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Differences in Clothing Pressure between Bandages and Stockings ⋆

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Abstract

Bandages and stockings are used in a wide variety of ways to provide pressure in medical application; bandages are used to compress part of the leg while a stocking is used to compress the whole leg. The proper use of a bandage or stocking depends on the healthcare setting. To understand the compression effects of bandages and stockings, the pressure of a bandage was compared with that of a stocking made under the same design conditions using Lycra yarn (4.4 Tex, type: T-127c). Multiple-regression analysis was carried out to clarify the factors affecting clothing pressure. The bandage/stocking clothing pressures were explained by the same three factors (i.e., the stretching rates across the width and along circumference and the radius curvature). The relation between stocking pressure (Y) and bandage pressure (x) was linear; Y = 0.89x (R^2= 0.984). The pressure of a stocking needs to be 11% greater than that of a bandage to achieve the same effect.

Keywords: Clothing pressure; Bandage; Stocking; Radius curvature; Loop tension; Multiple correlation

1 Introduction

Compression wear has become popular for controlling body shape and for reducing swelling in daily life. The pressure applied by clothing has advantages and disadvantages [1]. Moderate pressure is needed to achieve an aesthetic silhouette while excessive pressure may have adverse effects [2]. According to Kikufuji et al., menstrual cycles were significantly delayed by 14 days when participants wore a tight foundation layer of clothing compared with when they wore no foundation layer [3]. Meanwhile, Sugimoto reported an increase in urinary noradrenaline excretion when participants wore a girdle. It is possible that the pressure may cause the alternation of the autonomic nervous system [4]. It is therefore important to pay careful attention to the level, duration and frequency of pressure being applied to a particular body part [5, 6]. Among body parts, the legs are most insensitive to pressure and commercial compression wear products that reduce swelling of the legs [7] are widely available. Meanwhile, compression wear has been used for

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the treatment of burn injuries and venous and lymphatic disease; e.g., the treatment of varices by pressure has been reported [8, 9]. However, the pressure level can be a problem depending on the body part [10]. For example, the preferred elastic band pressures for the leg and arm should be higher than those for the neck and abdomen, due to the large presence of the autonomic nervous system at the surfaces of the neck and abdomen. The leg is thus an appropriate body part for applying high clothing pressure [11]. Bandages and stockings are used in a wide variety of ways to provide pressure in medical application; bandages are used to compress part of the leg while a stocking is used to compress the whole leg. The proper use of a bandage or stocking depends on the healthcare setting. We must consider these practical aspects when producing and using bandages and stockings. To understand the compression effect of bandages and stockings, the present paper compares the pressure of a bandage with that of stockings under the same design conditions [12].

2 Experimental Method

2.1 Samples and measurements of physical characteristics [12]

The two samples used in this study are shown in Fig. 1. Sample A comprises six bandages having a width of 5 cm (wale: 37/inch, course: 22/inch) that correspond to the six sensor positions of the device used to measure clothing pressure. Sample B is a stocking made from six bandages identical to those of Sample A stitched together using a flat-knitting machine. The circumferences of the bandages are given in Table 1, with the lengths corresponding to size 6 of Australian womenswear [11]. The connecting parts of the knit were made of a nylon yarn comprising 90 filaments. The knitted structure has a plain stitch. Figure 2 shows measuring points a–f of a wooden leg model. When the samples were placed on the wooden leg model, the circumferential stretch increased approximately 10% to 60%. The sample stretch and recovery properties were obtained using an Instron device (5565A) at 10% and 60% strain. The stress-versus-strain curves of the samples were obtained three times under the same conditions. Each sample was preloaded by 50 kPa (as decided in a preliminary experiment to flatten both curled ends of the bandage) in the first trial and extended by 60%. All experiments were carried out in a climate-controlled room (environmental temperature, 20 °C; relative humidity, 60%).

Fig. 1: Sample A (bandage) and Sample B (stocking)

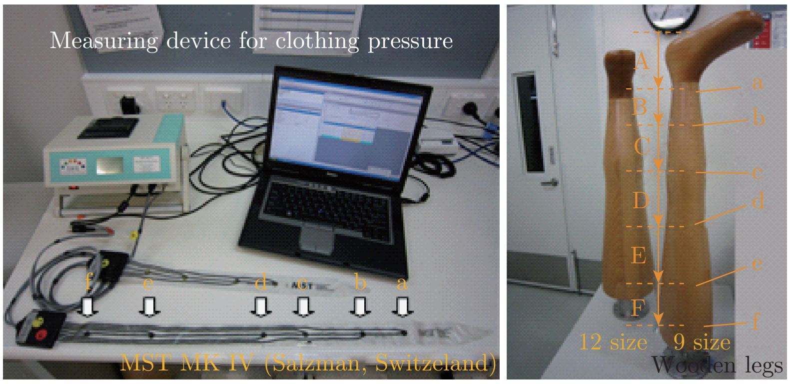


Fig. 2: Device for measuring clothing pressure and a wooden leg model

Table 1: Sample sizes (Australian womenswear size 6)

Measuring point (mm)					
a	b	c	d	e	f
210	265	330	310	440	480
Height (mm)					
A	B	C	D	E	F
120	200	310	390	600	720

Table 2: Wooden-model dimensions

Measuring point	Wooden model (mm)	
	9 size	12 size
Girth length		
a	240	270
b	300	340
c	375	420
d	355	400
e	485	450
f	540	600
Height		
A	120	120
B	200	200
C	310	310
D	390	390
E	600	600
F	720	720

2.2 Measuring device for clothing pressure and attached wooden leg model

Clothing pressure was measured using MST MK IV device (Salzman, Switzerland) as shown in the left image of Fig. 2. The arrows show six predetermined sensor locations for two wooden leg models (of size 9 and 12, see the right image) used in the study. Dimensions of the wooden models at the sensor positions are given in Table 2. The measuring points for clothing pressure are shown from at a to f points in the right image. The increasing rates of the circumferences of samples were 10% for the size-9 leg model and 50%–60% for the size-12 leg model.

2.3 Statistical analysis

Clothing pressure was measured three times for each of the two samples, and the averages of pressure were taken at each measuring point. The circumference and width stretching rates were respectively calculated using Equations (1) and (2).

$$\begin{aligned}&\text{(Circumference of sample after wearing — circumference of sample before wearing)/}\\&\quad\text{Circumference before wearing} \times 100 \qquad (1)\end{aligned}$$

$$\begin{aligned}&\text{(Width of sample after wearing — width of sample before wearing)/}\\&\quad\text{Width of sample before wearing} \times 100 \qquad (2)\end{aligned}$$

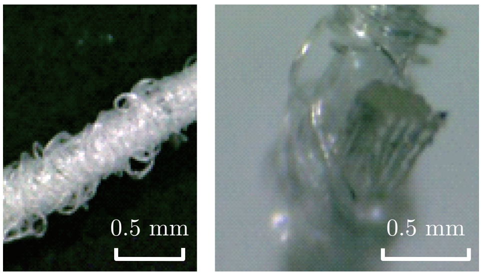
Significant differences in the clothing pressure and circumference/width stretching rate were obtained in a t-test. The radii of curvature at measuring points of a wooden model were calculated from the girth supposing the wooden model to be a cylinder. Multiple-regression analysis was conducted to obtain the relationship between stretching and clothing pressure.

3 Results and Discussion

3.1 Sample yarn and the stress/strain of samples

Figure 3 shows images of yarn taken using a digital microscope. Samples A and B were constructed from a 40D (4.4 tex) single-wrap yarn made of Lycra (type: T-127c, left image). The core yarn comprised 15 Lycra filaments and was wrapped with a nylon yarn comprising 90 filaments (right image). The connecting parts of the stocking sample were made only of nylon yarn comprising 90 filaments.

The stress-versus-strain curves of the samples for the same conditions were obtained three times each. The three curves show good reproducibility and were approximately linear. The relation between clothing pressure (see the result in section 3.2) and strain was calculated using the average data shown in Fig. 4. The figure shows that the clothing pressure increases proportionally with strain at stretching rates of 10% and 60%.



Used yarn

Covered nylon yarn and cored Lycra yarn

Fig. 3: Image of Lycra yarn

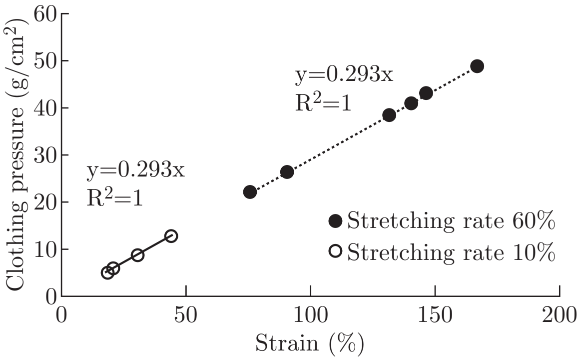


Fig. 4: Relation between clothing pressure and sample strain

3.2 Clothing pressure of the bandage and stocking

The clothing pressures of stocking and bandage samples (mean ± standard deviation) are shown in Fig. 5. The left graph shows the results for the size-9 wooden leg model while the right graph shows the results for the size-12 model. The bandage pressure was significantly higher than the stocking pressure for all combinations at all measuring points on the two leg models ($p < 0.05$ to $p < 0.001$).

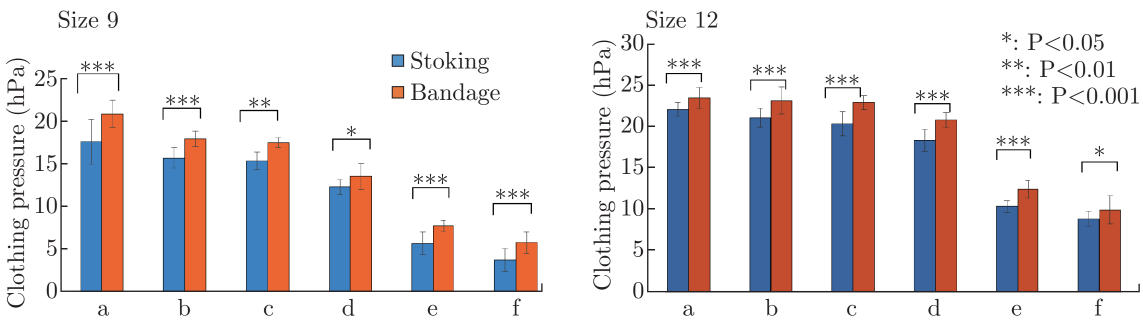


Fig. 5: Comparison of clothing pressure between stocking and bandage samples

3.3 Stretching rates of the circumferences and widths of samples

The stretching rates of the circumferences and widths (mean ± standard deviation) of samples are shown in Fig. 6. The upper graphs show the circumference stretching rate while the bottom graphs show the width stretching rate. The left and right graphs respectively show the results for size-9 and size-12 wooden leg models. A stretching rate of 100% indicates the final length is the original length. All circumference stretching rates exceeded 100%, while the width stretching rate was always under 100% for both samples. Circumference increasing rates at measuring points a, b, c, e, and f of the stocking were significantly higher than those of the bandage for both leg models. The width stretching rates at measuring points b and c of the stocking were significantly higher than those of the bandage sample for the size-9 model while those at measuring points c, d, and f of the bandage were significantly higher than those of the stocking sample for the size-12 model. The circumference stretching rate increased significantly from the size-9 model to the size-12 model for the bandage (from 112.5% ± 4.5% to 151.9% ±23.7%) and stocking (from 118.5% ± 6.9% to 160.3% ± 33.1%). The width stretching rate did not reduce from the size-9 model to the size-12 model for the bandage (a change from −5.2% ± 0.7% to −5.1% ± 5.1%) but did reduce for the stocking (from −3.1% ± 1.9% to −5.9% ± 1.3%). The stocking therefore increased in circumference and reduced in width as the leg size increased, while the bandage increased in circumference without reducing in width.

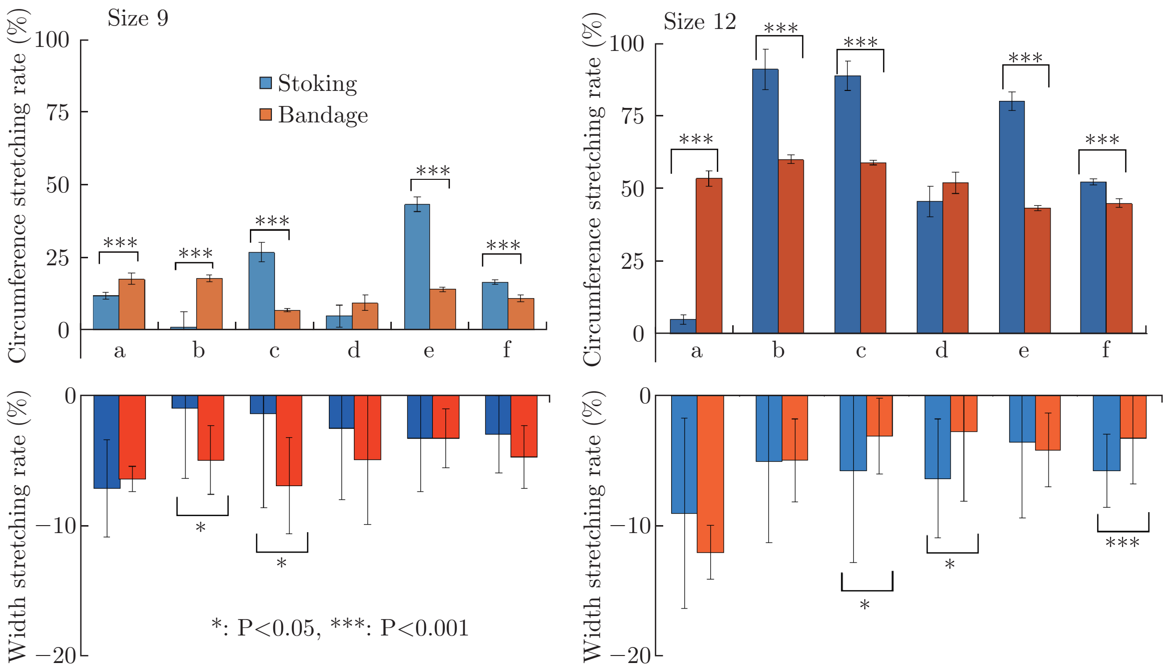


Fig. 6: Stretching rates of the circumference and width of samples

3.4 Relation among the clothing pressure, width/circumference stretching rate, and radius of curvature

Multiple-regression analysis was conducted to establish the relationship among the circumference/width stretching rates, radius of curvature, and clothing pressure. The bandage/stocking results of analysis are shown on the left/right of Table 3. Multiple correlation coefficients were 0.980 for bandage pressure and 0.960 for stocking pressure. Three factors contributed to the relationships: width reduction rate, circumference increasing rate, and radius curvature at the measuring point. Bandage and stocking pressures are thus given by Equations (3) and (4).

$$\text{Bandage clothing pressure} = 0.18\text{Circumference} + 0.23\text{Width} - 2.08\text{Radius curvature} \tag{3}$$
$$\text{Stocking clothing pressure} = 0.10\text{Circumference} + 0.15\text{Width} - 1.14\text{Radius curvature} \tag{4}$$

The width reducing rate versus circumference increasing rate versus radius of curvature proportions of variance were 45.9:26.1:28.0 for the bandage pressure and 40.8:35.0:24.2 for the stocking pressure. The proportion of the width reducing rate was higher for the bandage than for the stocking, while the proportion of the circumference increasing rate was higher for the stocking than for the bandange [12]. Similar trends were also observed by Kirk and Ibrahim [13].

Table 3: Results of analysis of the bandage (left table) and stocking (right table) clothing pressures, width/circumference stretching rates, and radii of curvature [12]

Bandage clothing pressure

Regression statistic	
Multiple R	0.9800
Adjusted R Square	0.9805
R Square	0.9091
Standerd Error	3.3407
Observation	24

ANOVA

	df	ss	MS	F	Significance F
Regression	3	5694.9	1898.3	170.1	2.12E-14
Residual	21	234.4	11.2		
Total	24	5929.2			

	Coefficient	Standard error	t State	P-value	Lower 95%	Upper 95%
Circum-ference	0.180	0.034	5.244	3.37E-05	0.109	0.251
Width	0.234	0.025	9.209	8.04E-09	0.181	0.286
Rudius curvature	−2.078	0.369	−5.627	1.39E-05	−2.846	−1.310

Stocking clothing pressure

Regression statistic	
Multiple R	0.9599
Adjusted R Square	0.9214
R Square	0.8663
Standard Error	4.2070
Observation	24

ANOVA

	df	ss	MS	F	Significance F
Regression	3	4358.0	1452.7	82.1	2.04E-11
Residual	21	371.7	17.7		
Total	24	4729.7			

	Coefficient	Standard error	t State	P-value	Lower 95%	Upper 95%
Circum-ference	0.102	0.027	3.783	0.00109	0.046	0.157
Width	0.151	0.034	4.405	0.00025	0.080	0.223
Rudius curvature	−1.138	0.436	−2.607	0.01645	−2.045	−0.230

The clothing pressure increased as the radius of curvature decreased (see Fig. 4) and tension increased, following the Equation (5) from Kirk and Ibrahim [13].

$$P = (\text{TH}/\rho\text{H}) + (\text{TV} + \rho\text{V}) \tag{5}$$

The equation gives the clothing pressure (P) as a function of the tensile load and radius of curvature, where ρH and ρV are, respectively, the horizontal and vertical radii of curvature and TH and TV are respectively horizontal and vertical tensions [13]. The clothing pressure is shown in Fig. 7 for each radius of curvature. The relation between the clothing pressure of the bandage/stocking and the radius of curvature was significantly linear. From 3 to 8 cm, as the radius of curvature became large, the clothing pressure decreased. The relation between the stocking pressure and bandage pressure was obtained as shown in Fig. 8. The relation between the stocking pressure (Y) and bandage pressure (x) was linear: Y = 0.89x (R^2 = 0.984). As an example, the stocking pressure will be 11% lower than the bandage pressure when the girth length was approximately 19 to 50 cm.

In both bandage and stocking systems, the clothing pressure increases as the width reducing rate and circumference increasing rate increase and the radius of curvature decreases. However,

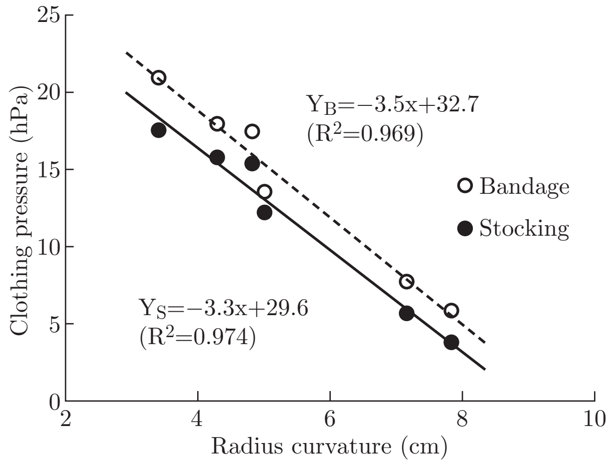


Fig. 7: Clothing pressure for each radius of curvature

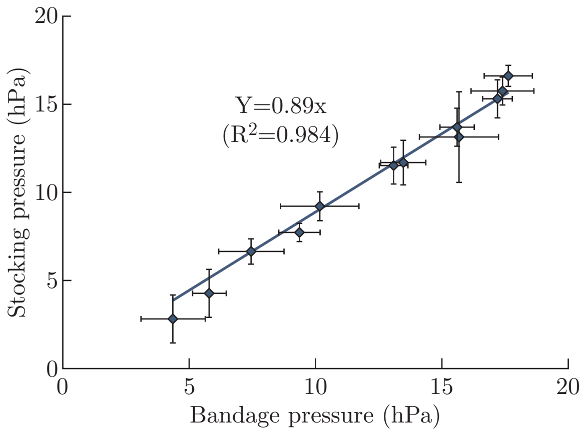


Fig. 8: Stocking pressure required for the same effect of the bandage pressure

according to the difference in proportions of variance, the width reducing rate of the stocking was smaller than that of the bandage (see Table 3). For the stocking, the clothing pressure decreased because loop tension was dispersed structurally in the wale direction. Loop tension then became low and the clothing pressure decreased. The pressure of the stocking needs to be 11% greater than that of the bandage to realize the same effect.

4 Conclusion

Bandages and stockings are used in a wide variety of ways to provide pressure in medical applications; bandages are used to compress part of the leg while a stocking is used to compress the whole leg. The proper use of a bandage or stocking depends on the healthcare setting. We must consider these practical aspects when producing and using bandages and stockings. To understand the compression effect of bandages and stockings, this paper compared the pressure of a bandage with that of stockings under the same design conditions. Two samples were used in this study. Sample A comprised six bandages having a width of 5 cm while Sample B was a stocking made of six bandages identical to those of Sample A knitted together with allowance. The yarn of the samples was made of Lycra and nylon. Clothing pressure was measured using an MST MK IV device for two wooden leg models (of sizes 9 and 12). The increasing rates of the circumferences of samples were 10% for the size-9 leg model and 50%–60% for the size-12 leg model. The bandage pressure was significantly higher than the stocking pressure at all measuring points on the two leg models. All circumference stretching rates increased while all width stretching rates decreased; i.e., all circumferences increased in length while all widths decreased. The circumference stretching rate increased significantly from the size-9 model to the size-12 model for the bandage and stocking. The width stretching rate did not reduce from the size-9 model to the size-12 model for the bandage but did for the stocking. The stocking therefore increased in circumference and reduced in width as the leg size increased, while the bandage increased in circumference without reducing in width. Multiple-regression analysis of the clothing pressure and circumference provided correlation coefficients of 0.980 for the bandage pressure and 0.960 for the stocking pressure. Three factors contributed to the relationships: the width reduction rate, circumference increasing rate, and radius of curvature at the measuring point. The proportions of variance of the width reducing rate versus circumference increasing rate versus radius of curvature were 45.9:26.1:28.0 for the bandage pressure and 40.8:35.0:24.2 for the stocking pressure. The proportion of the width reducing rate was higher for the bandage than for the stocking, while the proportion of the circumference increasing rate was higher for the stocking than for the bandage. In both bandage and stocking systems, the clothing pressure increases as the width reducing rate and circumference increasing rate increase and the radius of curvature decreases. The relations between the clothing pressure and radius of curvature for the bandage and stocking were significantly linear. From 3 to 8 cm, as the radius of curvature became large, the clothing pressure decreased. The relation between stocking pressure (Y) and bandage pressure (x) was linear: Y = 0.89x (R^2 = 0.984). As an example, the stocking pressure will be more than 11% less than the bandage pressure when the girth length was approximately 19 to 50 cm. However, according to the difference in proportions of variance, the width reducing rate of the stocking was smaller than that of the bandage. For the stocking, the clothing pressure likely decreased because the loop tension was dispersed structurally in the wale direction. The stocking pressure needs to be 11% greater than the bandage pressure to realize the same compression effect.

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