EFFECT OF ELASTIC ELONGATION ON COMPRESSION PRESSURE AND AIR-PERMEATION OF COMPRESSION SOCKS

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Abstract: *The aim of this research is to analyze effect of varying leg sizes on lateral compression pressure at ankle and calf portions and mutual graduation [%]. We also studied the effect of transverse elastic elongation [%] on air permeation [mm/sec] in relaxed (0% extension) and extended state (70% extension) of compression socks. To extend the compression socks at ankle and calf portions, a novel extension frame was used. Kikuhime pressure measuring device was used for measuring lateral compression and mutual graduation [%]. As far the comfortability of compression socks is concern, it was a great challenge to mitigate and convince the patients to use the compression socks who do not prefer to use due to ''too much hotness" and 'itching' registered in various studies. Air permeation tester was used for measurement of air permeability properties at ankle and calf portions of compression socks in relaxed and extended state. In this study, we found that as the elastic elongation in transverse direction of compression socks at ankle and calf portion increases, a significant change in lateral compression and air permeation was observed. We concluded that as the circumference of leg increases, a significant increase in compression pressure takes place. Air-permeation has also been changed with change in elastic elongation significantly (p value<0.05). Out the three socks samples the best sample was rib structured compression socks.*

Keywords: *Compression socks, Kikuhime device, Air-permeation.*

1 INTRODUCTION

Compression socks are the highly acclaimed textile garment for pressure exertion on the lower part of the leg. It is used to reduce venous hyper pressure [1]. Mechanism of action is lowering of pressure exertion from ankle to calf portion 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 mm Hg). 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].

Theoretically, the extent of compression socks pressure depends on the leg radius *r* and reversal force *T* [N] around the leg can described by Laplace's Law [8] that is:

$$P = \frac{T}{r} \tag{1}$$

where: *P* - pressure [Pa]; *T* - reversal fabric tension [N]; *r* - radius of leg [cm].

For human leg, circumference is required so equation (1) can be modified to:

$$P = \frac{T \times 2\pi}{C} \tag{2}$$

where: *P* - pressure [Pa]; *T* - reversal fabric tension [N]; *C* - circumference of leg [cm].

For upward blood flow, graduation in socks is of great importance from ankle to calf portion is calculated using formula:

$$G = \frac{P^c}{P^a} \times 100 \tag{3}$$

where: P^c - pressure at calf portion [Pa]; P^a - pressure at ankle portion [Pa].

As per literature review and equation (2), it can be concluded that lateral compression and graduation% (G %) in compression socks depends on its circumference and reduction%.

Reduction percentage% is actually the difference in the circumferential dimension of leg and compression socks at a specific point (ankle/calf). It can be calculated using below formula [7, 9-11]:

$$R = \frac{L - S}{L} \times 100 \tag{4}$$

where: *R* - width reduction [%]; *L* - leg width [cm]; *S* - socks width [cm].

In actual practice, when any pressure garment is worn, it extends to some extent. This stretch generates tension in the yarns which exert radial pressure on the curved human limb. In [11] is mentioned that practical elongation of compression sock of standard size must be extended to 50% maximum transversely.

This stretch also changes the loop shape, density and thickness of fabric. All these changes are expected to affect the comfort behavior of fabrics especially air permeation, thermal effusivity and thermal conductivity across the compression socks is analyzed and factors affecting the same.

Because of the extreme sensitivity of skin in the affected area, comfort characteristics of compression socks play a critical role in patient's compliance and healing.

Seshadri et al. [12] studied the use, compliance and efficacy of compression socks. In their study they analyzed 3,144 patients for tertiary venous practice. They concluded that only 21% patients uses stockings on daily basis, 12% most days, 4% used less option, 63% don't use. They inquired the reasons: 30% unable to give reason, 25% not recommended by physician, 14% did not help, 14% binding off, 8% too hot to wear, 2% limb soreness, 2% due to itching and 2% others (cost and work station). As far as pressure exertion and graduation in socks plays an important role to control re-occurrence of venous ulcer and venous insufficiency. It should exhibit optimum comfort properties to regulate heat and moisture transfer (comfortness) generated during different physical activities of patients.

Gupta et al. [13] studied the comfort properties of pressure garments at different extension levels from 0 to 60%. They extended the fabric by designing a frame (30×30 cm^2) made up of acrylic sheet and took sample of 14.4 cm×20 cm and marked square of 10×10 cm^2. But for compression socks this frame cannot be recommended as socks circumference at ankle is very low and higher at calf. For Compression class III and IV it is very hard to extend to 60% precisely. Wang et al. [14] mentioned the same while investigating dynamic pressure attenuation of elastic fabric for compression garment.

Fundamental parameters which govern the thermo-physiological properties of fabrics are fibre type, fibre conductivity, fibre moisture regain, yarn count, yarn twist per inch, yarn structure, spinning process, fabric structure, fabric loop length, fabric thickness, fabric porosity and finishing treatments [15].

Air flow through textiles is mainly affected by the pore characteristics of fabrics. It is quite clear that pore dimension and distribution is a function of fabric geometry. The yarn diameter, surface formation techniques and the number of loop, counts per unit area are the main factors affecting the porosity of textiles. The porosity of a fabric is connected with certain of its important features, such as air permeability, water permeability, dyeing properties etc. [15, 16].

Benltoufa et al. [16] investigated methods of determining jersey porosity, which proved that geometrical modeling is the most suitable and easiest method of determining porosity It was determined that porosity depended on fabric parameters and relaxation progression.

Fabric properties related to thermal behavior are bulk density, porosity and air permeability was determined. Total porosity of the knits *P* [%], defined as the portion of all air spaces in knitted fabric both between yarns and inside them, was determined according to the following equation:

$$P = 100 - \frac{\delta}{\rho} \times 100 \quad (5)$$

where: *P* - porosity; *ρ* - fiber density [g/m^3]; *δ* - bulk density [kg/m^3] [17].

$$P = 1 - \frac{m}{\rho . h} \times 100 \quad (6)$$

where: *P* - porosity; *m* - fabric areal density [g/cm^2]; *ρ* - fiber density [g/m^3]; *h* - thickness [cm] [18].

To extend the compression socks at ankle and calf portion, it was very challenging to design a frame that can elongate the socks samples with more precision and accuracy in uni-axial direction. For this, novel extension frame was introduced.

The aim of this study was to investigate the effect of elastic elongation on air permeation [mm/sec] to get rid of sweat accumulation between garment and skin in relaxed and extended state.

It was also studied the effect of 2 different leg sizes on compression pressure

2 MATERIALS AND METHODS

Three type of compression socks were purchased and structurally analyzed with great precision and accuracy.

2.1 Physical testing of compression socks

All the three sock samples were evaluated for courses and wales per inch using pick glass in relaxed (0% extension) and extended state (up to 70% extension). Thickness of fabric was measured using Digital thickness tester of type M034A, SDL (Atlas) according to standard test method along with porosity. Physical testing results of socks samples are given in Table 1.

Table 1 Physical testing of compression socks in relaxed state (0% extension)

Sample codes	Position	BIISJ*	BIIISJ*	DGIIRIB*
Socks circumference [cm]	Ankle	16.6	16	16.4
	Calf	23	25.6	26
Courses/cm	Ankle	144.80	124.50	142.20
	Calf	147.32	124.46	58147.32
Wales/cm	Ankle	132	124.46	106.70
	Calf	106.70	91.5	68.60
Stitch/cm^2	Ankle	1168.40	944.90	924.5
	Calf	705.10	693.42	617.22
Thickness b [mm]	Ankle	0.75	0.95	1.20
	Calf			
Areal density [g/m^2]	Ankle	308.80	378.47	350.97
	Calf	291.80	368.47	292.47
Porosity [%]	Ankle	64.19	65.35	74.56
	Calf	66.16	66.27	76.23

BIISJ BIIISJ- beige-compression level-single jersey; *DGIIRIB- dark grey- compression level-rib structured.

2.2 Characterization of compression socks

Pressure measurement

Three socks samples were worn on human legs of two different circumferences *L1* and *L2*. Due to different circumferences, it exhibit varying reduction percentages *R1* and *R2* [%] calculated using equation (4), mean compression pressure values *P1* and *P2* [mm Hg] using pressure measuring device and mutual graduation percentages *G*; *G1* and *G2* [%] were calculated using equation (3) as mentioned in Table 2.

Pressure was measured by sitting upright on a flat seat chair with flat backrest at 45 cm high from the floor using Kikuhime (TT med, Denmark) pressure measuring device. The probe of pressure measuring device was placed between socks and skin at ankle and calf portions simultaneously as shown in Figures 1 and 2.

Figure 1 Pressure measurement in sitting position (single jersey)

Figure 2 Pressure measurement in sitting position (Rib)

2.3 Novel extension frame

When compression socks worn it extends to both longitudinal and horizontal direction according to circumference and length of leg. Various studies exist in which we found that the socks are extended to maximum 60% depending on extent of pressure (20 to 40 mm Hg) relates to intensity of the disease (Edema to venous Ulcer).

Novel extension frame is drived using combination of three gears as shown in Figure 2. Middle gear, connected with revolving handle, drives the two movable jaws in opposite direction. Maximum distance between jaws can be achieved up to 36 cm. As we rotate the handle, the jaws move apart and extend the fabric to required level (up to 70% and more). Total length of frame is 40 cm; width of jaws is 14.5 cm.

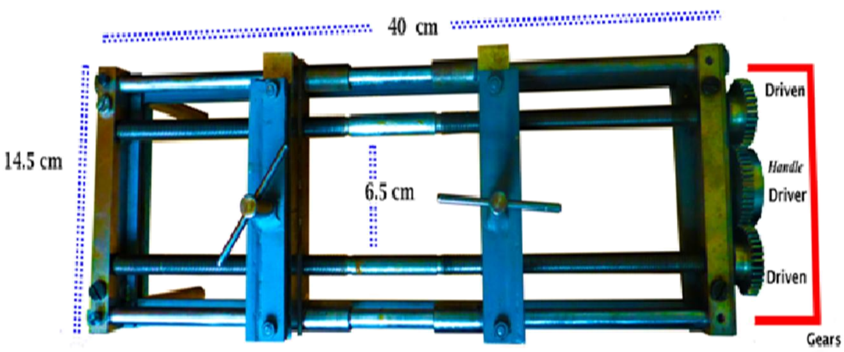


Figure 3 Novel extensibility frame

Table 2 Legs circumferences vs compression pressure

Sample codes	Position/symbols	*BIISJ	*BIIISJ	*DGIIRIB
Socks circumference [cm]	Ankle	16.6	16	16.4
	Calf	23	25.6	26
Socks areal graduation [%]	G	72.17	62.5	63.07
Leg circumference *L1* [cm]	Ankle		22±0.5	
	Calf		35±0.5	
Reduction *R1* [%]	Ankle	24.54	27.27	25.45
	Calf	34.28	26.85	25.71
Pressure *P1* [mm Hg]	Ankle	26±1	37±1	21±1
	Calf	22±1	29±1	14±1
Pressure graduation *G1* [%]	G	84.61	78.37	66.66
Leg circumference *L2* [cm]	Ankle		24.5±0.5	
	Calf		38.5±0.5	
Pressure graduation *G2* [%]	G	85.71	78.37	66.66
Reduction *R2* [%]	Ankle	32.24	34.69	33.06
	Calf	56.88	58.44	57.40
Pressure *P2* [mm Hg]	Ankle	35±1	42±1	25±1
	Calf	30±1	40±1	24±1
Pressure graduation *G2* [%]	G	85.71%	95.23	96%

BIISJ BIIISJ- beige-compression level-single jersey; *DGIIRIB- dark grey- compression level-rib structured.

2.4 Air permeability measurement

All the three socks were cut in longitudinal direction and allow them to be relaxed for long time under standard test method AATCC 99.

Air permeability of all samples in relaxed state and in extended state was measured accordingly to EN ISO 9237:1995 using Air permeability tester. Air pressure of 20 Pa was set across the surface of compression socks. The measuring area of the sample and machine was 20 cm^2. Average of at least 10 values were measured under controlled laboratory conditions of 20±2°C, 65±4% relative humidity and analyzed using Mintab 17 data analysis. Air permeability is measured as:

$$AP = \frac{q\nu}{A} \times 10 \qquad (7)$$

where: $q\nu$ - volumetric air flow per second [cm^3/sec]; *A*- area [cm^2] [19, 20].

<u>*Air permeability in relaxed and extended state*</u>

All socks samples (8×8 cm), were installed on air permeability machine one by one and notified for air permeability results in relaxed state. Then all samples were re-installed on novel extension frame and calibrated with previously measured values in relaxed state (at 0% extension) at ankle and calf portion simultaneously. Once the same values obtained before and after installation of socks at extension frame, we started notifying values from relaxed state (*L0*, 0% extension). We continued to notify the volumetric air flow (cm^3/sec) after periodical increment of 10% extension up to 70% for each cut samples. For each reading, the distance between the jaws was measured as initial value (*L0*) and then extended maximum up to 70% (*L70*) with increment of 10% increase in distance between the jaws (*L10, L20, L30, L40, L50, L60* and *L70*). Air volumetric flow at each 10% incremental distance was measured as shown in Figure 4.

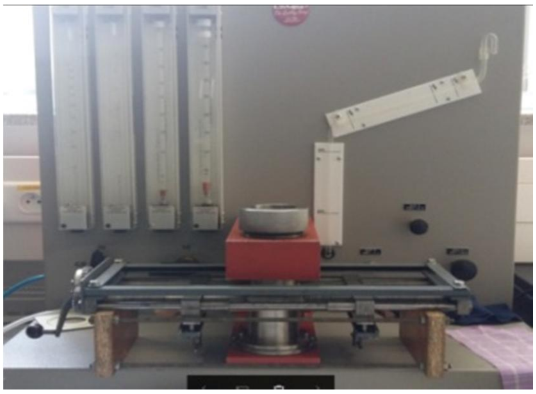


Figure 4 Air permeability measurements (front view)

3 RESULTS AND DISCUSSION

3.1 Compression pressure measurements

<u>*Effect of leg circumference on compression pressure at ankle*</u>

Table 2 and Graph 1 depict the change in compression pressure; *P1* and *P2* and reduction percentages; *R1* and *R2* among three socks samples (BIISJ, BIIISJ and DGIIRIB). Firstly, we worn BIISJ socks samples on leg *L1* and then on leg *L2*, exhibiting circumferences at ankle *L1* 22±0.5 cm and *L2* 24.5±0.5 cm, we found an incredible increase in compression pressure at ankle from *P1* 26±1 mm Hg to *P2* 35±1 mm Hg along with increase in reduction percentage from *R1* 24.54% to *R2* 32.24%. For socks samples BIIISJ, we also found an incredible increase in compression pressure from *P1* 37±1 to *P2* 42±1 as well as in reduction percentage from *R1* 27.27% to *R2* 34.69% while for socks samples DGIIRIB, compression pressure was increased from *P1* 21±1 to *P2* 25±1 while reduction percentage from *R1* 25.45% to *R2* 33.06%.

Effect of leg dimension on compression pressure at calf

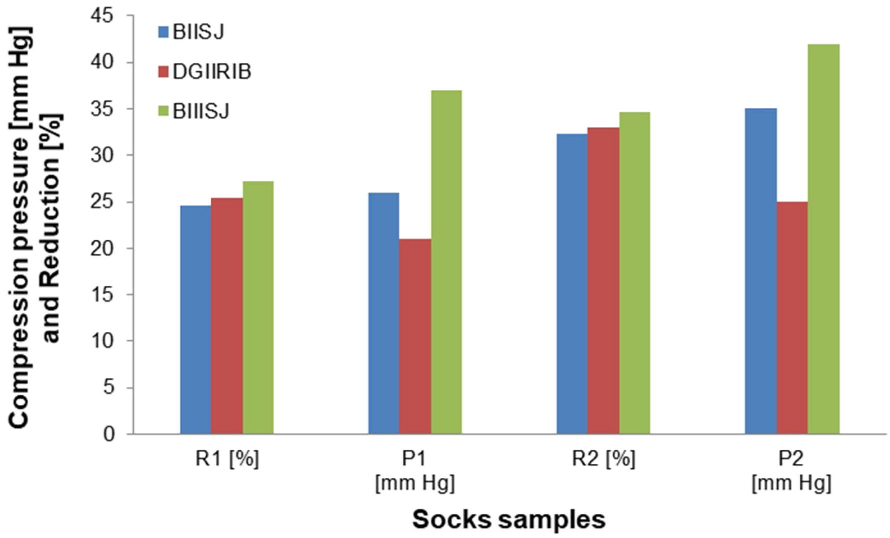
Table 2 and Graph 2 depict the change in compression pressure and reduction percentage between due to change in circumference of leg at calf portion.

When worn BIISJ socks samples on leg *L1* and then leg *L2*, exhibiting circumferences values 35±0.5 and 38.5±0.5 cm simultaneously, we found an incredible increase in compression pressure *P1* 22±1 to *P2* 30±1 mm Hg, as well as reduction percentage from *R1* 34.28 to *R2* 56.88%. For socks sample BIIISJ, we found an incredible increase in compression pressure from *P1* 29±1 to *P2* 40±1 and reduction percentage from *R1* 26.85 to *R2* 58.44%. Similarly, for DGIIRIB, increase in compression pressure from *P1* 14±1 to *P2* 24±1 as well as in reduction percentage from *R1* 25.71 to *R2* 57.40% was observed.

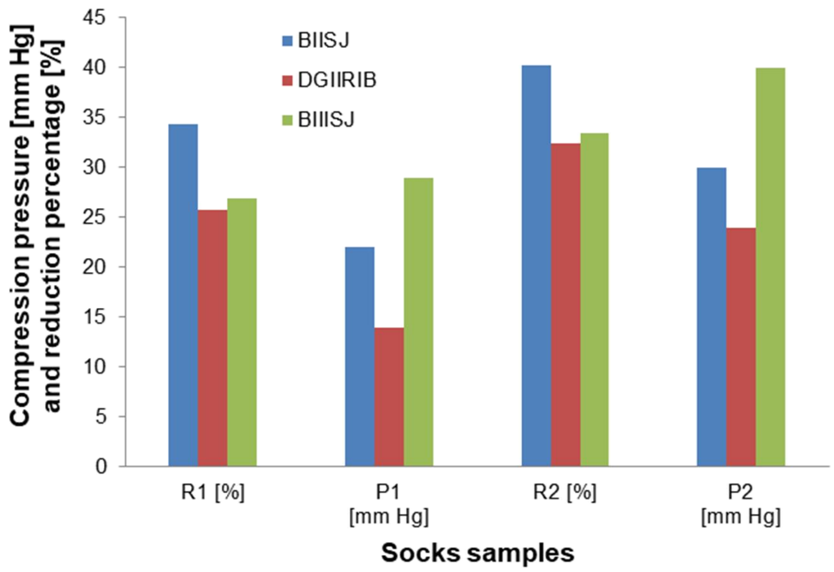
Effect of leg dimension on gradation percentage G [%]

Table 2 and Graphs 3 portray the change in graduation percentage G [%] between the three socks samples (BIISJ, BIII SJ and DGIIRIB) due to change in circumference of two legs *L1* and *L2* at ankle and calf portions of compression socks.

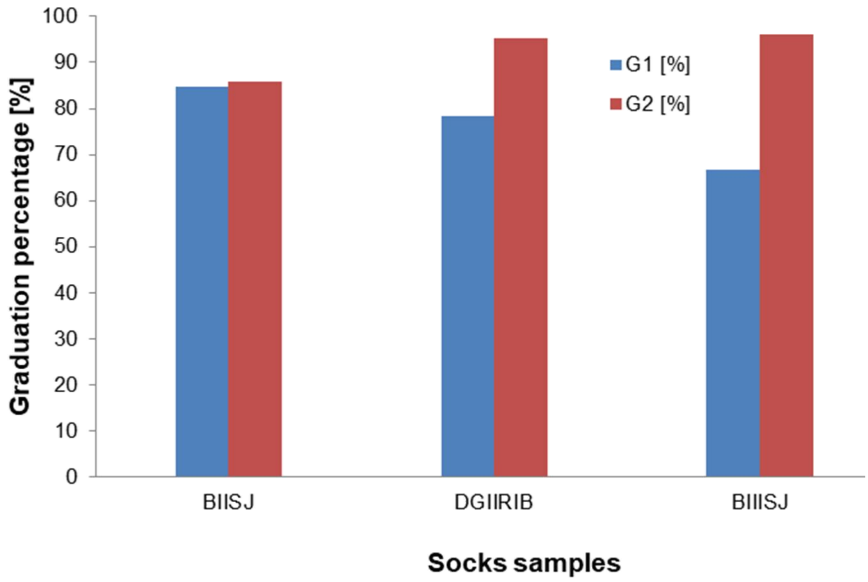
We found that as leg size *L1* changes to *L2* (specifications mentioned in Table 2), there is an incredible change in graduation percentages of all the three socks samples BIISJ, BIII SJ and DGIIRIB occurs from *G1* 84.61, 78.37 and, 66.66% to *G2* 85.71, 95.23 and 96% simultaneously cause reverse flow of blood ultimately happening of hypertension inside the veins and muscles.



Graph 1 Reduction percentage [%] and compression pressure [mm Hg] at ankle vs leg circumference (*L1* to *L2*)



Graph 2 Reduction percentage [%] and compression pressure [mm Hg] at calf vs leg dimension change (*L1* to *L2*)



Graph 3 Effect of leg circumference change on graduation percentage G [%]

3.2 Air permeability measurement

Air permeability values of all the socks samples at ankle and calf portions of compression socks were measured at various levels; relaxed state (0% extension) and then to extended state (up to 70% extension). The results are plotted and analyzed using Minitab 17 using regression analysis tool as shown in Graphs 4-5 and Tables 3-4.

Air permeation in relaxed state (0% extension)

Table 1 shows the results of stitch density per inch^2, porosity and air permeation of all the three socks samples in relaxed state (0% extension). Out of three socks samples, BIISJ, BIIISJ and DGIIRIB, we conclude that DGIIRIB sample exhibit the highest value of air permeation 22 mm/sec at ankle then calf portion 25 mm/sec as shown in Graphs 4 and 5. This is due to the lowest value of stitch density i.e. 364 stitches per inch^2 and the highest value of porosity i.e. 74.56 than rest of 2 socks samples BIISJ and BIIISJ at ankle. While socks samples DGIIRIB, exhibit lower stitch density of 343 stitches per inch^2 and higher porosity (76.23) at calf portion than at ankle due which it allows more air 25 mm/sec to flow than at ankle portion of socks samples.

Air permeation in extended state

Table 3 and graphs 4-5 portray effect of elastic elongation on stitch density and its ultimate effect on air permeation at ankle and calf portions as well. Table 4 depicts the regression relation between elastic elongation and air permeation at ankle and calf portion as well.

Air permeability values of all the socks samples at ankle and calf portions of compression socks were measured at various levels; relaxed state (0% extension in Table 2) to extended state (70% extension in Table 3).

The results are plotted and analyzed using Minitab 17 regression analysis tool as shown in Graphs 4–9 and in Tables 2 and 3.

Air permeation [mm/sec] in relaxed state at ankle and calf portion of compression socks

Table 3 shows the results of stitch density per inch^2 and porosity that was measured using equation (5) and equation (6).

We found that out of three compression socks samples BIISJ, BIIISJ and DGIIRIB when evaluated in relaxed state for air permeability, sample socks DGIIRIB acquired the maximum flow of air at ankle portion i.e. 22 mm/sec. but the at calf portion air permeation was 25 mm/sec.

Graph 4 portray that air permeability of socks sample DGIIRIB exhibit highest value of air permeation 22 mm/sec with the lowest value of stitch density i.e. 364 stitches per inch^2 and the highest value of porosity i.e. 76.27% than rest of 2 socks samples BIISJ and BIIISJ at ankle while at calf portion the stitch density and porosity is higher that ankle due to which the air permeation is higher at calf portions of compression socks than at ankle portion i.e. 22 mm/sec but the at calf portion air permeation was 25 mm/sec.

Effect of elastic elongation on air- permeability (at ankle)

Graph 4 and Table 3 depict that when we extend the socks from relaxed to extended state, we found an incredible increase in flow of air across socks sample takes place. It is due to decrease in stitch density [stitches per inch^2].

Out of three samples, BIISJ, BIIISJ and DGIIRIB, we observed DGIIRIB exhibit highest permeation of air flow 22.5 mm/sec than rest of two socks samples BII9SJ, BIIISJ exhibit 4.5 mm/sec and 11.5 mm/sec at relaxed state.

We also observed when it was extended to 70% extension acquiring the values 190 mm/sec while rest of two socks samples, BIISJ and BIIISJ exhibit 75 mm/sec and 150 mm/sec successively. The reason of higher permeation of air across DGIIRIB is due to successive decrease in stitch density per inch^2 as well as increase of pore size of socks samples.

Statistical effects of elastic elongation (0% to 70%) of all samples were evaluated by Minitab 17 using simple regression tool.

The results of regression analysis of effect of elastic elongation on air permeation are analyzed with *p* value<0.005 (at 95% significant level) and other related parameters mentioned in Table 4.

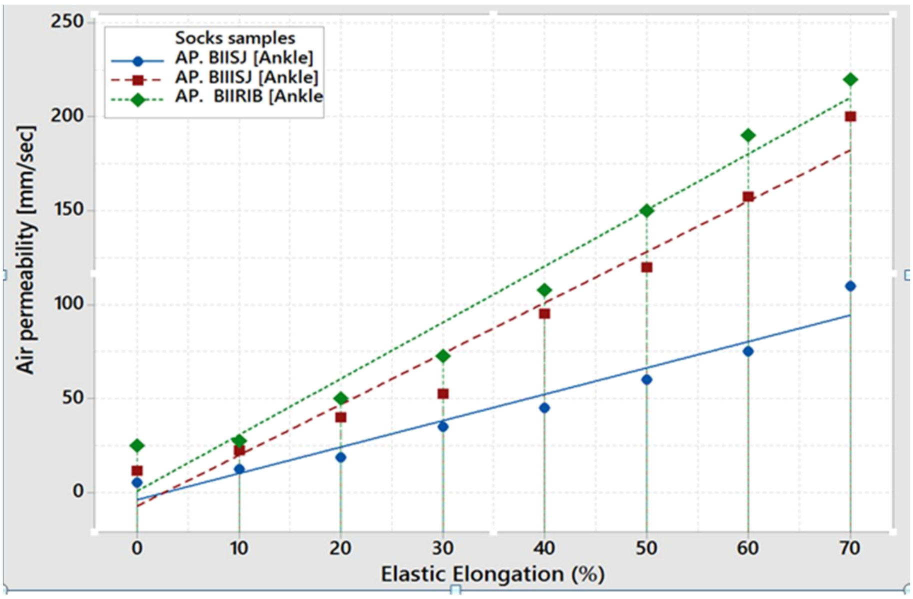
Table 3 Air permeability vs stitch density results in extended state

Position	Socks Code	Parameters	Extension [%]							
			0	10	20	30	40	50	60	70
Ankle	*BIISJ	stitches/cm^2	1168.40	1094.70	1043.90	992.40	936.5	889	861	821.7
Calf			959.10	906.8	850.9	792.50	756.9	708.6	675.6	635
Ankle		AP [mm/sec]	4.5	10	13.5	25	35	50	62.5	75
Calf			5	12.5	18.5	35	45	60	75	110
Ankle	*BIIISJ	stitches/cm^2	944.90	892.80	838.2	784.90	731.5	685.7	640	589.30
Calf			693.4	640	584.2	528.8	492.76	454.66	417.5	381
Ankle		AP [mm/sec]	11	18	30	40	60	87.5	107.5	150
Calf			11.5	22.5	40	52.5	95	120	157.5	200
Ankle	*DGIIRIB	stitches/cm^2	924.56	863.8	800.10	759.56	718.82	655.30	589.3	525.8
Calf			617.20	574	530.86	510.54	464.82	421.64	400	378.46
Ankle		AP [mm/sec]	22.5	29	35	45.25	82.5	110	150	190
Calf			25	27.5	50	72.5	107.5	150	190	220

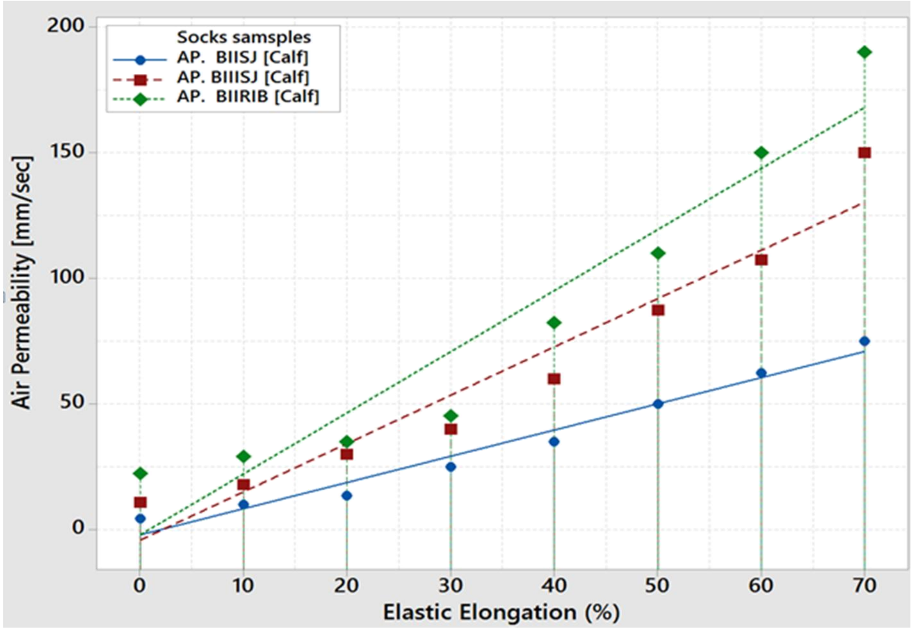
BIISJ BIIISJ- beige-compression level-single jersey; *DGIIRIB- dark grey- compression level-rib structured.

Table 4 Statistical analysis of each parameter

Socks Code	Parameters	Position	R-Square Value	p value<0.05	Correlation	Regression Equation
BIISJ	Air Permeability	Ankle	94.41	*0.001	0.97	Y= -4.125 + 1.407X
		Calf	97.15	*0.001	0.99	Y= -2.042 + 1.042X
BIIISJ		Ankle	95.55	*0.001	0.97	Y= -7.500 + 2.711X
		Calf	93.83	*0.001	0.97	Y= -4.208 + 1.920 X
DGIIRIB		Ankle	96.43	*0.001	9.8	Y= 0.625 + 2.991 X
		Calf	91.82	*0.001	0.96	Y= -1.96 + 2.428X



Graph 4 Effect of elastic elongation and stitch density on air permeability at ankle



Graph 5 Effect of elastic elongation [%] and stitch density on air permeability at calf

Effect of elastic elongation on air permeability (at calf)

Graph 5 and Table 3 portray that as elastic elongation increases from 0% extension to 70% extension, an incredible increase in air flow across the samples has occurred.

Out of three socks samples, it was found that the socks sample DGIIRIB exhibit the highest permeation of air as it exhibit rib construction and minimum stitches density and higher distribution of pores per unit area as shown in Graph 4 and testing results mentioned in Table 3.

Statistically effect of elastic elongation (0 to 70%) of all the socks samples were evaluated by Minitab 17 using simple regression tool. We found that elastic elongation significantly affect, *p* value <0.005, quantitative flow of air across samples. Statistical analysis results of elastic elongation are given in Table 4.

4 CONCLUSION

In this research we concluded that:

As the size of circumference of leg at ankle and calf portion increases, the exertion of reverse pressure increases which can be recommended to those patients who needs intensive pressure exertion with passage of time. But the limitation we found is increase in graduation % increased to more than 80%. It is studied that it should be moderate not more than 80%. It reduces the rate of flow of blood from ankle to calf portion as the leg size varies increasing reversal pressure.

Air-permeation of all the three socks samples were evaluated and finalized that the socks sample DGIIRIB exhibit excellent results of air permeation as extended up to maximum of 70%.

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5 REFERENCES

1. Flaud P., Bassez P., Counord J.: Comparative in vitro study of three inter-face pressure sensors used to evaluate medical compression hosiery, Dermatologic Surgery 12, 2010, pp. 1930-1940
2. Harpa R., Piroi C., Radu C.D.: A new approach for testing medical stockings, Tex Res J 80, 2010, pp. 683-695
3. Smith M.W.L., Dalbey J.C.: Gradient compression hosiery knitted using core spun yarns, Patent application 7895863-B2 USA, 2011
4. Partsch H.: The use of pressure change on standing as a surrogate measure of the stiffness of a compression bandage, Eur. Journal of Vascular Endovascular Surgery 30, 2005, pp. 415-421
5. Liu R., Kwok Y.L., Lao T.T.H., et al.: Objective evaluation of skin pressure distribution of graduated elastic compression stockings, Dermatologic Surgery 31, 2005, pp. 615-624
6. Partsch H., Partsch B., Braun W.: Interface pressure and stiffness of ready-made compression stockings: Comparison of in vivo and in vitro measurements, J of Vascular Surgery 44, 2006, pp. 809-814
7. Bera M., Chattopadhay R., Gupta D.: The effects of fibre blend on comfort characteristics of elastic knitted fabrics used for pressure garments, Journal of the Institution of Engineers 95, 2014, pp. 41-47
8. Macintyre L., Baird M.: Pressure garments for use in the treatment of hyper-trophic scars–an evaluation

of current construction techniques in NHS hospitals, Burns 31, 2005, pp. 11-14

9. Chattopadhyay R., Gupta D., Bera M.: Effect of input tension of inlay yarn on the characteristics of knitted circular stretch fabrics and pressure generation, Journal of Textile Institute 103, 2012, pp. 636-642
10. Tsujisaka T., Azuma Y. and Matsumoto Y.I.: Comfort pressure of the top part of men’s socks, Textile Research Journal 74, 2004, pp. 598-602
11. RAL-GZ 387/2, Medical Compression Armsleeves, Quality Assurance, RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V., Sankt Augustin, DE, 2008
12. Seshadri R, Kathryn H., Peter N., Flowood M.: Use of compression stockings in chronic venous disease: patient compliance and efficacy, Ann. Vasc. Surg. 21, 2007, pp. 790-795
13. Gupta D., Chattopadhyay R., Bera M.: Comfort properties of pressure garments in extended state, Indian Journal of Fiber and Textile Research 36, 2011, pp. 415-421
14. Wang Y., Zhang P., Zhang Y.: Experimental investigation the dynamic pressure attenuation of elastic fabric for compression garment, Textile Research Journal 84, 2014, pp. 572-582
15. Majumdar A., Mukhopadhyay S., Yadav R.: Thermal properties of knitted fabrics made from cotton and regenerated bamboo cellulosic fibers, International Journal of Thermal Sciences 49; 2010, pp. 2042-2048
16. Benltoufa S., Fayala F., Cheikhrouhou M., Ben Nasrallah S.: Porosity Determination of jersey structure, AUTEX Res. J. 7(1), 2007, pp. 63-69
17. Dias T., Delkumburewatte G.B.: Changing porosity of knitted structures by changing tightness, Fibers and Polymers 9, 2008, pp. 76-79
18. Nilgün Ö., ArzuMarmaralı S. and Dönmez K,: Effect of yarn properties on thermal comfort of knitted fabrics. International Journal of Thermal Sciences 46, 2007, pp. 1318–1322
19. Bivainyte A., Mikučioniene D.: Investigation on the air and water vapour permeability of double-layered weft knitted fabrics. Fibres & Textiles in Eastern Europe 19(3), 2011: 18: 69-73
20. Ogulata, R.T., Mavruz, S. Investigation of porosity and air permeability values of plain knitted fabrics. Fibres & Textiles in Eastern Europe 2010; 18(82): 71-75