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A Pilot Study of Posture Change When Wearing High-Heeled Shoes and Pantyhose

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ABSTRACT

Women often wear high-heeled shoes and pantyhose to appear taller and to make their legs look longer. Measurements of myoelectric potentials showed a significant positive correlation between muscle activity for bare feet and wearing heels and our designed pantyhose. We measured the pelvis rotation when participants wore pantyhose and heeled shoes from two-dimensional imagery. The wearing of shoes resulted in a pelvis angle larger than that for bare feet whereas the wearing pantyhose resulted in a smaller pelvis angle. Specifically, the pelvis rotated backward when wearing high heels. When wearing pantyhose, the pelvis rotated forward, which is a potential explanation for the muscle activity of bare feet being similar to the activity when wearing pantyhose B with high heels.

Keywords: Pelvic tilt, Pantyhose, High heels, Women, Two-dimensional image

INTRODUCTION

Women desire to be taller and to make their legs look longer and thus often wear high-heeled shoes and pantyhose (Kim et al., 2013). Our final goal is to develop pantyhose that reduce muscle fatigue (Wiedemeijer and Otten, 2018; Barkema et al., 2012; Simonsen, 2014; Blanchette et al., 2011) when wearing high-heeled shoes. We previously applied the panty part of support half-pants that we developed in 2016 to the design (Mitsuno and Hibino, 2016) of two types of pantyhose that provide pressure that varies appropriately for each body part (Kondo and Mitsuno, 2022; Mitsuno and Kondo, 2022). The measurement of myoelectric potentials at eight points on the lower extremities showed positive correlation between muscle activity for bare feet and muscle activity when wearing high heels (Mitsuno and Sugawara, 2022) and pantyhose B/when wearing low heels and pantyhose A (Mitsuno and Kondo, 2022a). Therefore, even in the case of wearing high-heeled shoes, we can reproduce muscle activity close to that of bare feet by wearing pantyhose that match the shoes (Mitsuno and Kondo, 2022b). We consider that this result relates to the change in posture when wearing shoes and pantyhose, and we thus investigated the changes in posture and the use of muscles in the present study.

EXPERIMENT

Participants and experimental pantyhose and shoes: The participants were three Japanese women in their twenties, whose physical characteristics were typical of Japanese females in their twenties, although somewhat slender (height: 158.8 ± 1.4 cm, weight: 50.5 ± 5.3 kg, waist girth: 66.9 ± 2.8 cm, hip girth: 90.3 ± 3.4 cm). Two sizes of pantyhose were examined in this study, namely sizes M and L. Eight-eight percent of Japanese women are covered by the JIS standards for sizes S, M and L (corresponding to heights of approximately 150, 158 and 166 cm). The pantyhose used in this study were sized M. The material and knitting structures of the two experimental pantyhose comprised a single covered yarn of 20D (2.2 tex) polyurethane/12D (1.3 tex) nylon in the legs. In the panty part, the thickness of the nylon yarn varied from 12D (1.3 tex) to 30D (3.3 tex), and wooly nylon yarn was added to increase the strength in pantyhose A. Using the design of pantyhose A as a baseline, the single covered yarn was partially doubled in pantyhose B to change the supporting pressure of the panty part (Mitsuno and Kondo, 2023a). The participants wore three types of shoes with different heel heights; i.e., running shoes with a heel height of 9.8 ± 10.3 mm, low-heeled shoes with a heel height of 37.4 ± 8.3mm and high-heeled shoes with a heel height of 79.9 ± 7.8 mm. All shoes belonged to the participants.
Measurement of posture from a two-dimensional image: The layout of the participant and experimental equipment is shown in Figure 1, and a typical experimental image is shown in Figure 2. The left diagram in Fig. 1 shows the arrangement of the equipment used to confirm that the participant was standing perpendicular to the camera. The participants were asked to wear the 10 reflective markers shown in the photograph of Fig. 1 at the target positions in advance (see the left figure of Fig. 2). A small cap with a reflective marker and a guide rod was attached to the top of the head with a hair elastic band (see Fig. 1, right figure ① and Fig. 2, left figure).

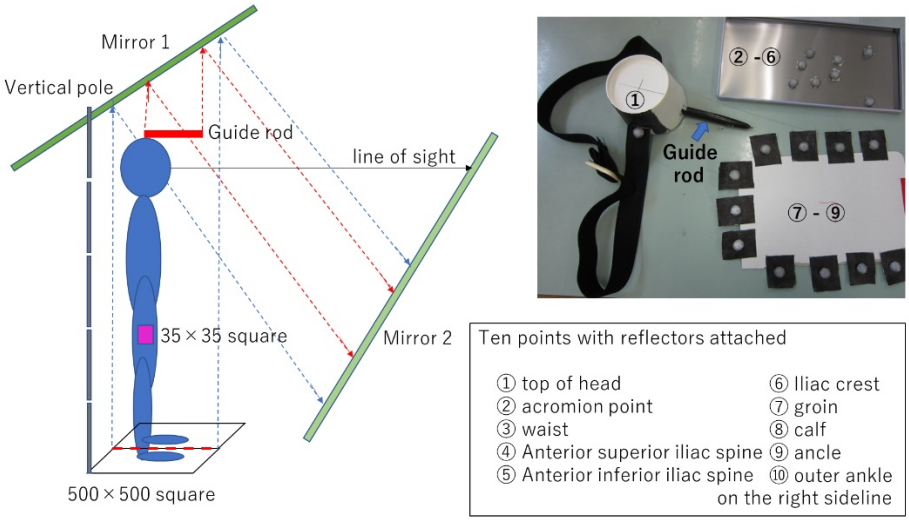

Figure 1: Layout of the participant and experimental equipment.

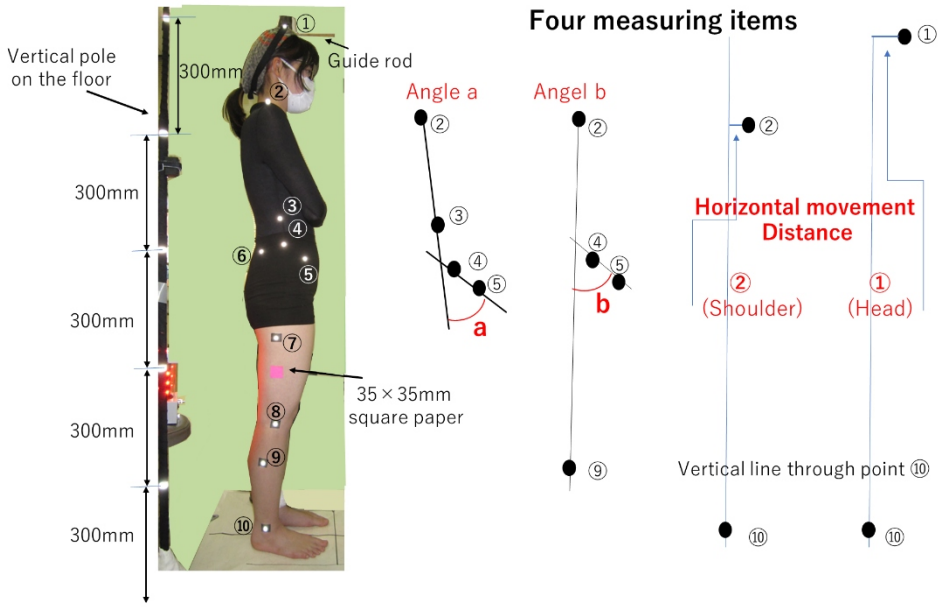

Figure 2: Typical experimental image and the four measuring items.

A hand-made reflector on a hemisphere with a diameter of 10 mm was used. Reflectors ② to ⑥ were taped to measurement points from the acromion to the pelvis. Reflectors ⑦ to ⑨ were taped to measurement points from the groin to the outer ankle (see the photograph in Fig. 2). Distances were determined using a 35-mm-square piece of paper attached to the thigh and a vertical pole with a length of 1800 mm and marked 300-mm intervals in the image.

Two mirrors, a 500-mm square at the foot, and the guide rod set on top of the head were used to confirm that the right side of the participant's body was perpendicular to the camera, i.e., the participant's body was not twisted. The 500-mm-square on the floor was drawn horizontally across a bisector (see the red dotted line in the left diagram of Fig. 1). The angle of mirror 1 was adjusted and the twist of the participant's body axis was eliminated such that the guide rod on the top of the head (red solid line) and the bisector of the foot (red dashed line) overlapped in mirror 2. Postures were then photographed under four experimental conditions, namely being barefoot, wearing three types of shoes with different heel heights without pantyhose, wearing only the two types of pantyhose, and wearing a combination of the three types of shoes and two types of pantyhose. The photography was conducted three times interrupted standing posture by sometimes stepping on per each condition. The four measurement items are shown at the right of Fig. 2. The angle *a* between line ②–③ and line ④–⑤ and the angle *b* between line ②–⑨ and line ④–⑤, which are indices of the rotation of the pelvis, were obtained. Additionally, the distances that the head ① and shoulder ② moved horizontally with reference to the outer ankle ⑩ was measured.

RESULTS AND DISCUSSION

We took the angles formed by the body axis I connecting the acromion point and the waist (line ②–③ in Fig. 2), the body axis II connecting the acromion point and the calf (line ②–⑨ in Fig. 2), and the line connecting the iliac crest and the anterior superior iliac spine (line ④–⑤) as angles *a* and *b*. Additionally, the horizontal distances between the outer ankle and the top of the head/acromion were determined. These four observation items are shown in Figure 3, and the changing rates are shown in Figure 4.

Owing to the small number of participants, a significant difference test was not possible, but the horizontal movements of the head and shoulders and the angles *a* and *b* did not change greatly when wearing shoes without pantyhose and when barefoot (see blue bars graph in the figure). However, when pantyhose A (orange bars) and B (gray bars) were worn, the differences among the three bars of the angles *a* and *b* in Fig. 3 were smaller, and the positions of the head and shoulders moved horizontally behind the outer ankle. These results need to be investigated further for a greater number of participants.

The coefficients of correlation between the four observation items, namely angles *a* and *b* and the horizontal movements of ① the head and ② the shoulder (see Fig. 2), showed a significant positive correlation between angles *a* and *b* and a significant positive correlation between the horizontal movements of ① the head and ② the shoulder. There was also a significant negative correlation between the angle *a*/*b* and the horizontal movement of ① the head. Therefore, smaller angles *a* and *b* corresponded to greater forward rotation of the pelvis and forward movement of the head.

Furthermore, the coefficients of correlation between the four observation items mentioned above and the participants' height, girth, and body

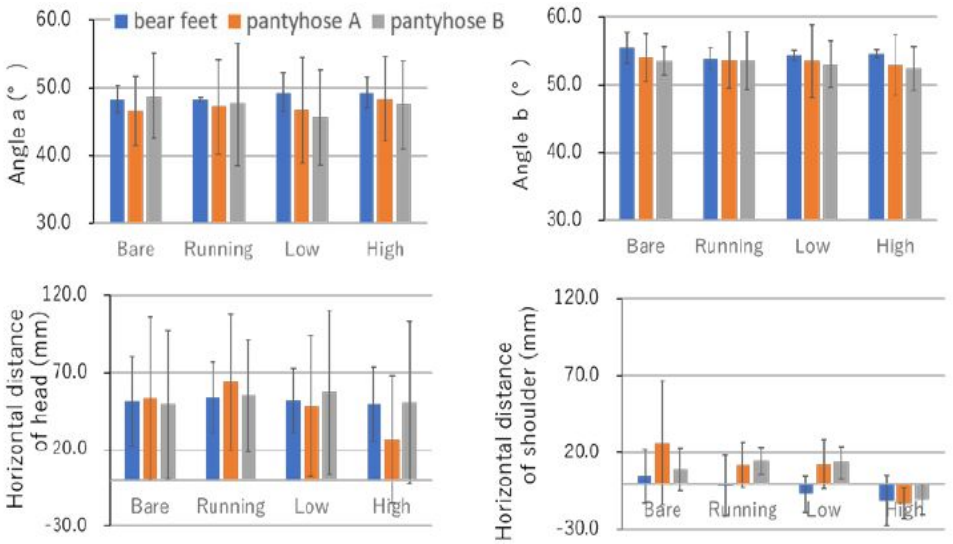

Figure 3: Results of the four observation items.

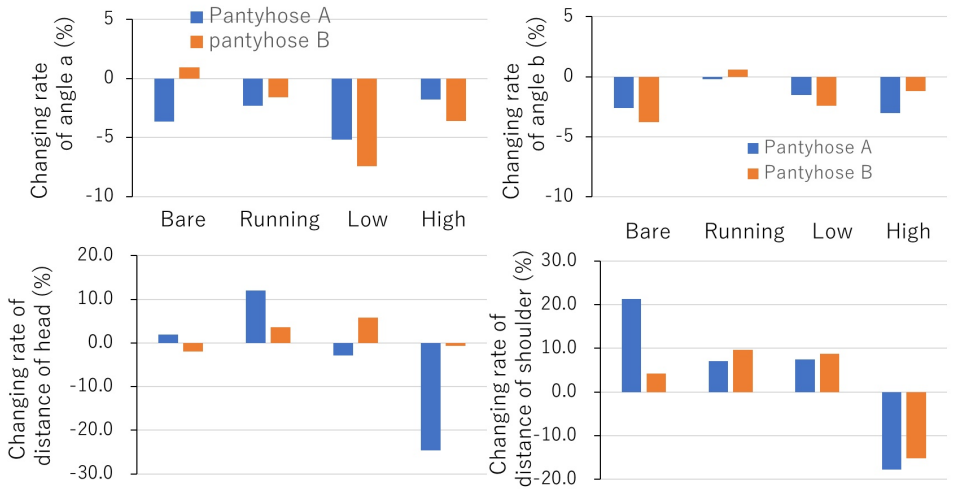

Figure 4: Change rates for the four observation items with reference to the results for bare feet.

composition were calculated. There was no significant correlation between the angle *a*/*b* and the horizontal movement of ① the head/② the shoulder under the conditions of being barefoot and wearing shoes with the three different heel heights. We therefore calculated the correlation coefficient when wearing only pantyhose and when wearing pantyhose and the three types of shoes. Table 1 gives the coefficients of correlation between angle *a* and the participants' physical characteristics. There were significant negative correlations between angle *a* when wearing shoes/pantyhose and the height items, whereas there were significant positive correlations between angle *a* and the girth and body composition items.

There was a significant negative correlation between angle *a* when wearing pantyhose A/B without shoes and the height items (height/groin), in that there was a greater forward tilt of the pelvis when pantyhose were worn by a participant who was taller or had longer legs. Additionally, there was a greater backward tilt of the pelvis when the participant had a thicker trunk or was fatter. These correlations remained significant under the experimental conditions of wearing running shoes and pantyhose A, low-heeled shoes and pantyhose B, and high-heeled shoes and pantyhose A/B. It was thus found that taller participants tilted their pelvis forward more when wearing pantyhose than when barefoot, and, especially in the case of wearing pantyhose B, it was found that the participants leaned forward when the inguinal meridian was higher. However, no significant difference was observed when the participants were barefoot and when the three types of shoe were worn without pantyhose. It is thus considered that this result was due to the wearing of pantyhose. Previous reports showed that the height of the groin was 2 cm higher and the legs thus looked longer when pantyhose B was worn than when pantyhose B was not worn. The reason for this is that

Table 1. Coefficients of correlation between the participants' physical characteristics and rotation angle of the iliac crest when wearing pantyhose A and B.

Shoes	Pantyhose	Height item				Girth item						Body composition	
		Height		Grain		Waist		Hip		Tight		Body fat	
		Correlate	Judge	Correlate	Judge	Correlate	Judge	Correlate	Judge	Correlate	Judge	Correlate	Judge
Bare	A	−1.000	**	−0.998	*	0.994		0.997	*	0.999	*	0.992	
	B	−0.998	*	−1.000	**	0.999	*	0.990		0.993		0.998	*
Running	A	−0.994		−0.999	*	1.000	**	0.984		0.988		1.000	**
	B	−0.986		−0.973		0.962		0.996		0.993		0.957	
Low	A	−0.969		−0.983		0.990		0.948		0.956		0.993	
	B	−0.998	*	−0.992		0.986		1.000	**	1.000	**	0.982	
High	A	−0.991		−0.998	*	1.000	* *	0.979		0.983		1.000	**
	B	−1.000	**	−0.997	*	0.993		0.998	*	0.999	*	0.990	

pantyhose B has the same leg design as pantyhose A, but only the panty part has a double structure for the abdomen and back, which has the effect of tilting the pelvis forward.

Angles *a* and *b* were larger when wearing shoes than for bare feet and were smaller when wearing pantyhose, i.e., the pelvis rotated backward when wearing high heels. When wearing pantyhose, the pelvis rotated forward, which potentially explains why the muscle activity for bare feet was similar to that when wearing pantyhose B with high heels. Additionally, the posture of the lower leg changed, but balance was achieved by changing the position of the head and shoulders. When a participant wore high heels and became taller, her shoulders moved back to balance the head moving forward. In future work, it will be necessary to increase the number of participants and classify them according to their standing posture while barefoot to investigate these relationships.

CONCLUSION

Women desire to be taller and to make their legs look longer and thus often wear high-heeled shoes and pantyhose. Three participants of 20's women who wore designed two types of pantyhose A/B with three kinds of height heels shoes. The measurement of myoelectric potentials at eight points on the lower extremities showed positive correlation between muscle activity for bare feet and muscle activity when wearing high heels and pantyhose B/when wearing low heels and pantyhose A. Therefore, even in the case of wearing high-heeled shoes, we can reproduce muscle activity close to that of bare feet by wearing pantyhose that match the shoes. We consider that this result relates to the change in posture when wearing shoes and pantyhose, and we thus investigated the changes in posture and the use of muscles in the present study. Participants' postures were then photographed under four experimental conditions, namely being barefoot, wearing three types of shoes with different heel heights without pantyhose, wearing only the two types of pantyhose, and wearing a combination of the three types of shoes and two types of pantyhose. The angle a between line shoulder to waist points and line anterior superior iliac spine to anterior inferior iliac spine points, and the angle b between line shoulder to calf points and line anterior superior iliac spine to anterior inferior iliac spine points, which are indices of the rotation of the pelvis, were obtained. Angles a and b were larger when wearing shoes than for bare feet and were smaller when wearing pantyhose, i.e., the pelvis rotated backward when wearing high heels. When wearing pantyhose, the pelvis rotated forward, which potentially explains why the muscle activity for bare feet was similar to that when wearing pantyhose B with high heels. Additionally, the posture of the lower leg changed, but balance was achieved by changing the position of the head and shoulders. When a participant wore high heels and became taller, her shoulders moved back to balance the head moving forward. In future work, it will be necessary to increase the number of participants and classify them according to their standing posture while barefoot to investigate these relationships.

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