [6] as follows:

$$s = \frac{l_1 - l_2}{l_1} . 100 \qquad (1)$$

where: s is shrinkage [%], l_1 is the initial dimension of the sample [mm] and l_2 is the dimension of the sample after washing [mm].

Change in dimensions is indicated (+) if shrinkage occurs or (-) when fabric is extended. The higher the dimensional change value, the more shrinkage or extension occurred. Table 9 shows the total dimensional change for course and wale in [%] for the marked square at ankle level of each MCS after being hand washed.

Table 9 Dimensional change in percent after hand washing

Sample identification	D_{AHW} course x wale [%]		
AI	0	x	3
BII	2	x	0
CIII	2	x	1

From the results of percentage dimensional changes is obvious that no fabric extension happened, but shrinkage occurs for all types of MCS. Wale direction can be labelled as a less stable direction due to the higher values for shrinkage.

The results demonstrate that shrinkage occurs during washing, but the amount of dimensional changes after washing does not occur with the same trend. Also, MCS samples with the same or similar stitch density or composition do not behave in laundering with the same trend, so influence of those factors on overall performance of MCS cannot be confirmed.

4 CONCLUSION

It is concluded from the research that the compression socks loses pressure insertion with respect to time. After just 4 hours of wearing there is minimum decrease of 10% whereas after 48 hours of wearing the compression pressure is decreased by 23%. For medical patients the precise pressure management is very important for health.

From the washing test it was concluded that the socks have insignificant change in the compression pressure after hand washing. The slight increase in the mean value was observed which is due to the shrinkage of the knitted structure.

It is recommended from the research to change the medical socks after 6 hours to have precise pressure rating.

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