**An Analysis of Waist-nipper Factors that Affect Subjective Feeling and
Physiological Response
For the Design of Comfortable Women's Foundation Garments**

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Abstract: To obtain fundamental data for designing comfortable women's foundation garments, we analyzed waist-nipper factors that affect subjective feeling (compressive feeling, comfort and silhouette-satisfaction) and physiological responses (heart rate, skin blood flow, skin and oral temperature) in terms of materials, structure, size and clothing pressure. Seven women were employed as subjects. The clothing pressure was not dependent on the tensile property of individual parts of the materials used for waist-nipper, but on the tensile property of the waist-nipper viewed as a composite object, including structure. The changes in physiological variables were smaller with the waist-nipper having a large non-stretch area than with that having a small non-stretch area. However, the former type of waist-nipper caused higher compressive feeling and discomfort. When the waist-nipper mostly composed of stretch materials were worn, size had great effects on clothing pressure, subjective feeling and physiological responses. The effects of clothing pressure on physiological responses were highest at the center of the abdomen.

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1. Introduction

Women wear foundation garments in order to improve their apparent body shape, by redistributing their body fat. Many women seem to believe that foundation garments that compress hard against the body are more effective than looser ones for obtaining the desired effect.

Many previous studies have demonstrated that the pressure caused by foundation garments (clothing pressure) has negative physiological effects on the human body: wearing the strong compression girdles increased complaints of discomfort and exerted various kind of stress in the human excretions [1-5]. However, the relationships between foundation garments' effects on the body and the intensity, site and extent of clothing pressure have not yet been clarified. It appears important to women's well-being to design foundation garments that have few negative effects on human physiology while being adequate in terms of control.

The present study was undertaken to examine how differences in material, structure and size of a

waist-nipper (a foundation garment used to correct the waist and abdomen) would affect the pressure caused by this item on the waist and abdomen of the women wearing it. The study was also designed to analyze how these waist-nipper factors affect subjective feeling and physiological response of the women wearing it. We expected that the results of this study could serve as data for the design of waist-nippers with comfortable body support properties.

2. Subjects and methods

2.1 Subjects

The subjects of this study were seven healthy middle-aged women (ages: 41-56 years), this group desires to wear foundation garments. Table 1 shows the age, height, body weight, body fat, body mass index (BMI) and waist circumference of each subject. The waist circumference was measured at three points, i.e., the waist line (*WL*), a point 5cm above the waist (*WL + 5cm*) and a point 5cm below the waist (*WL - 5cm*). The mean figure of the subjects was approximately the

Table 1 Physical characteristics of subjects.

Subject No	Age (years)	Height (cm)	Body weight (kg)	Body fat (%)	BMI*	Waist circumference (cm)		
						WL	WL + 5cm	WL - 5cm
1	54	167.0	59.4	24.3	21.3	70.0	71.4	81.6
2	46	153.5	54.0	28.4	22.9	66.2	68.8	78.2
3	49	160.0	56.2	23.2	22.0	68.0	70.3	77.0
4	41	163.0	58.4	29.9	22.0	74.5	75.5	85.2
5	50	158.5	64.0	31.1	25.5	75.7	78.2	86.7
6	51	154.0	48.6	25.1	20.5	72.1	72.2	83.6
7	43	161.0	60.2	30.9	23.2	78.0	79.3	87.5
Mean	47.7	159.6	57.3	27.6	22.5	72.1	73.7	82.8
Standard deviation	4.6	4.8	4.9	3.3	1.6	4.3	4.0	4.1

* BMI = Body weight (kg) / Height (m)²**Table 2** Structural properties of materials used for waist-nippers.

Sample	Knitted structure	Contents (%)	Yarn count (dtex)	Gauge (-)	Thickness* (mm)	Weight (g/m ²)
W	Power-net	E 68	55	64	0.42	240
		U 32	462			
B	Power-net	Ny 82	78	48	0.47	184
		U 18	308			
N	Power-net	Ny 45	88	56	0.48	199
		U 16	308			

E: polyester, U: polyurethane, Ny: nylon

* Thickness is measured under 0.6 kPa

same of the mean figure for Japanese women [6].

2.2 Test samples

Table 2 shows details of the three types of waist-nippers used for this study. All of these are commercially available in Japan. The stretch part of each sample was made of power-net. The polyurethane fibers used for Sample **W** had a larger yarn count than the fibers used for the other samples. The gauge of Sample **W** was larger than for the other samples. The gauge of Sample **N** was larger than that of Sample **B**.

Fig. 1 shows the structures of the three waist-nippers. Samples **W** and **B** were composed of a double layers of power-net panel, a single layer of power-net panel and a non-stretch panel for the abdomen (marked with wave lines). The area of the non-stretch part was smaller on Sample **N** than on Samples **W** and **B**. Most of Sample **N** was composed of double layers of power-net and stretch lace. Metal coil bones were inserted in six points (marked with black lines) to minimize back ling deformation of waist-nipper.

Each of these three types of waist-nipper was obtained in two different sizes: **L** size (about 5% smaller than the waist circumference) and **S** size (about 15% smaller than the waist circumference).

2.3 Tensile properties of the materials

It is known that the clothing pressure is determined

Fig. 1 Structures of waist nippers

□ double layers of power-net, ▨ single layer of power-net
 ▩ double layers of power-net and stretch lace
 ▭ non stretch parts, — metal coil bones

by the radius of curvature of the body and the tensile force produced by the stretch of the clothing fabric when worn [7].

First, we measured the tensile properties of each material. This measurement was performed using a KES-FB1 (Kato Tech Co., Ltd., in Japan), with the tensile speed set at 0.4mm/sec and the maximum load set at 0.98N/cm.

Fig. 2 shows the results of these measurements. The tensile resistance of the single layer of power-net was greatest in the order of Sample **W** > Sample **N** > Sample **B**. Thus, tensile resistance tended to be greater as polyurethane yarn count and gauge increased. The tensile resistance of the double layers of power-net was about twice as great as that of the single layer. Like the single layer of power-net, the double layers had the greatest tensile resistance in Sample **W**. The tensile resistance of the double layers of power-net in Samples

Fig. 2 Tensile properties of materials used for waist-nippers.

B and *N* were similar. For each sample, the tensile resistance of the non-stretch part was about 10 times that of the stretch part.

2.4 Experimental methods

This study was conducted in an artificial climate chamber where the temperature was controlled at 27.5 ± 1.4 and the relative humidity at $31 \pm 4.5\%$. Each subject entered the chamber 30 minutes or more before the start of the experiment so that she could become accustomed to the experimental environment. Each subject wore a brassiere, a girdle, an undershirt with a three quarters sleeve length (made of 69% Nylon, 24% cotton and 7% polyurethane), and a semi-tight skirt extending to the knee (made of 100% cotton), each of which was obtained specifically for this experiment. The subject, wearing these clothes, remained sitting still for 30 minutes. Then, the subject put on a control foundation garment (Sample *C*, composed of double layers of power-net to allow uniform thermal insulation, designed to cause almost no pressure against the body) to collect baseline data. At that time, the subject took sequential postures from supine to sitting and then standing. Each posture was held for 5 minutes, and clothing pressure and physiological variables were measured during this period. The subject then put on *L* size and then *S* size of waist-nipper in ascending order. While she changed her posture sequentially as described for baseline data above, clothing pressure and physiological variables were measured (Fig. 3).

In this kind of study, baseline data is often collected when the subject wears no waist-nipper. However, the thermal insulation of clothing varies greatly depending on whether or not the subject wears a waist-nipper. Differences in thermal insulation can markedly affect human physiology. Therefore, to minimize differences in thermal insulation, we obtained values for physiological variables during the use of Sample *C* to use

Fig. 3 Experimental protocol.

as baseline data.

2.5 Measurement of clothing pressure

The pressure caused by a waist-nipper in women wearing it was measured at intervals of 5 seconds, using a clothing pressure measuring device AMI3037 (AMI Co., Ltd., in Japan) [8, 9]. The pressure sensor used was a T-shaped air bag made of thin (0.035mm) polypropylene. A small amount (about 0.2ml) of air was infused into the air bag to make its thickness about 1 mm. The Teflon tube attached to one end of the air bag was connected to a pressure transducer and a recording device. Clothing pressure was measured at seven points of the body surface, i.e., three points on the anterior part of the (*WL* + 5cm), and one point each on the anterior, lateral and posterior part along the waist line (*WL*) and the anterior center of the (*WL* - 5cm) part.

2.6 Physiological variables measured and experimental protocol

The physiological variables measured were heart rate (*HR*), skin blood flow (*Bs*), skin temperature (*Ts*) and oral temperature (*Tor*). Heart rate was measured with a Polar Vantage XL (Polar Electro Oy, in Finland) at intervals of 5 seconds. Skin blood flow was measured at intervals of 5 seconds, using an ALF21 (Advance Co., Ltd., in Japan) and attaching its circular probe (10mm in diameter) to the ventral side of the first toe of the right foot. Skin temperature was measured at intervals of 5 seconds, using a thermocouple type temperature sensor (ANRITSU METER Co., Ltd., in Japan), at six points of the body surface (the chest, upper arm, thigh, lower leg, ventral side of the first toe of the right foot and the right thumb). Oral temperature was measured using a thermistor sensor.

To minimize the effects of menstrual cycles and circadian rhythm on body temperature, the experiment was carried out during the early follicular phase of each woman, and two sizes of one type of waist-nipper were tested for each woman on each day of the experiment. The subject took a meal 2 hours or more before the experiment and took no food or water during the experiment. The wearing order of three types of waist-nippers was randomized.

At the end of the experiment on each day, the subject wore *L* and *S* size waist-nipper in this order again and evaluated compressive feeling, comfort and silhouette-satisfaction by semantic differential method on a 7-grade scale.

3. Results and discussion

3.1 The clothing pressure caused by waist-nippers

Fig. 4 shows the mean values of clothing pressure measurement. In this figure, the *L* and *S* attached to the name of samples (e.g., W_L and W_S) indicate *L* and *S* sizes, respectively.

Clothing pressure was higher with *S* size samples than with *L* size samples. However, the influence of size on clothing pressure varied among different points of the body surface and was smaller at some points. Clothing pressure was high in the order of Sample $W > Sample B > Sample N$. Thus, clothing pressure was high with Sample *W* which had high tensile resistance. However, the clothing pressure differed between Samples *B* and *N* which had similar tensile resistance. The clothing pressure caused at point (c) (coil bone part of waist-nipper) and (g) (hypogastric part) by *S* size of Samples *W* and *B* was as high as about 4kPa, equivalent to the physiological limit [10]. However, the clothing pressure at these points caused by *S* size of Sample *N* was about 1-2kPa lower. The clothing pressure at point (c) had been expected to be similar for all samples. In practice, however, the pressure at this point caused by Sample *N* was about half the pressure caused by Samples

Fig. 4 Clothing pressure of waist-nippers in standing posture.

W and *B*. This suggests that the tensile property of materials in the vicinity of coil bone parts of waist-nipper contributes to the intensity of clothing pressure. The lower pressure caused by Sample *N* seems to be explained by the fact that one side of Sample *N* was composed of non-stretch material and the other side was made of stretch material, unlike Samples *W* and *B* whose both sides of coil bone parts of waist-nipper were made of non-stretch material. At point (g), the smaller non-stretch area with Sample *N* (i.e., the different structure of Sample *N*) seemed to have greatly contributed to reducing the clothing pressure.

These results suggest that the actual clothing pressure does not necessarily reflect the tensile property of individual parts of the materials but is depending on the tensile property of the waist-nipper viewed as a composite object, including structure.

3.2 Subjective evaluations

Fig. 5 shows the results of subjective evaluations. Higher scores mean higher compressive feeling, higher comfort or higher silhouette-satisfaction. A negative correlation was noted between compressive feeling and comfort; an increase in the compressive feeling led to less comfort. The effect of size on the compressive feeling was large. The comfort of Sample *N* was affected more greatly by size than those of Samples *B* and *W*. Sample N_L that had the lowest clothing pressure was evaluated as most comfortable. The silhouette-satisfaction tended to be greater as the compressive feeling became higher. The silhouette-satisfaction was relatively low for Sample *N*, although the difference among different samples was small.

3.3 Effects of clothing pressure on physiological variables

For each physiological variable measured (*HR*, *Bs*, *Ts* and *Tor*), the mean for 5 minutes in each posture (supine, sitting and standing) was calculated. Because physiological variables show large inter-individual and intra-individual variances, the changes of each variable in each subject, relative to the baseline level on each day of experiment (measured in the supine posture while wearing Sample *C*), was analyzed.

(1) Effects of clothing pressure on heart rate

Fig. 6 shows changes in heart rate (ΔHR). Changes in heart rate while wearing Sample *C* and *L* and *S* sizes of each waist-nipper in this order are shown here for each body posture. When Sample *C* was worn, heart rate increased as the body posture was changed from the supine posture to the sitting posture and then to the standing posture, probably reflecting an increase in the

Fig. 5 Relationships between compressive feeling and comfort, silhouette-satisfaction.

Fig. 6 Changes in heart rate (ΔHR) during experiments.

Fig. 7 Changes in skin blood flow (ΔB_S) during experiments.

level of energy metabolism [11].

Heart rate tended to decrease slightly while a waist-nipper was worn. Assumed that energy metabolism is the same in all postures, cardiac output (=stroke volume $\times$ heart rate) will be the same irrespective of the type of waist-nipper worn [11]. The results indicate that compression of the abdomen increased the venous return through its respiratory pumping effect, leading to an increase in stroke volume and a decrease in heart rate while wearing a waist-nipper. However, the amount of changes in heart rate differed little among different samples.

(2) Effects of clothing pressure on skin blood flow

Fig. 7 shows changes in skin blood flow (ΔB_S). The change in skin blood flow while wearing Sample C in the sitting or standing posture was on the minus side, probably reflecting a hydrostatic pressure difference.

At a temperature of about 28°C at which thermal vasoconstriction is unlikely to occur, we have reported the skin blood flow in the peripheral parts of decreased greatly as the clothing pressure at body became higher

[12-15]. In this study, it was also noted that the skin blood flow in the toe decreased while wearing a waist-nipper and the decrease was greater with S size than with L size. When Sample N mostly composed of stretch material was worn in the supine posture and standing posture, the skin blood flow tended to decrease greatly although the clothing pressure produced by this sample was lower than that produced by any other sample.

(3) Effects of clothing pressure on skin temperature

Fig. 8 shows changes in skin temperature (ΔT_s). At toe, skin temperature decreased greatly. Considering the knowledge that skin temperature is closely related to skin blood flow, the change in skin temperature is attributable to the above-mentioned decrease in skin blood flow [11].

Skin temperature at finger was decreased more greatly by S size sample than by L size sample. However, the decrease at finger was smaller than that at

Fig. 8 Changes in skin temperature (ΔT_s) at toe and finger during experiment.

toe. This suggests that the effect of compression by the waist-nipper on blood circulation is greater in the area below the compressed part than in the area above it. It was thus shown that wearing a waist-nipper could greatly reduce the skin temperature at toe.

The mean skin temperature, determined by the Ramanathan's four-point method [16], tended to be decrease more greatly by *S* size than by *L* size. Although there was no significant difference in the amount of decrease in skin temperature among different samples, the decrease was greatest with Sample *N* which had produced the lowest clothing pressure.

(4) Effects of clothing pressure on oral temperature

Fig. 9 shows changes in oral temperature (ΔT_{or}). The baseline level of oral temperature, which is an indicator of deep body temperature, increased as the body posture was changed from the supine posture to the sitting posture and then to the standing posture. This probably reflects an increase in the level of energy metabolism [11]. Wearing waist-nippers reduced the oral temperature. For each sample, the decrease in oral temperature was greater with *S* size sample than with *L* size sample. The decrease in oral temperature tended to be greater with Sample *N* which had shown a larger decrease in mean skin temperature. The oral temperature while wearing Sample *N* tended to be closer to the baseline level recorded in the supine posture.

Thus, Sample *N* had greater effects on blood circulation, although the clothing pressure caused by this sample was lower than that caused by any other sample. The difference in the amount of effects between *L* and *S* sizes also tended to be greater with Sample *N*. Sample *W* resembled Sample *B* in terms of effects on blood circulation. The size in Samples *W* and *B* did not markedly affect the effects of these samples. Sample *W*,

Fig. 9 Changes in oral temperature (ΔT_{or}) during experiment.

which had the highest clothing pressure, tended to have small effects on blood circulation. These results suggest that a waist-nipper mostly composed of stretch material (Sample *N*) compresses the entire waist and abdomen, and that when waist-nippers having more non-stretch material (Samples *W* and *B*) are worn, a gap is created in the non-stretch part facing the skeleton, etc., thus lessening the effect of the waist-nipper on blood circulation. However, since the latter types of waist-nippers can compress the anterior part of the human body extensively and intensely, the compression will be higher. Furthermore, since these types restrict stroke volume, the sense of discomfort will be higher.

3.4 Relationships between clothing pressure at each point of body surface and physiological variables

We attempted to identify the points of the body at which compression by waist-nipper exerts great physiological effects.

Table 3 shows the correlation coefficients between the clothing pressure at each point of body and changes in physiological variables (ΔHR , ΔB_s , ΔT_s and ΔT_{or}). At point (d), a significant correlation was noted between

Table 3 Correlation coefficients between the clothing pressure and physiological variables.

Measurement points	ΔHR	ΔBs	$\overline{\Delta Ts}$	ΔTs		ΔTor
				Toe	Finger	
(a)	0.11	-0.25	-0.06	0.00	-0.26	0.05
(b)	-0.04	-0.10	0.15	-0.01	0.11	-0.27
(c)	0.11	-0.10	0.00	0.19	0.26	-0.30
(d)	0.08	-0.52**	0.42*	-0.27	0.01	-0.36*
(e)	0.23	-0.20	0.20	0.21	-0.14	-0.24
(f)	0.23	-0.31	-0.08	0.22	0.15	-0.34*
(g)	0.12	-0.17	0.00	0.05	-0.07	-0.20

*: $p < 0.05$, **: $p < 0.01$

clothing pressure and ΔBs , ΔTs and ΔTor . This indicates that the effect of clothing pressure on physiological variables is highest at the anterior central part along the waist line (WL). We concluded that when designing a waist-nipper with less effect on blood circulation, it is essential to reduce clothing pressure in this part.

4. Conclusions

In the present study, the waist-nipper factors that affect clothing pressure, subjective feeling and blood circulation of users were analyzed in terms of material, structure and size.

The study revealed that the clothing pressure produced by waist-nippers is more dependent on the tensile property of the waist-nipper viewed as a composite object (including structure) than on the tensile property of the individual parts of materials used. Regarding the effects of waist-nippers on blood circulation, the study disclosed that the effects differed greatly depending on the area of the non-stretch part of the waist-nipper, and that changes in physiological variables were smaller with waist-nipper having a large non-stretch area and larger with waist-nippers having a small non-stretch area. However, the former type caused higher compressive feeling than the latter type and was perceived by the user as more uncomfortable. Thus, changes in physiological variables were not always identical with the subjective feeling, and structure of the waist-nipper was found to greatly affect these factors. When waist-nippers mostly composed of stretch material were worn, size had great effects on changes in physiological variables, clothing pressure and subjective feeling. However, the silhouette-satisfaction was little affected by structure or size of waist-nippers. The compressive feeling and comfort were largely affected by the size of waist-nippers. The clothing pressure

affected the silhouette-satisfaction but it differed little among different samples. Analysis of the correlation between the clothing pressure at each point of waist-nipper and changes in physiological variables revealed that the clothing pressure at the center of the abdomen had the greatest impact on blood circulation. This indicates that when designing a waist-nipper, it is essential to reduce the clothing pressure in this part.

In the future, it is necessary to study the effects of the clothing pressure by foundation garments on other physiological variables such as indicators of respiratory function.

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