Effect of graduated compression stockings on venous lower limb hemodynamics in healthy amateur runners

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ABSTRACT

Objective: The objective of this study was to analyze the effect of graduated compression stockings (GCS) on venous lower limb hemodynamics in healthy amateur runners.

Methods: Ten runners were evaluated during rest and after a 10-km run without and with knee-high GCS of 20 to 30 mm Hg. Air plethysmography evaluated venous filling index (VFI), ejection fraction, and residual volume fraction (RVF) in both limbs. Capillary lactate level and heart rate were also measured.

Results: Right VFI was 1.38 mL/s during rest, 1.98 mL/s without compression, and 1.32 mL/s with compression ($P = .006$). Left VFI was 1.35 mL/s during rest, 1.64 mL/s without compression, and 1.21 mL/s with compression ($P = .006$). In both limbs, ejection fraction was not different in the three situations. Right RVF was 22.35% during rest, 19.40% without compression, and 10.50% with compression ($P = .006$). Left RVF was similar in all situations. Capillary lactate level increased in runners without compression ($P = .004$) but kept stable in those wearing compression. The difference between after-run and before-run capillary lactate levels was similar in runners with and without compression. Rest, peak, and after-run heart rates were similar in runners with and without compression.

Conclusions: Healthy amateur runners had associated hemodynamic improvements when wearing knee-high GCS of 20 to 30 mm Hg during a 10-km treadmill run. VFI dropped in both limbs and RVF dropped at least in the right limb. There was no positive effect on calf muscle pump; capillary lactate variation; or rest, peak, and after-run heart rates. (J Vasc Surg: Venous and Lym Dis 2017;■:1-7.)

Graduated compression stockings (GCS) are gaining popularity among amateur runners.[1] Currently, there is some evidence that wearing GCS while running might slightly enhance endurance performance because of improvements in running economy, biomechanics, perception, and muscle temperature.[2] There is also some evidence that they facilitate recovery of muscle function and reduce muscle soreness.[3] One proposed explanation for these recovery benefits is that GCS increase venous return, reducing leg edema. This effect would occur even in subjects without any sign of venous disease.[4] A study has demonstrated that GCS prevented an increase in leg volume just after a running exercise.[1] However, the literature about the effects of GCS on venous hemodynamics is inconclusive.[2,5] There is no consensus about the type and the degree of compression.[6]

Air plethysmography (APG) is a noninvasive test that evaluates venous hemodynamics through a cuff placed around the calf.[7] It was widely used in the 1980s to study chronic venous diseases.[8,9] Through APG, Christopoulos et al[10] demonstrated that GCS improved venous hemodynamics in patients with chronic venous disease. Ibegbuna et al[11] used APG to study effects of GCS in patients with chronic venous disease during walking and showed a significant improvement in venous hemodynamics.[11] In a literature search, we found no study using APG to evaluate the effect of GCS on venous hemodynamics in runners.

There is also some evidence that wearing GCS during running improves clearance of blood lactate by enhancing venous hemodynamics.[12] This effect would also favor recovery and running performance.[13] The relationship between GCS, venous hemodynamics, lactate kinetics, and running performance has been the subject of several investigations. Unfortunately, the results are conflicting; there are studies showing that wearing GCS during exercise determines decreased,[14] increased,[5] or even unaltered[15] levels of circulating lactate. Currently, the literature about the effect of wearing GCS during running on circulating lactate remains unclear.[12]

Based on these considerations, we hypothesized that wearing GCS during running would improve venous hemodynamics. To test these considerations, APG was employed for the first time in runners to study the effectiveness of GCS. Capillary lactate was also measured. The

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objective of this study was to analyze the effect of GCS on venous lower limb hemodynamics and circulating lactate in amateur healthy runners.

ARTICLE HIGHLIGHTS

- **Type of Research:** Single-center prospective cohort study
- **Take Home Message:** Venous hemodynamics, measured with plethysmography, improved in 10 healthy amateur runners when they wore knee-high compression stockings of 20 to 30 mm Hg during a 10-km treadmill run. There was significant improvement in venous filling index but no effect on ejection fraction, capillary lactate levels, or heart rate.
- **Recommendation:** This study suggests wearing knee-high compression stockings of 20 to 30 mm Hg during long-distance running to improve venous hemodynamics that may enhance recovery of muscle function and reduce muscle soreness.

METHODS

Subjects. The study was conducted in the host institution university hospital from June 2014 to August 2015. Participants were recruited in a community fitness center. We recruited volunteer healthy amateur runners from both sexes who met the following criteria: the runners practiced running a minimum of three times a week for at least 1 year; the runners completed at least one amateur 10-km race in the previous 6 months; a detailed physical examination showed absence of venous diseases, except for telangiectasias or reticular veins; age <60 years; body mass index <25 kg/m^2; and absence of previous venous surgery, diabetes mellitus, heart disease, arterial and lymphatic disease, collagenoses, myopathies, osteopathies, and arthropathies. We excluded from the study runners who could not complete either of the two runs in <60 minutes. The study was approved by the local Institutional Review Board under process number 2719/2015, and all participants provided signed informed consent. All procedures performed in this study were in accordance with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Design. We conducted an experimental study that is delineated in the Fig. Participants were assessed in three situations: (1) during rest, just before the run; (2) just after a 10-km run on a treadmill without GCS; and (3) just after another 10-km run, with the same effort intensity, wearing GCS on both lower limbs. The time interval between runs was 1 week.

In the three described situations, the following variables were obtained:

- Hemodynamic indices in both limbs: venous filling index (VFI) was used to measure valvular competence, ejection fraction (EF) was used to evaluate calf muscle pump, and residual volume fraction (RVF) was used to assess venous pressure;
- Capillary lactate before (rest) and after runs; and
- Heart rate before (rest) and after runs and peak heart rate during each run.

Methodology. The runs were performed on a commercially available motorized treadmill (Club Series Treadmill; Life Fitness, Rosemont, Ill). Runners were asked to run 10 km at an inclination of 1% and at a speed they were used to on recruitment. An inclination of 1% in the treadmill simulates the effort required in outdoor running.[16] All runners were entirely familiarized with the treadmill before formal assessments. Runners were freely allowed to drink water during exercises. The runs were performed in a room with constant temperature and humidity (about 22°C and 60%, respectively).

Knee-high GCS Venosan Sportactive 20 to 30 mm Hg (Salzmann AG, St. Gallen, Switzerland) were employed in both legs. Before the experiment, leg measurements were taken to ensure that participants received the correct stocking size based on the manufacturer's recommendations. These commercially available GCS were specially designed for running and are made of 69% polyamide/nylon and 31% elastane/spandex. They cover the leg from the ankle to below the knee, leaving feet uncovered. The manufacturer claims that they provide compression of 30 mm Hg at ankle level and 20 mm Hg at knee level. Runners wore their own low-cut socks over the stockings. These low-cut socks do not exert any additional compression. When appropriate, GCS were worn during runs but never during APG measurements.

Venous hemodynamics were assessed by APG, a noninvasive test that measures changes in air volume on a cuff placed on the calf during orthostatic ankle plantar flexion-dorsiflexion movements (tiptoe movements) and postural changes. This test provides information about venous reflux, valvular function, calf muscle pump function, and venous emptying.[17] We employed an SDV 3000 device (Angiotec Ltda, Belo Horizonte, Brazil) with computer-automated calibration. Testing was performed during evening hours, after a procedural demonstration, ensuring the participant's complete understanding of the process. Room temperature was kept at 22°C. We employed the technique described and standardized by Christopoulos et al.[8] The obtained tracings permitted acquisition of the following hemodynamic indices:

- VFI, evaluation of the global lower limb valvular competence, expressed in milliliters per second

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