The effect of abdominal pressure stimulation on forearm blood flow volume

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The level of clothing pressure affects not only the wearer's comfort but also their health. Therefore, we examined the effect of abdominal pressure stimulation on forearm blood flow volume. Nine Japanese female subjects (average age = 22.3 ± 0.5 years) had their abdomens constricted with a 25-mm-wide band inside a belt for 2 minutes at four different pressure intensities from 2.7 hPa to 12.4 hPa. The pressure intensities were measured using the hydrostatic pressure-balanced method on their waistlines and pressure sensations were evaluated on a ratio scale. Using the ultrasound Doppler method, blood flow velocity was assessed on the subject's right arm. Using clothing pressure with a perfect fitting feeling (5.0±1.8 to 8.3±1.8 hPa), the blood flow volume increased, while a slightly tight feeling (12.0±1.4 hPa) decreased the blood flow volume. This finding indicates that clothing pressure has a significant effect on vascular physiology.
Keywords: *Clothing pressure, Pressure stimulation, Blood flow volume, Ultrasound Doppler method.*

1. Introduction

Compression wear for the body aids in reducing swelling and improving body shape, but its effects on human health and stress are relatively unknown and controversial. The level of clothing pressure affects not only the wearer's comfort but also their health [1].

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Every day, the abdomen is subject to various levels of clothing pressure that result from wearing items such as skirts, pants, stockings, and tights. In a previous study, we reported that wearing a waistband affected not only the magnitude of clothing pressure but also respiratory movement, as well as the thickness of subcutaneous fat [2]. However, the physiological effect on the human body was not reported. Therefore, in this study, the impact of abdominal pressure stimulation on forearm blood flow volume was examined. The overall goal of this study was to develop comfortable support wear, and we believe that the findings will serve as a foundation for future work.

2. Methods

All the experiments were performed in a climate-controlled room with the following atmospheric conditions: room temperature 24.5±0.3°C, relative humidity 50±0.5%, air current 0.11±0.16 m/s, and illumination 827±32 lx. Subjects entered the room 2 hours after eating and maintained a sitting posture for 1 h before the start of the experiment.

2.1 Description of subjects and experimental band

The experimental subjects were nine Japanese women (average age = 22.3 ± 0.5 years). They were non-smokers with no histories of systemic disease and were not engaged in physical training or dietary programs. Analysis of the subjects' physical characteristics demonstrated that the average body mass index (BMI) was similar to that for Japanese women of the same age. The average cross-sectional area of the ulnar artery was also measured using Doppler ultrasonography (Tab.1).
The experimental band had a width of 25 mm and was placed on the inside of the belt, which length was fixed using a double clip exerting 5.5 gf by the experimenter under perticipants' wearing feeling. It was a plain weave comprising nylon filaments (weft) and polyester span yarn (wrap). The tensile force and strain were measured using a Autograph (S-100, Shimazu, Kyoto, Japan) under the following conditions: grab width 100 mm and strain rate 50 mm/min. The samples were strained to 5 mm and relaxed (Fig.1). The experimental band was thick (1.2±0.2mm, n=9), so a material was hard to stretch.

2.2. Clothing pressure and evaluation of pressure sensation

The four pressure intensities for each subject were determined using a non-elastic band inside a belt (25 mm width) (Fig.1). The subject's waist was constricted with the belt for 2 min at four dif-

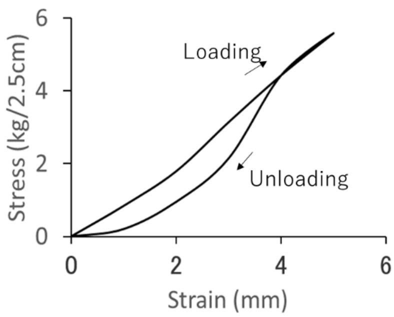

Fig.1 Stress–strain curve for an experimental band

ferent pressure intensities, which were measured using the hydrostatic pressure-balanced method combined with sensory evaluations.
Clothing pressure was measured using the hydrostatic pressure-balanced method [3] at 12 cross-sectional points on the waistline (Fig.2).

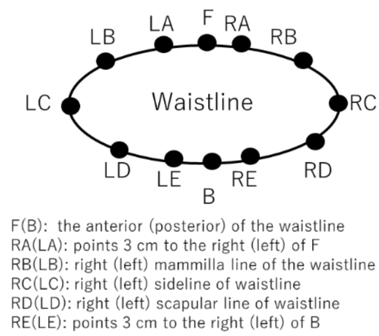

Fig.2 Measuring points for clothing pressure

F and B are the cross-sectional points along the middle between the anterior and posterior of the waistline. RA and LA (anterior) are points 3 cm to the right and left of F and are parallel to RE and LE (posterior), respectively. RB and LB (anterior) are points that to the right and left of F, in line with the mammilla, and parallel to the points RD and LD (posterior), respectively. The cross-section of the points RC and LC is perpendicular to the cross-section of the points F and B. Pressure sensation was evaluated using the ratio scale [4, 5]. The subjects evaluated themselves in terms of the pressure they felt when wearing the experimental band by completing a questionnaire (Fig.3). The subjects performed independent evaluations based on the pressure they felt when wearing the experimental band. Before putting on the experimental band, the subjects estimated what they considered to be "loose-fitting", "perfect-fitting," and "tight-fitting." The subjects were asked to indicate individual pressure sensations and to mark points on a line in the questionnaire corresponding to the three fittings. Next, the subjects tightened the experimental band to four different pressure intensities (from loose to tight) and marked a point on a line (in the questionnaire) proportional to that feeling. The length of the line connecting the points marked by the subjects (to indicate the loose-, perfect-, and tight-fitting feelings) was measured. Numerical values for the pressure sensation were obtained by assigning a score of zero (0) to the sensation without tightening and a score of one (1) to a perfect-fitting feeling. If the numerical value was >1, participants felt that the experimental band was tight, whereas, if it was <1, they felt that the band was loose.

2.3. Blood flow volume using Doppler ultrasonography

Ultrasound tomographic images and doppler ultrasound tomographic images were obtained using ultrasonic diagnostic equipment (TOSHIBA, Nemio XG

Tab.1 Subjects' physical characteristics

Characteristic (Unit)	Age (Year)	Height (m)	Weight (kg)	Waist girth (cm) Just on line	Waist girth (cm) 3 cm upper line	Waist girth (cm) 3.5 cm lower line	BMI (kg/m^2)	Cross-section area of blood vessel (mm^2)
Mean ± SD	22.3±0.5	1.59±0.04	52.4±6.8	70.9±6.7	70.7±5.3	74.1±7.6	21±2.7	1.9±1.269

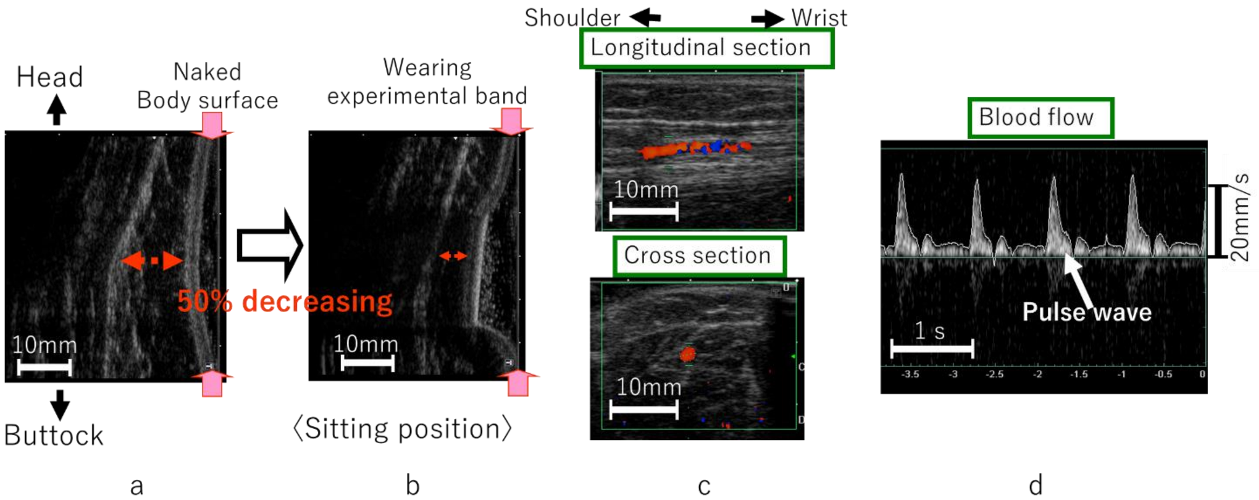

Fig.4 Ultrasound tomographic image and Doppler ultrasonographic image. Ultrasound tomography at RC (See Figure 2) are shown in: a. Naked body surface; b. Wearing an experimental band; c. Doppler ultrasonographic image of the right forearm ulnar artery (upper figure shows a longitudinal section and lower figure shows a cross-section) and d. Blood pulse waves

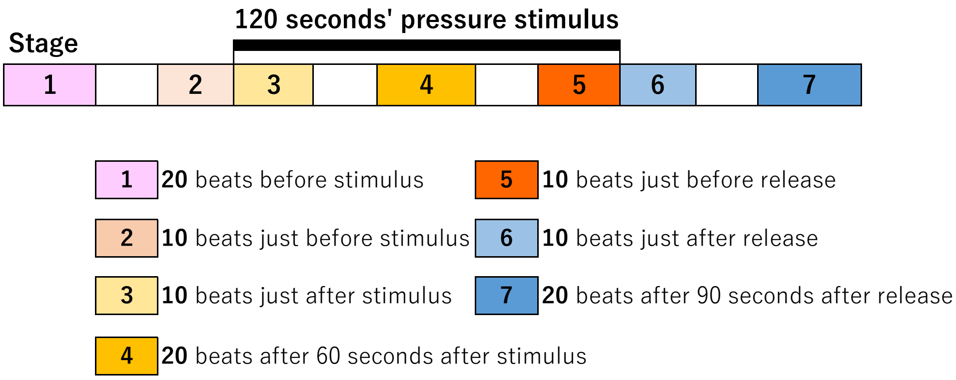

Fig.5 Pulse wave measurement time as an index of heartbeats and the 2-minute pressure stimulus

SSA-580A, Japan). An example of an ultrasound tomographic image of the abdomen is shown in Fig.4. The naked body surface at the abdomen (Fig.4a) and the same position with the subject wearing a band (Fig.4b) are shown. A 50% decrease in the thickness of the subcutaneous fat was observed. When the band was compressed on the abdomen, the subcutaneous fat moved away from or compressed under the band. Pressure stimulation affected not only the thickness of the subcutaneous fat but also the blood flow. A Doppler ultrasonographic image of the right forearm ulnar artery is shown in Fig.4c (upper figure shows a longitudinal section and lower figure shows a cross-section). The diameter of the target artery was calculated from the two images. The blood pulse waves shown in Fig.4d were used to calculate the blood flow speed.

The pulse wave measurement time as an index of heartbeats and the 2-minute pressure stimulus is shown in Figure 5. Subjects were stimulated with 2 minutes of pressure using the experimental band. One minute before pressure stimulation, pulse waves for the duration of 20 heartbeats were measured (Stage 1). Immediately before the start of the pressure stimulus (Stage 2) and shortly after (Stage 3), pulse waves lasting 10 heartbeats were measured. One minute after the beginning of the stimulus, pulse waves lasting 20 heartbeats were measured (Stage 4). Immediately before (Stage 5) the stimulus was ended (release of the experimental band) and after (Stage 6), pulse waves lasting 10 heartbeats were measured. Finally, 90 s after ending the stimulus, pulse waves lasting 20 heartbeats were recorded (Stage 7).

From these Doppler ultrasound tomographic images, blood flow volumes were calculated:

$$\text{Blood flow volume} = \text{Blood flow speed} \times \text{time} \times \text{blood vessel diameter} \qquad (1)$$

Blood flow speed and time were obtained from Fig.4d and blood vessel diameter was obtained from Fig.4c. In this way, the changes in blood flow volume (ml/s) associated with the four levels of pressure stimulation were calculated for the forearm ulnar artery. Paired t-tests were employed to assess the significance of differences because the blood flow volume differed among individuals. Furthermore, relative blood flows were calculated at each stage and significant differences before, during, and after the application of the stimulus were evaluated.

3. Results

3.1. Sensory evaluation of the clothing pressure

Figure 6 shows four levels of clothing pressure from I to IV and their associated pressure sensations. The four different intensities were 2.7±0.8, 5.0±1.8, 8.3±1.8, and 12.4±1.4 hPa (mean±SD). The pressure sensations were measured on a ratio scale in which “0“ was not wearing the waistband and “1“ was “a perfect fitting sensetion”. The associated feelings of the four pressure intensities were measured as 0.9±0.2, 1.0±0.1, 1.2±0.3, and 1.5±0.3 hPa, respecttively. The level that the subjects felt was too tight was 1.7±0.3 hPa in the basal feeling (See the second paragraph in 2.2). Therefore, this constricting condition was not used in the present study.

3.2. Blood flow volume using Doppler ultrasonography

Figure 7 shows a typical example of a blood pulse wave chart with pressure stimulation. Stimulation with level IV pressure intensity was employed at the location indicated by the pressure stimulation arrow. Clear wave pulses were observed after the fourth pulse (stage 3). However, 2 min after the start of stimulation (stage 5), the pulse was smaller than during stage 3. Furthermore, the experimental band was released between stages 5 and 6 (shown by the blue arrow). When the subject was not stimulated by the experimental band, the pulses were unclear (stage 6). Therefore, without clothing pressure, the blood flow was not clearly visible.

The relative blood flow was calculated using the method described in section 2.3; the results for all subjects are shown in Fig. 8. At pressure level II, that level is a

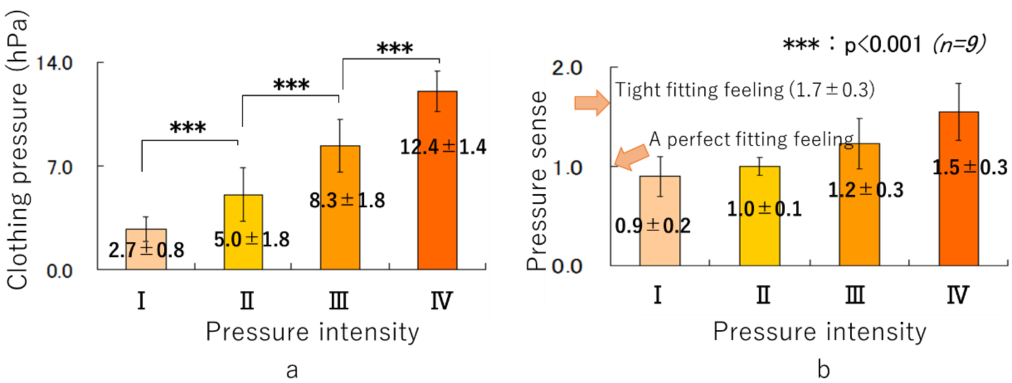

Fig.6 a) Four levels of clothing pressure from I to IV and b) The associated pressure sensation

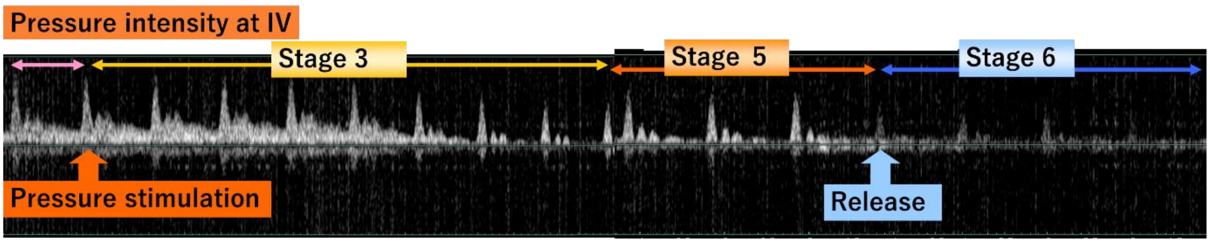

Fig.7 Typical example of a blood pulse wave chart with pressure stimulation

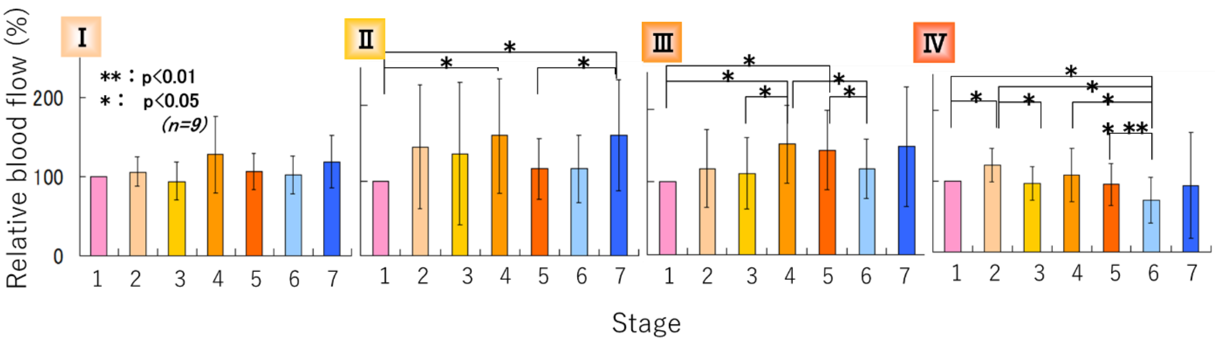

Fig.8 Effects of pressure stimulation with pressure intensities I to IV on relative blood flow

perfect fitting feeling (1.0±0.1), relative blood flow in stage 4 (1 min after pressure stimulus) and stage 7 (90 s after releasing the pressure stimulus) was signify-cantly increased compared with the control (stage 1). However at pressure level IV (clothing pressure: 12.0±1.4 hPa, pressure sensation: 1.5±0.3 hPa), relative blood flow in stage 2 (just after starting the pressure stimulus) was significantly decreased compared with the control (stage 1). Furthermore, at pressure levels III (clothing pressure: 8.3±1.8 hPa, pressure sensation: 1.2±0.3 hPa) and IV (clothing pressure: 12.4±1.4 hPa, pressure sensation: 1.5±0.3 hPa), the relative blood flow (just after stimulation; stage 3) was significantly decreased compared with just before stimu-lation (stage 2). This finding indicates that stimulation using clothing pressure with a perfect fitting feeling increased blood flow, but a tight-fitting feeling decreased blood flow. This is because the clothing pressure activated the sympathetic nerve, which narrowed the blood vessel and resulted in decreased blood flow.

5. Conclusion

Compression wear for the body aids in reducing swelling and improving body shape, but its effects on human health and stress are relatively unknown and con-troversial. The level of clothing pressure affects not only the wearer's comfort but also their health. Therefore, the impact of abdominal pressure stimulation on forearm blood flow volume was examined. Nine Japanese female subjects (average age = 22.3 ± 0.5 years) had their abdomens con-stricted with a 25-mm-wide band inside a belt for 2 min at four different pressure intensities from 2.7 hPa to 12.4 hPa. The pressure intensities were measured using the hydrostatic pressure-balanced method on their waistlines and pressure sensations were evalu-ated on a ratio scale. Using the ultrasound Doppler method, blood flow velocity was assessed on the subject's right arm. Using clothing pressure with a perfect fitting feeling (5.0±1.8 to 8.3±1.8 hPa), the blood flow volume increased, while a slightly tight feeling (12.0±1.4 hPa) decreased the blood flow volume.
This finding indicates that stimu-lation using clothing pressure with a perfect fitting feeling increased blood flow, but a tight-fitting feeling decreased blood flow. This finding indicates that clothing pressure for the waist has a significant effect on not only upper arm but also vascular physiology. This is because the clothing pressure activated the sympathetic nerve, which narrowed the blood vessel and resulted in decreased blood flow. Even people chose the clothes with perfect fitting feeling, the body keep good condition, however the clothes with tight fitting feeling affected their vascular system. So, from the viewpoint of vascular physiology the tight feeling clothes should not be chosen, even if it is nice design. The overall goal of this study was to develop comfortable support wear, and these findings will serve as a foundation for future work.

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