Occupational Leg Oedema is More Reduced by Antigraduated than by Graduated Stockings

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WHAT THIS PAPER ADDS
Graduated compression is considered a quality prerequisite of all compression devices. Recently, it has been shown that compression devices with a negative gradient (higher over the calf than over the ankle) are more effective in improving venous pumping function. Nevertheless, these devices could produce oedema in the ankle region because of a possible hindrance to the venous outflow.

With this paper we try to show that this is not the case; on the contrary, the so-called progressive stockings are able to prevent occupational oedema more than graduated stockings in normal volunteers staying sitting or standing all time while working.

Introduction:
Elastic compression stockings exerting a progressive pressure, higher at the calf than at the ankle (progressive elastic compression stockings, PECS), have already proved to be more comfortable, easier to put on and more effective in improving venous pumping function compared to graduated compression elastic stockings (GECS). Nevertheless, PECS could have a negative effect on the prevention and treatment of oedema or even favour oedema formation.

The aim of the present study was to investigate if, in normal volunteers, PECS are able to prevent leg swelling during their working shift.

Methods:
A total of 30 normal volunteers (14 males, 16 females aged 36.4 ± 6.6 years) staying standing or sitting during their shift were enrolled into the study. Their leg volume was measured at the beginning and at the end of their working shift on 2 consecutive days. On one day, the volunteers did not put on any stockings; on the other day, they wore GECS on one leg and PECS on the other. The difference between the leg volume measured at the end of the shift and the basal volume in the morning was called ‘occupational oedema’.

Interface pressure at points B1 and C was measured immediately after stockings’ application and before removal. The volunteers were asked to report about difficulty of putting on the stockings and comfort during wearing time. The results were submitted to statistical analysis.

Results:
The GECS and PECS groups had similar baseline leg volumes (3143 vs. 3154 ml) and occupational oedema (134 vs. 137.5 ml); after putting on the stockings, occupational oedema was reduced in both legs but the reduction was significantly greater with PECS (20 vs. 40 ml with GECS) (P < 0.05). Interface pressure at ankle level is higher with GECS on one leg and PECS on the other. The difference between the leg volume measured at the end of the shift and the basal volume in the morning was called ‘occupational oedema’.

Interface pressure at points B1 and C was measured immediately after stockings’ application and before removal. The volunteers were asked to report about difficulty of putting on the stockings and comfort during wearing time. The results were submitted to statistical analysis.

Conclusion:
PECS are easier to put on and more comfortable and produce a significantly higher reduction of occupational oedema compared with GECS in normal volunteers. Nevertheless leg volumetry, providing a global leg-volume evaluation, is not able to localise the oedema reduction and to assess if it occurs more in the calf or the ankle area. Theoretically, despite a global volume reduction, PECS could even promote a slight oedema formation at ankle level over-compensated by a greater oedema reduction at calf level. Further studies need to concentrate on patients with venous disease and on the local distribution of this global effect.

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Elastic compression stockings exerting a progressive pressure, higher at the calf than at the ankle (progressive elastic compression stockings, PECS), have already proved to be comfortable and easier to put on compared to graduated compression elastic stockings (GECS) in sports’ and in
patients with mild venous insufficiency; PECS are more effective than GECS in improving the venous pumping function in active patients with severe venous insufficiency. Despite these advantages, an inverse pressure gradient could theoretically produce a hindrance to the venous return at calf level in non-active subjects, have a negative effect on prevention and treatment of oedema or even favour oedema formation.

The aim of the present study was to investigate if, compared to GECS, PEGS actually favour occupational oedema or if they are able to prevent leg swelling in normal volunteers during their working shift.

METHODS
A total of 30 healthy volunteers (nurses in the operating theatre mainly standing or office employees mainly sitting during their shift; 14 males, 16 females aged 36.4 ± 6.6 years) were enrolled. They were fully informed and gave their written consent to participate in the study. Ethical committee approval is not required by the Italian authorities because all procedures were non-invasive, of short duration and performed with CE-marked materials and devices during the working shift under the surveillance of doctors.

Inclusion criteria: normal volunteers, both sexes, age between 18 and 65 years staying standing or sitting all time during their work shift.

Exclusion criteria: venous disease and other causes of oedema — cardiac, kidney, liver disease and orthopaedic disorders causing a calf-pump dysfunction or a Ca²⁺ antagonist which could favour oedema.

The absence of venous pathophysiology was investigated by a duplex scanner (Esaote MyLab 60® with a multi-frequency linear probe 7.5–12 MHz; Esaote S.p.A. Genoa, Italy); each leg was examined in standing position; absence of reflux was checked by means of the Valsalva manoeuvre and by compression/relaxation manoeuvre of the leg segment below the examined site. Venous obstruction was ruled out by assessing venous flow phases using the Doppler mode and by compression tests.

Primary outcome of the study was the change of leg volume induced by the two different elastic stocking types; secondary outcomes were interface pressure, comfort and ease of putting on the stockings.

Leg volumetry was performed by water displacement, at the working place of the volunteers, on 2 consecutive days at the end of the working shift. On one day the volunteers did not put on any stockings; on the other day they wore GECS on one leg and PEGS on the other. On one of the 2 days the baseline leg volume was measured before starting the working shift. In order to prevent oedema formation before the measurement the volunteers put on GECS at 23—32 mmHg pressure after getting up from bed and wore them on their way to the clinic. In a preliminary study we could observe that the leg volume measured early in the morning in normal volunteers stayed practically the same for the next hours when a stocking at 23—32 mmHg was used. Therefore, baseline leg volumetry was performed only on one day. The sequence of days without and with compression, the day for baseline measurement and the application of the stockings to the right and left leg followed a randomised order.

The difference between the leg volume measured at the end of the shift and the basal volume in the morning was called ‘occupational oedema’.

Interface pressure at points B1 (the medial aspect of the calf where gastrocnemius tendon turns into its muscular part; approximately 10—12 cm above the medial malleolus) and C (the maximum diameter of the calf) was measured with a pneumatic measuring system (Picopress®; Micro- labitalia, Padua, Italy) immediately after stockings’ application and before removal. The volunteers were asked to report about the difficulty of putting on the stockings and comfort during wearing time. Both outcomes were measured by a 0—10 visual analogue scale (VAS). For putting on difficulty ‘0’ was considered as very easy and ‘10’ as very difficult; for comfort ‘0’ was considered as very uncomfortable and ‘10’ as very comfortable.

Statistical analysis
In the present work median values and interquartile ranges are given.

The Kruskal—Wallis test with Dunn’s multiple comparisons were used to compare occupational oedema without and with the stockings. The Mann—Whitney test was used to compare the effects of GECS and PEGS concerning reduction of occupational oedema, difficulty of putting on and wearing comfort. Differences with a P < 0.05 were considered statistically significant.

The graphs and the statistical evaluations were generated by using GraphPad Prism and Graph Mate software (GraphPad, La Jolla, CA, USA).

RESULTS
Volumetry
Baseline leg volume was similar in the two groups of legs without any statistical difference (n.s.) (Fig. 1(A)). The leg volume increase at the end of the working shift without any stocking was very similar: 4.3% in the GECS and 4.0% in the PEGS group (n.s.) (Fig. 1(B)).

Median values of occupational oedema were 134.5 ml (interquartile range (IQR) 115.3–159.8) in the GECS group and 137.5 ml (IQR 111.0–165.5) in the PEGS without compression, 40 ml (IQR 24–60.2) after GECS and 20 ml (IQR 10.7–39) after PEGS (significant differences between no compression and compression for both products; Kruskal—Wallis test P < 0.001) (Fig. 2).

Comparing leg volume at the end of the work shift without and with stockings, both stockings produce a significant decrease in oedema formation (P < 0.001) (Fig. 2) but the leg-volume reduction was −2.7% with GECS and −3.4% with PEGS with a significant difference in favour of PEGS (P < 0.05) (Fig. 3).

Interface pressure
Graduated stockings have a ‘degressive’ pressure profile from ankle to calf; in supine position they exert a median
A pressure of 22 mmHg (IQR 21–24) at B1 (about 10 cm above the inner ankle) and 18 mmHg (IQR 16.7–20) at the calf (Fig. 4(A)). Progressive stockings achieve a median pressure of 18 mmHg (IQR 16–20) at ankle level and 30 mmHg (IQR 26.7–32) at calf level (Fig. 4(B)).

In standing position the pressure level increases but the pressure profile is maintained. GECS exert a pressure of 25 mmHg (IQR 23.7–26.2) at ankle level and of 21 mmHg (IQR 20–23) at the calf area (Fig. 5(A)); PECS produce 19 mmHg (IQR 18–22) at ankle level and 32.5 mmHg (30.7–34.2) at calf level (Fig. 5(B)).

Putting on difficulty

Volunteers reported less difficulty in wearing PECS (average score 7; IQR 7–8) compared to GECS (average score 6; IQR 5–7); the difference is small but highly significant ($P < 0.001$).

Comfort

Both GECS (average score 9; IQR 8–9) and PECS (average score 9; IQR 9–10) were reported to be very comfortable. PECS were slightly more comfortable ($P < 0.05$).

DISCUSSION

Leg volumetry by water displacement is the ‘gold standard’ to evaluate leg volume with high precision (0.7%) measured from two consecutive measurements of the same patient leg by two different observers and very low intra-individual variability (1.3%); therefore it can be considered a reliable method in measuring even small volume differences in normal volunteers with occupational oedema. Tape measurement of the leg circumference at different leg levels followed by calculation of leg volumetry with the mathematical formula of a truncated cone shows a very good correlation with water-displacement measurements for both legs and arms. This method does not include the foot (or the hand) in the measurement and for this reason was not used in our study but it would have the advantage...

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**Figure 1.** Baseline leg volumetry, before working shift (A), and % leg volume increase at the end of the working shift (B) in GECS and PECS groups.

<table>
<thead>
<tr>
<th></th>
<th>GECS group</th>
<th>PECS group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>2157</td>
<td>2238</td>
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<tr>
<td>25% Percentile</td>
<td>2837</td>
<td>2809</td>
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<tr>
<td>Median</td>
<td>3143</td>
<td>3154</td>
</tr>
<tr>
<td>75% Percentile</td>
<td>3380</td>
<td>3417</td>
</tr>
<tr>
<td>Maximum</td>
<td>4096</td>
<td>4098</td>
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</table>

**Figure 2.** Occupational oedema without and with GECS and PECS.

<table>
<thead>
<tr>
<th></th>
<th>no compress</th>
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<th>PECS</th>
</tr>
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<tbody>
<tr>
<td>Minimum</td>
<td>41.00</td>
<td>-44.00</td>
<td>-42.00</td>
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<tr>
<td>25% Percentile</td>
<td>115.3</td>
<td>24.50</td>
<td>111.0</td>
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<tr>
<td>Median</td>
<td>134.0</td>
<td>40.00</td>
<td>137.5</td>
</tr>
<tr>
<td>75% Percentile</td>
<td>159.8</td>
<td>60.25</td>
<td>165.5</td>
</tr>
<tr>
<td>Maximum</td>
<td>244.0</td>
<td>151.0</td>
<td>211.0</td>
</tr>
</tbody>
</table>

**Figure 3.** Volume decrease in percent with GECS and PECS.

<table>
<thead>
<tr>
<th></th>
<th>GECS</th>
<th>PECS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum</td>
<td>-5.010</td>
<td>-4.880</td>
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<tr>
<td>25% Percentile</td>
<td>-3.250</td>
<td>-4.270</td>
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<tr>
<td>Median</td>
<td>-2.725</td>
<td>-3.410</td>
</tr>
<tr>
<td>75% Percentile</td>
<td>-2.320</td>
<td>-2.968</td>
</tr>
<tr>
<td>Maximum</td>
<td>-0.7500</td>
<td>-0.5900</td>
</tr>
</tbody>
</table>

**Figure 4.** Occupational oedema without and with GECS and PECS.
Venous incompetence during walking cannot be responsible for the more pronounced oedema reduction observed in the lower leg compared to GECS, occupational oedema in the whole leg was significantly more reduced by PECS (Fig. 3).

The interpretation of these surprising results is difficult. The haemodynamic superiority of PECS in patients with venous incompetence during walking cannot be responsible for the more pronounced oedema reduction observed in the lower leg compared to GECS, occupational oedema in the whole leg was significantly more reduced by PECS (Fig. 3).

As we know from studies using duplex ultrasound and magnetic resonance imaging (MRI) compression is able to narrow and even occlude the vein lumen depending on the exerted pressure and the body position. In sitting and standing positions a pressure of 30–40 mmHg starts to narrow both superficial and deep leg veins.8,9 PECS, but not GECS, exert this pressure range at calf level. The reduction of blood volume, associated with an increase of tissue pressure, produced by compression, will reduce capillary filtration in the compressed areas.

The fact that PECS achieved a greater reduction of occupational oedema in the whole leg could be explained by the higher basic volume in the calf region compared to that in the distal parts of the leg. Any percent change of volume over this region will therefore result in a disproportionate volume reduction of the whole leg. It may well be that the segmental reduction of occupational oedema by PECS is less pronounced in the gaiter region although there is a greater reduction of the global leg volume.

Therefore, based on the reported results, it would be too early to recommend PECS for routine prevention of occupational oedema. Before that, it will be necessary to exclude a potential promotion of oedema in the gaiter area, which is the preferred location of further skin changes and ulceration. Future trials concentrating on local volume changes depending on the local pressure will be necessary to solve this question. The presented results need to be complemented by studies focussing on segmental assessment of volume changes or measurement of the leg circumference at different levels.

Studying long-term effects of this new negative gradient concept of compression stockings in people with reduced physical activity will also be important.

CONCLUSIONS

Compared with GECS, PECS, which are easier to be put on and more comfortable to be worn, produced a significantly higher reduction of occupational oedema measured by volumetry of the lower leg in a case series of normal volunteers. Further studies need to concentrate on patients with venous disease and on the local distribution of this global effect.

CONFLICT OF INTEREST/FUNDING

None.
REFERENCES


