Compression Stockings Reduce Occupational Leg Swelling

HUGO PARTSCH, MD,† JOHANN WINIGER,‡ AND BERTRAND LUN

*Department of Dermatology, University of Vienna, Austria; †Medical and Institutional Relations, Ganzoni Management AG, Winterthur, Switzerland; and ‡Research Department of Ganzoni group, St Just, France

BACKGROUND. Evening edema of the legs is a physiologic phenomenon occurring after sitting and standing.

OBJECTIVE. The objective of this study was to investigate which compression pressure is necessary to prevent leg swelling.

METHODS. In 12 volunteers, the volume of both lower legs was measured in the morning and 7 h later, the difference being defined as evening edema (mL). The procedure was carried out for 4 days, in which the subjects wore below-knee stockings of different compression levels alternatively on one leg only in a random order. Compression pressure was assessed using the HATRA device.

RESULTS. The average evening edema of the noncompressed legs was 62.4 mL on the left side and 94.4 mL on the right side (n.s.). Evening edema was significantly reduced to 40.3 mL by light support stockings, to 34.1 mL by compression class A, to 39.6 by compression class I, and to 59.1 mL by compression class II. Mainly stockings exerting a pressure above 10 mmHg improved subjective symptoms.

CONCLUSION. Calf-length compression stockings with a pressure range between 11 and 21 mmHg are able to reduce or totally prevent evening edema and may therefore be recommended for people with a profession connected with long periods of sitting or standing.

HUGO PARTSCH, MD, JOHANN WINIGER, AND BERTRAND LUN HAVE INDICATED NO SIGNIFICANT INTEREST WITH COMMERCIAL SUPPORTERS.

THE COMMON experience of legs that swell at the end of a working day is the result of a physiologic phenomenon. It is caused by extravasation of fluid from the venules because of a steadily increased venous pressure in the dependent regions of the body, owing to gravity.

This natural phenomenon is exacerbated in pathologic conditions that cause deficiency of the venous leg pump. These include ankle stiffness or paresis and valve damage. In these conditions, edema formation may become a clinical problem leading to induration and trophic disturbances of the skin.

In healthy individuals this evening swelling is mostly asymptomatic and will disappear overnight. Nevertheless, unpleasant subjective feelings of heaviness and tiredness may be reported.

Three groups of investigators have demonstrated beneficial effects of different kinds of compression stockings on such symptoms and on quality of life. Measurement of the leg volume in the morning and evening were performed by different water displacement methods and by an optoelectronic device, all revealing a diurnal volume increase. All three groups of investigators showed a reduction of this evening edema by different kinds of compression stockings, ranging from ordinary light support panty hose with a pressure at the ankle of 8 to 10–15 mmHg compression stockings and 20 to 30 mmHg stockings. Nevertheless, evaluation of the optimal compression level required to completely prevent the evening edema has not been investigated until now.

Materials and Methods

Subjects

Twelve individuals working in a compression stocking company volunteered to take part in this study. Relevant medical history information, including complaints concerning the legs, was asked in a questionnaire. They were carefully informed of all details and prerequisites before inclusion into the trial and signed a written consent. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki. Individuals taking diuretics, venotonics, vasodilators, or antihypertensive drugs were excluded.

On the morning of the first day a clinical examination of the legs was performed and the findings in the 24 legs were ascribed to clinical classes C0 to C3.
according to the CEAP classification. Anatomy and pathophysiology were analyzed by a venous duplex examination in the pathologic cases, concentrating on refluxes in the superficial, deep, and perforating veins.

The basic characteristics of the subjects are summarized in Table 1. Seven subjects used to wear support or compression class I stockings occasionally, and two subjects with large varicose veins and venous edema, respectively, used compression stockings (class II) as a routine.

### Stockings

All volunteers taking part in the study were asked not to wear any other compression class I stockings occasionally, and two subjects with large varicose veins and venous edema, respectively, used compression stockings (class II) as a routine.

### Volumetry

A similar Plexiglas boot as described by Vayssairat and coworkers was used. In contrast to the original method the height of the container was taller (43 cm) to measure the entire volume of foot and lower leg reaching up to below the knee. Instead of 24°C, we used a water temperature of 30°C, as proposed by Thulesius et al. This higher temperature was used to better exclude cutaneous venomotor responses.

After filling the device with warm water the standing subject introduced one leg with extreme care into the volumeter. The displaced water volume was thoroughly collected and weighted using a precision scale. One gram of displaced water was assumed to correspond to 1 mL of volume.

The difference between the leg volume in the evening and the leg volume in the morning is defined as “evening edema.” The time difference between the volume measurement in the evening and in the morning was 7 h on average.

### Stocking Pressure

Individual stocking pressure at the ankle level (“b level”) was measured for each stocking fitted to each individual using the Hosiery Trade Research Association (HATRA) instrument. (The HATRA system is a mechanical testing model to measure the pressure profiles of stockings.)
Subjective Symptoms

In the questionnaire leg complaints like heaviness and tiredness in the evening were reported by five subjects (Table 1). During the investigation period the subjects were asked on each evening to describe their subjective feelings in comparison with the leg without compression (better, worse, or equal).

Statistics

A sample size calculation assuming a reduction of evening edema from $30.8 \pm 15.2$ to $4.3 \pm 2.8$ mL revealed that six patients were required to reach an error of probability of $<5\%$ and a power of $80\%$. The primary concept was to perform an intraindividual comparison between the volume changes of one leg without compression and the contra lateral leg with compression.

Surprisingly a statistically significant difference was found between the morning volumes of the left and the right legs (Table 3). Therefore, the volume increase of each leg without stocking was compared to the volume increase of the same leg treated with four different types of stockings on four different days using the Student's $t$ test. (Figure 4). The graphs plotting each single measurement was carried out with Graph Pad Prism 3 software.

Precision and Reproducibility

The variation coefficient as a parameter for the precision of the volumetry, calculated from three consecutive measurements in 10 subjects, was 0.8 (95% confidence interval (CI) 0.43–1.18). Twenty-four measurements of the leg volume 2 days apart revealed variation coefficients of 0.74 (95% CI 0.5–0.98) for the morning volume and 0.59 (95% CI 0.33–0.85) for the evening volume. This shows that the volume of a leg measured after 2 days remains quite constant.

<table>
<thead>
<tr>
<th>Table 3. Average Leg Volume (mL) in the Morning Measured with a Time Difference of 2 Days (± SD) ($n = 12$)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Leg</td>
</tr>
<tr>
<td>Volume (mL)</td>
</tr>
<tr>
<td>Day 1</td>
</tr>
<tr>
<td>Two days later</td>
</tr>
<tr>
<td>Average</td>
</tr>
</tbody>
</table>

*There is a statistically significant difference between the two legs ($p < 0.01$).

Results

Stocking Pressure

Figure 1 shows the pressure values at the ankle level for the four different stockings. The measured values fulfill the criteria of the European prestandard of CEN. The following mean values were measured ($\pm$ standard deviation (SD)):

- Light support stocking, 5.9 $\pm$ 2.4 mmHg;
- Compression class A stocking, 11.2 $\pm$ 1.2 mmHg;
- Compression class I stocking, 18.1 $\pm$ 2.7 mmHg;
- Compression class II stocking, 21.8 $\pm$ 1.8 mmHg.

The difference between the pressure values in these four classes is statistically significant ($p < 0.001$).

Lower Leg Volume

The average volumes of both legs measured with a time difference of 2 days in the morning are shown in Table 3. Surprisingly the mean values of the lower leg volumes were significantly higher on the left side than on the right ($p < 0.05$). There is a statistically significant correlation between the leg volume and the body mass index ($r = 0.81$; 95% CI 0.46–0.95) (Figure 2).

Evening Edema

The mean values of evening edema without stockings on two different days are shown in Table 4. There were higher values on the right side but the difference between both legs was not significant.

The amount of evening edema ranged between 10.2 and 220.3 mL. (The outlier of 220.3 mL was measured in a 56-year-old lady, BMI 28, without varicose veins...
who showed 2 days later a value of 79.8 mL.) There was no single measurement that revealed a lower leg volume in the evening than in the morning. Patients with varicose veins (CEAP C2) and with venous edema (C3) seem to have more pronounced evening edema than individuals without visible veins (C0) or with telangiectases (C1) (Figure 3). Nevertheless, the difference was not statistically significant owing to the low number of measurements. There was also no difference between evening edema in subjects who had leg complaints (83.01 ± 50.1 mL) and those who did not (74.97 ± 43.2 mL).

Reduction of Evening Edema by Compression

Figure 4 shows the reduction of the evening edema by different kinds of below knee compression stockings, measured on the same leg on different days. Support stockings reduced evening edema by 50% on average (p < 0.05). Stockings with a pressure at the ankle level above 10 mmHg were able to reduce the leg volume to values that on average were even smaller in the evening than in the morning (p < 0.0001).

Subjective Symptoms

The subjective leg feeling on each evening comparing the stocking with the side without stocking is summarized in Figure 5. The best results were obtained with the compression class I stocking, whereas ordinary light support stockings showed the
highest score of negative reactions. Those two subjects with varicose veins and edema who were used to wearing stockings regularly preferred compression class II stockings.

Discussion

The measurement of lower leg volume by the water displacement method is an accurate method with good reproducibility. Our method using a larger water container, a higher water temperature, and a precision scale may have reduced the imprecision in comparison to the first publication. In the experiments presented here with three consecutive measurements in 10 individuals a variation coefficient of 0.8 could be achieved. Foot volumetry as described by Thulesius and coworkers measures only the foot volume, which is approximately 1200 mL on average, and was designed to assess the venous pumping function and not volume changes of the foot. One of the main advantages of our relatively simple device compared with optoelectronic instruments is the fact that very clearly defined segments of the lower extremity including the foot are measured in the standing position.

One disadvantage is the weight of the water column in the container compresses the leg, thereby reducing the volume that is measured. Owing to the higher hydrostatic pressure at the bottom of the container this will affect the foot more than the calf. Nevertheless, this artifact will always be consistent.

The measured volume of the lower legs showed significantly higher mean values on the left leg, which may be to some part explained by the preponderance of venous pathology on the left side in the investigated population. Therefore, it seemed to be inappropriate to perform intraindividual comparisons taking the contralateral leg without compression as the control.

In contrast, repeated measurements, carried out on the same leg at the same time in the morning with 1 day in between, revealed a good reproducibility (coefficient of variation 0.74%; 95% CI 0.5–0.98; Table 3). For that reason, comparisons between no stocking and stocking were performed for the same leg measured on different days.

The significant correlation of the measured leg volume and the body mass index (Figure 2) is a plausible finding. The difference between the leg volume measured after a working day in the sitting or standing position in the evening minus the volume in the morning has been defined as “evening edema.” Fluid accumulation in the legs after sitting has been demonstrated also in experiments mimicking flight conditions. The assumption that the volume increase of the leg is due to fluid extravasation into the tissue is only true when there is no increase of blood volume. Although some distension of the veins may occur during a working day, it can be assumed that the water temperature of 30°C will lead to the same maximal venous dilatation at each measurement.

Our results demonstrate that this evening edema may be very variable from one day to another. Patients with venous edema and large varicose veins show a tendency toward more evening edema, but a correlation with subjective leg complaints seems to be lacking.

Different studies have shown that even light compression stockings are able to reduce evening swelling and subjective symptoms. Not only the pressure, but also the elastic properties of the stockings, have an influence on this effect. The question how high compression pressure must be chosen to completely prevent evening edema has not been investigated until now.

Surprisingly support stockings with a pressure on the lower leg of less than 10 mmHg are able to reduce evening edema significantly. This finding is in accordance with the results of de Boer and coworkers who reported a similar outcome based on optoelectronic volume measurements in the lying position. These authors clearly stated that the volume reduction was unrelated to a decrease of unpleasant subjective feelings like tiredness and heaviness.

Also in our study only 1 from 12 subjects reported an improvement of such feelings wearing a support stocking (Figure 5). The pressure of ordinary or so-called support stockings is not standardized and is therefore not controlled. The pressure of medical compression stockings, however, fulfills the criteria of the CEN prenorm ENV 12718 in which precision and reproducibility are given, the stockings are therefore controlled. Additionally the CEN prenorm also standardizes the decrease of compression and other criteria. Such demands do not exist for ordinary or support stockings.

Medical compression stockings with class A, class I, and class II were able to prevent evening swelling completely in the majority of our measurements (in 7/12 cases with compression class A stockings, in 8/12 of compression class I and in 11/12 of compression class II stockings) (Figure 5). After wearing these stockings for 1 working day the mean volume of the lower leg was even lower in the evening than in the morning.

As to the indication for different compression classes depending on the absence or presence of an underlying venous disease, no clear-cut consequences may be drawn from our investigations, which were performed mainly in healthy people. In one of our volunteers who presented with varicose veins and...
venous edema (C3), evening swelling could be greatly reduced by class A and compression class I stockings, but only a compression class II stocking reduced the leg volume to a level lower than the morning value and gave him a satisfactory subjective improvement.

Future studies should concentrate on effects of the tested stockings separately on control subjects and on patients, according to the CEAP classification. Concerning venous hemodynamics it has been demonstrated that class I compression stockings are able to improve venous pumping function even in patients. Concerning subjective feelings most have the subjects preferred compression class A and compression class I stockings. This finding is in accordance with the results of a recently published randomized controlled trial that clearly demonstrated an improvement of subjective symptoms after wearing medical compression stockings of 10 to 15 mmHg but not after placebo stockings.

Our working population fulfilled different jobs, most of them spending more time sitting than standing. The fact that they worked in a factory producing compression garments and that nine of them wore different kinds of below-knee compression stockings, at least occasionally, may explain some bias in favor of their preference for higher compression classes (Figure 5).

Several authors have already demonstrated that leg swelling at the end of a working day in people with a standing or sitting profession may be associated with subjective symptoms and that this phenomenon can be reduced by medical compression stockings. Recently analog results have also been described in patients. Concerning subjective feelings most have the subjects preferred compression class A and compression class I stockings. This finding is in accordance with the results of a recently published randomized controlled trial that clearly demonstrated an improvement of subjective symptoms after wearing medical compression stockings of 10 to 15 mmHg but not after placebo stockings.

Our working population fulfilled different jobs, most of them spending more time sitting than standing. The fact that they worked in a factory producing compression garments and that nine of them wore different kinds of below-knee compression stockings, at least occasionally, may explain some bias in favor of their preference for higher compression classes (Figure 5).

Several authors have already demonstrated that leg swelling at the end of a working day in people with a standing or sitting profession may be associated with subjective symptoms and that this phenomenon can be reduced by medical compression stockings. Recently analog results have also been described in passengers after long-haul flights. This is the first study demonstrating that medical compression stockings with a pressure at the ankle level of higher than 10 mmHg may prevent occupational leg swelling at the end of the day completely.

There may be clinical consequences arising from “physiologic swelling” after prolonged sitting or standing. These are:

1. Under normal conditions the increased amount of fluid extravasation into the tissue will be compensated by a normal working lymphatic drainage. When this mechanism is overloaded, specifically in the case of deficient lymph transport, persistent lymphedema may start. Especially in patients who do not move their ankle pump, the so called “dependency syndrome” with indurated edema is a frequent clinical consequence, which does not respond to diuretics but should be treated with compression.

2. Fluid extravasation leads to an increase of local hematocrit in the leg veins. Together with a decrease in venous blood flow velocity, this may promote thrombus formation according to the clinical entity of a thrombosis after prolonged sitting.

As a consequence, the protection of leg edema owing to long sitting or standing by wearing adequate medical compression stockings is advisable not only to improve symptoms of heaviness and tiredness, but also to counteract potential clinical hazards of persistent edema and thrombotic events.

Acknowledgment This work was performed at Ganzoni Headquarters, St Gallen, Switzerland.

References
Commentary

Once again we have a well-done practical study proving that calf-length compression stockings with a pressure range between 11 and 21 mmHg are able to reduce or totally prevent evening edema. The importance of this study is to justify our recommendations to both our patients and the insurance industry that people with a profession connected with long periods of sitting or standing wear graduated compression stockings. The question of how high the compression pressure must be to completely prevent evening edema has been answered in this study as, surprisingly, less than 10 mmHg. The good news for our patients is that compression stockings at this pressure are easy to put on as well as comfortable to wear.

MITCHEL GOLDMAN, MD
La Jolla, California