

## Interface Pressures Derived from Oversize Compression Stockings

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**Objectives:** To clarify interface pressures (IP) derived from class II and III oversize stockings.

**Methods:** Healthy volunteers with legs fitting size S (n = 10), M (n = 6), or L (n = 6) stockings wore class II and III stockings of various sizes up to 5L. IPs were measured in the supine and the standing position with each stocking on.

**Results:** In the subjects with size S legs, the IPs in the standing position while wearing S and M class III stockings were  $43.5 \pm 4.7$  and  $40.4 \pm 5.4$  mmHg respectively. These IPs were significantly higher than the IP while wearing the S size class II stocking ( $33.3 \pm 5.9$  mmHg). IPs derived from L, LL, 3L, 4L, 5L class III stockings were not significantly different from IP with the S size class II stocking. The results were similar for the subjects with size M legs while wearing the size M and L class III stockings and for the subjects with size L legs while wearing the size L and LL class III stockings vs. the appropriate size class II stocking.

**Conclusion:** Based on these findings, a larger size class III stocking can provide similar or even higher IPs compared to an appropriate size class II stocking.

**Keywords:** compression stockings, interface pressure, stiffness, chronic venous insufficiency

### INTRODUCTION

Compression therapy is the primary treatment for chronic venous insufficiency (CVI). The necessary pressure to treat CVI, based on clinical severity, is 30–40 mmHg for CEAP classes 4 to 6, and 40 to 50 mmHg for recurrent ulcers.<sup>1–3</sup> Although these higher pressure stockings are ideal, they are too tight and resistant for weak, elderly, or handicapped people to put on by themselves. For these cases, many physicians prescribe either stock-

ings of a larger size or lower pressure. However, because the interface pressures (IPs) achieved by these stockings have not been investigated well, we lack a theoretical basis on which to prescribe the most appropriate stockings. The present study aims to clarify this point.

### PATIENTS AND METHODS

This study was approved by Institutional Review Board of Yamaguchi University Hospital (Ube, Yamaguchi, Japan). All participants signed an informed consent before enrollment.

The class II and III stockings evaluated in this study were knee-high, round-knitted stockings (ready-made Maxis Micro compression stocking<sup>®</sup>, MAXIS a.s., Krásno nad Bečvou, Czech Republic). Class II and III stockings are designed to generate 23–32 mmHg and 34–46 mmHg at the ankle in the standing position, respectively. The subjects were 22 healthy volunteers (8 men and 14 women, aged 23–50 (median 29) years),

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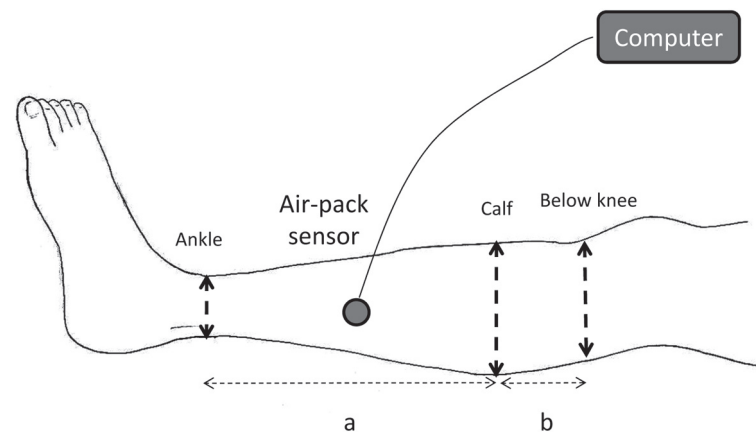
**Table 1** Definitions of stocking sizes according to leg circumferences (cm)

	S	M	L
Below knee	28–35	31–38	33–41
Calf	29–36	32–39	34–42
Ankle	19–21	21–23	23–25

**Table 2** Subjects' leg sizes (cm)

	S (n = 10)	M (n = 6)	L (n = 6)
Below knee	32.2 ± 1.1 (29.8–33.9)	33.3 ± 1.7 (30.8–35.2)	34.6 ± 1.3 (32.7–36.3)
Calf	33.7 ± 1.1 (31.4–33.8)	36.3 ± 1.4 (34.3–37.6)	39.1 ± 3.2 (34.1–42.9)
Ankle	20.1 ± 0.8 (18.5–20.8)	21.6 ± 1.2 (20.6–22.7)	22.8 ± 1.1 (22.3–23.9)
Leg length	30.5 ± 2.7 (27.4–35.3)	29.7 ± 2.4 (25.5–33.0)	30.8 ± 2.0 (28.9–34.0)

Ranges of circumference in parentheses.

**Fig. 1** Points of measurements.

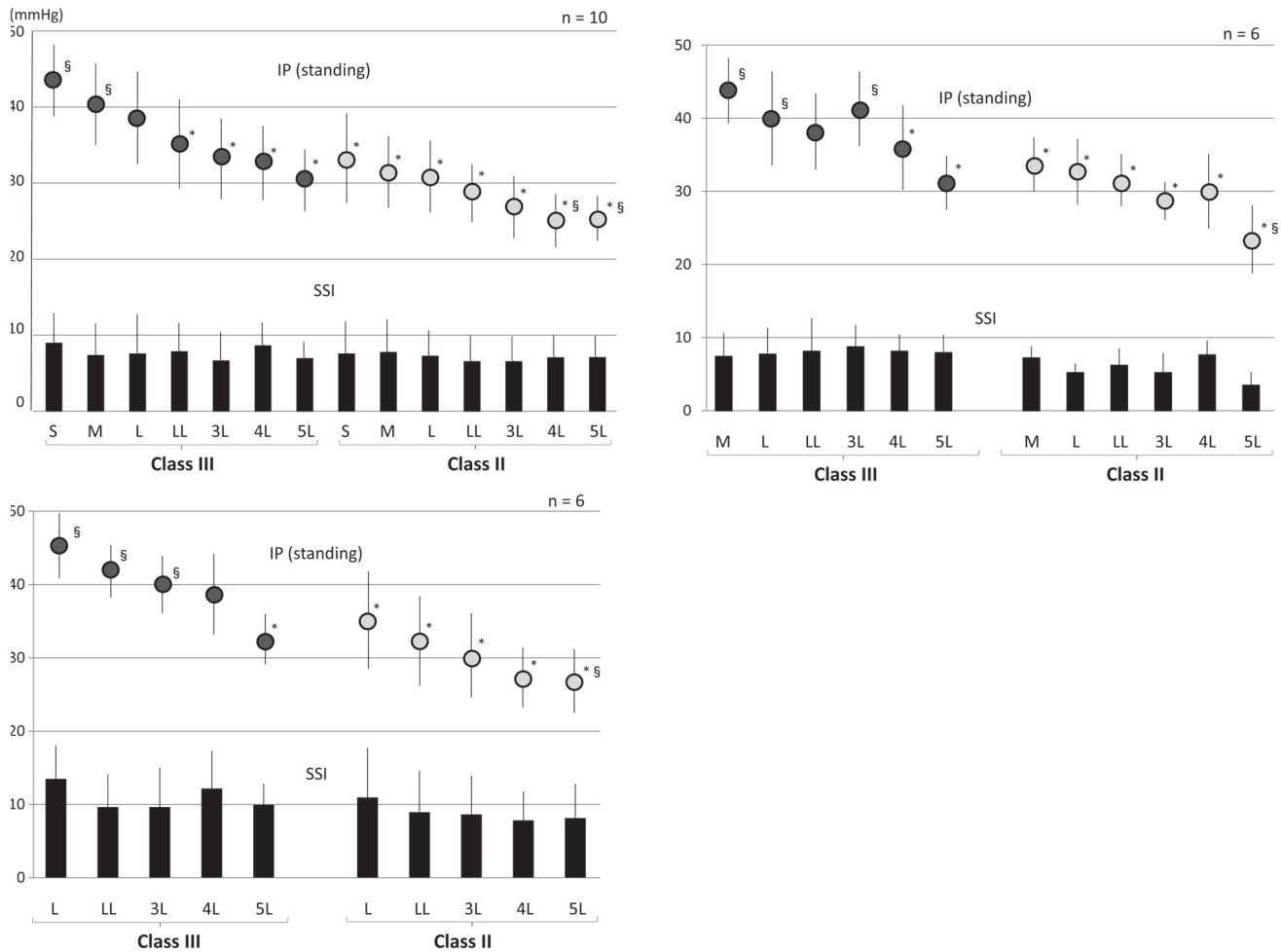
the leg sizes of 10, 6, and 6 of whom were fitted as an S stocking, an M stocking, and an L stocking, respectively; divided according to the brochure (**Table 1**). The characteristics of the subjects' legs are summarized in **Table 2**. There were significant overlaps among the definitions of leg sizes, but each subject was assigned to the size under which his/her leg shape fell best.

First, the subject put on a size 5L class II stocking, and then changed down sizes until they were wearing their appropriate size. For example, a subject with an S-size leg first put on a 5L class II stocking, then changed into a 4L, 3L, LL, L, M, and S stocking in that order. The same steps were taken with class III stockings. The IP under each stocking was measured with the subject

in the supine position and then in the standing position, using an air pack-type analyzer (Model AMI-3037-SB, AMI Co., Tokyo, Japan). The sensor was placed at the transition of the medial gastrocnemius muscle into the Achilles tendon, at the level of B1.<sup>4)</sup> **Figure 1** shows the points of measurement and the position of the sensor. To evaluate the stiffness of the stockings, the static stiffness index (SSI) was used. SSI is defined as the difference between the interface pressure in the supine and in standing positions.<sup>5)</sup>

### Statistical Analysis

Results are expressed as means ± standard deviation



**Fig. 2**

A: Interface pressures and static stiffness indexes in the legs fitted for S size stockings.

IP: interface pressure (in the standing position), SSI (static stiffness index).

\*:  $p < 0.05$  compared with a size S class III stocking. §:  $p < 0.05$  compared with a size S class II stocking.

B: Interface pressures and static stiffness indexes in the legs fitted for M size stockings.

IP, SSI: as in Fig. 1.

\*:  $p < 0.05$  compared with a size M class III stocking. §:  $p < 0.05$  compared with a size M class II stocking.

C: Interface pressures and static stiffness indexes in the legs fitted for L size stockings.

IP, SSI: as in Fig. 1.

\*:  $p < 0.05$  compared with a size L class III stocking. §:  $p < 0.05$  compared with a size L class II stocking.

A	B
C	

or count, unless otherwise indicated. The Mann-Whitney *U*-test was used to determine the significances of the changes in IPs and SSIs with stockings. Statistical analyses were performed using StatView J-5.0 (SAS Institute, Cary, NC, USA). A *p*-value of less than 0.05 was considered significant.

## RESULTS

**Figure 2A** lists the IPs and SSIs recorded for each stocking worn by the subjects with an S-size leg-fitting.

An IP of  $43.5 \pm 4.7$  mmHg in the standing position was recorded for an S-size class III stocking at B1 point; this decreased slightly to  $40.4 \pm 5.4$  mmHg for an M-size class III stocking; and to  $38.6 \pm 6.1$  mmHg for an L-size class III stocking. The IPs in the standing position also decreased gradually from  $35.2 \pm 5.9$  to  $33.2 \pm 5.3$ ,  $32.7 \pm 4.9$ , and  $30.4 \pm 4.0$  mmHg for the LL, 3L, 4L, and 5L-size class III stockings, respectively. The 4L and 5L class III stockings were too loose to stay properly on the legs of one and two subjects, respectively. With a class II-S stocking worn by the subjects with an S-size leg-fitting, the IP in the standing position was  $33.3 \pm 5.9$

mmHg. As with class III stockings, the IPs in the standing position decreased gradually to  $31.5 \pm 4.7$ ,  $30.9 \pm 4.7$ ,  $28.7 \pm 3.8$ ,  $26.9 \pm 4.1$ ,  $25.1 \pm 3.5$ ,  $23.6 \pm 4.6$  mmHg for the M, L, LL, 3L, 4L, and 5L class II stockings, respectively. In one subject, the 5L class II stocking was too loose.

The IPs recorded for the class III stockings in sizes S and M were consistently higher than IP for the S-size class II stocking. On the other hand, the IPs for the class III stockings in sizes L, LL, 3L, 4L, and 5L were not significantly different from that for the S-size class II stocking.

Similar results were obtained for the subjects with M (**Fig. 2B**) and L (**Fig. 2C**) size leg-fittings. The IPs of the M-size legs decreased gradually as the stocking size was increased, except for 3L-size class III stockings and the 4L-size class II stockings. Significantly higher IPs were obtained for size M, L, and 3L class III stockings than for the size M class II stockings. In one subject, size 5L class II and III stockings were too loose. Likewise, the IPs of the L-size legs decreased gradually as the stocking size was increased. Significantly higher IPs were obtained for size L, LL, and 3L class III stockings than for the size L class II stockings. None of the stockings were too loose in this group of subjects.

The SSI did not differ significantly among all sizes of the class II and III stockings.

## DISCUSSION

The major findings in this study were as follows: First, the IPs obtained by class III stockings one sizes too large is significantly higher than those obtained by the appropriate size class II stocking; second, the IPs obtained by class III stockings two or more sizes too large were not statistically different from those obtained by the appropriate size class II stocking; and third, the SSIs achieved by any size of class II and III stockings were not statistically different.

Non-compliance with wearing high pressure stockings is one of the major reasons for giving up on compression therapy, particularly for weak, elderly, or handicapped patients. For these patients, we may have to offer feasible alternatives, such as larger and/or lower pressure stockings. When a ready-made class III stocking of appropriate size seems most likely to generate an IP of the therapeutic range; then, the current results show that a class III stocking one size larger maintained equivalent pressure which is greater than the IP achieved by the appropriate size class II stocking. Moreover, IPs obtained with even larger class III stockings were not significantly differ-

ent from those obtained with an appropriate size class II stocking. In clinical practice, it is not unusual to find that extremity edema in a patients with CVI improves more with class III stockings that are three to four sizes too big than with appropriate size class II stockings. The current results may partly explain this fact. Particularly, when the patient is not familiar with donning stockings, prescribing a larger class III stocking may be good as an induction; then, as the patient becomes more familiar with wearing them, they would be more likely to start putting on the appropriate size ones and be comfortable with them. Since edematous legs will get smaller by wearing hosiery so that stockings need to be renewed to a smaller size in order to maintain a proper pressure.

In contrast to class III stockings, there seemed no significant differences in the IP achieved by the class II stockings according to whether they were of an appropriate size, one size larger, or two sizes larger. As a matter of course, the current results should be considered flexibly since the size, shape, stiffness, and IP, are set differently by each manufacturer. Additionally, because the leg sizes are generally defined to allow significant overlaps, the IPs may differ between a smaller leg and a larger leg even though they are classified as the same size. Thus, in the practical situation, it is better to measure the IP in each case.

SSIs did not differ among all the stockings in the current study, but this may be a reasonable result. Hirai et al.<sup>6)</sup> reported that SSIs derived from thick round-knitted stockings, firm round-knitted stockings, and flat-knitted stockings were not significantly different. Similarly, van der Wegen-Franken et al.<sup>7)</sup> tested SSIs using 18 different brands of stockings, but did not find differences between the IPs with class II and class III round-knitted stockings, possibly due to large standard deviations. As the static stiffness will remain the same in any position of elongation of any given elastic material, it is not surprising that IP will drop only slightly for oversized stockings. However the dynamic stiffness, as defined by Stolk et al. will be much lower due to less hysteresis during walking.<sup>8)</sup> By this, the pressure amplitude's during walking will be much lower. Moreover, van der Wegen et al. demonstrated that stiffness remains the same but pressure drops significantly during the day.<sup>7)</sup>

Interestingly, a paradoxical increase in the IP was observed in the patients whose legs fitted size M stockings; namely, the phenomenon that the IPs derived from larger stockings was higher than the IPs derived from smaller stockings. We took measurements two to three

times in the same setting, but this phenomenon was reproducible in five of six subjects. This could be explained by the changes occurring in the extremity; that is, the calf muscle shape by compression, or shift of the sensor attached to the skin surface when stockings were put on. The compatibility between the leg shape, being the circumferences and length of the leg, and stocking design could be another explanation. This would become a pitfall, particularly at the time of single measurement of IP in the clinic, so the cause of this phenomenon needs to be investigated.

In the presented study, only IPs measured immediately after application of stockings in healthy volunteers presenting with different leg dimensions were discussed. However IP alone cannot be a surrogate parameter both for the efficacy and tolerability of a compression stocking and this may lead to an oversimplification which is far away from clinical reality and does not allow general recommendations. In practice, it is ambulant compression therapy that is effective and not static compression. Additionally the study population was very small. This is especially problematic because we used ready-made stockings. As among the population, a wide variety in leg sizes exist and these stockings only fit different legs by their tolerance (stiffness and hysteresis), an obligatory wide number of patients (legs) may be needed to obtain sufficient statistic evidence.

## CONCLUSION

In conclusion, a larger size class III stocking can provide similar or even higher IPs compared to an appropriate size class II stocking. We cannot recommend to prescribe larger sized compression stockings with a higher compression class just in order to make donning easier. However the current result could be a reference when we consider feasible alternatives.

## ACKNOWLEDGMENT

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## DISCLOSURE STATEMENT

There are no conflicts of interest to declare.

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