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Original Article

Effect of below-the-knee compression stockings on severity of obstructive sleep apnea

Laura H. White [a,c], Owen D. Lyons [a,c], Azadeh Yadollahi [a,b], Clodagh M. Ryan [a,c,d], T. Douglas Bradley [a,c,d,*]

[a] Sleep Research Laboratory of the University Health Network Toronto Rehabilitation Institute, Toronto, ON, Canada
[b] Institute of Biomaterial and Biomedical Engineering, University of Toronto, Toronto, ON, Canada
[c] Centre for Sleep Medicine and Circadian Biology of the University of Toronto, Toronto, ON, Canada
[d] Department of Medicine of the University Health Network Toronto General Hospital, Toronto, ON, Canada

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ABSTRACT

Background: Overnight fluid shift from the legs to the neck may narrow the upper airway and contribute to obstructive sleep apnea (OSA) pathogenesis. We hypothesized that below-the-knee compression stockings will decrease OSA severity in a general OSA population by decreasing daytime leg fluid accumulation and overnight fluid shift and increasing upper-airway size.
Methods: Patients with OSA (apnea–hypopnea index ≥10) were randomized to wear compression stockings during the daytime or to a control group for 2 weeks. Overnight polysomnography with measurement of leg and neck fluid volumes and upper-airway cross-sectional area before and after sleep was performed at baseline and follow-up. The primary outcome was change in the apnea–hypopnea index.
Results: Twenty-two patients randomized to compression stockings and 23 to control completed the study. The apnea–hypopnea index decreased significantly more in the compression stockings than in the control group (from 32.4 ± 20.0 to 23.8 ± 15.5 vs. from 31.2 ± 25.0 to 30.3 ± 23.8, $p = 0.042$), in association with a significantly greater reduction in the overnight decrease in leg fluid volume ($p = 0.028$), and a significantly greater increase in morning upper-airway cross-sectional area ($p = 0.006$). Overnight change in neck fluid volume was unchanged.
Conclusion: These observations suggest that in, a general OSA population, below-the-knee compression stockings decrease OSA severity modestly via attenuation of overnight fluid shift and consequent upper-airway dilatation.

1. Introduction

Obstructive sleep apnea (OSA) is a common condition caused by repetitive collapse of the upper airway during sleep. Continuous positive airway pressure (CPAP), the most common treatment for OSA, is effective but poorly tolerated by many patients. Therefore, new treatments are needed [1]. One novel therapeutic target may be fluid accumulation in the neck during sleep, which may narrow the upper airway and increase its collapsibility [2]. During the daytime, fluid collects in the intravascular and interstitial spaces of the legs due to gravity, and at it night redistributes rostrally towards the neck where it may increase peripharyngeal tissue pressure and narrow the upper airway [3]. Daytime leg fluid accumulation is exacerbated by sedentary lifestyle and prolonged sitting [4]. In nonobese men, the frequency of apneas and hypopneas per hour of sleep (apnea–hypopnea index, AHI) correlated with the volume of fluid moving out of the legs overnight, which was in turn related to the degree of overnight increase in neck circumference as well as the time spent sitting during the daytime [3].

Compression stockings, a widely used treatment for varicose veins and edema, exert pressure on the legs and reduce dependent fluid movement from the intravascular to the interstitial space by counteracting the capillary hydrostatic pressure [5]. In two small studies involving sedentary men and in patients with chronic venous insufficiency, thigh-length compression stockings reduced the AHI by approximately 35% in association with reductions in the volume of fluid moving out of the legs overnight [6,7].

Abbreviations: AHI, Apnea–hypopnea index; CPAP, Continuous positive airway pressure; ESS, Epworth Sleepiness Scale; FOSQ-10, Functional Outcomes of Sleep Questionnaire-10; LFV, Leg fluid volume; NFV, Neck fluid volume; NSAID, Nonsteroidal anti-inflammatory drug; OSA, Obstructive sleep apnea; PVT, Psychomotor vigilance task; REM, Rapid eye movement; UA-XSA, Upper airway cross-sectional area.

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* Corresponding author. University Health Network Toronto General Hospital 9N-943, 200 Elizabeth Street, Toronto, ON M5G 2C4, Canada. Tel.: +1 416 340 4719; fax: +1 416 340 4197.
E-mail address: douglas.bradley@utoronto.ca (T.D. Bradley).

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However, no randomized studies of compression stockings in unselected OSA patients have been reported. Furthermore, thigh-length stockings are impractical to wear for individuals without varicose veins or edema and are unlikely to be tolerated well by the general OSA population. By contrast, below-the-knee compression stockings are much easier to apply and should be better tolerated in this population. Therefore, we performed a randomized controlled trial to test the hypothesis that, in a general OSA population, below-the-knee compression stockings will reduce the AHI in association with a reduction in overnight leg fluid volume (LFV) change. We further hypothesized that the reduction in overnight LFV change with compression stockings would be associated with a reduction in the overnight increase in neck fluid volume (NFV) and an increase in upper-airway cross-sectional area (UA-XSA).

2. Methods

2.1. Subjects

The inclusion criteria were patients aged 18–80 years referred to the University Health Network Toronto General Hospital Sleep Clinic for polysomnography because of a clinical suspicion of and diagnosed with OSA (AHI ≥10 with ≥50% of events obstructive). The exclusion criteria were OSA treated within the last 3 months, total sleep time <1.5 h, current use of compression stockings, tonsillar hypertrophy, history of heart failure, stroke or end-stage renal or liver disease, and use of drugs affecting fluid balance or level of consciousness (eg, diuretics, nonsteroidal anti-inflammatory drugs (NSAIDs), corticosteroids, sedatives, and opiates) at any time during the study. The protocol was approved by the Research Ethics Board of the University Health Network, and all patients provided written informed consent before participation.

2.2. Polysomnography

Overnight polysomnography was performed using standard techniques and scoring criteria for sleep stages and arousals [8]. Thoracoabdominal motion was monitored by respiratory inductance plethysmography and nasal airflow by nasal pressure cannulae. Oxyhemoglobin saturation (SaO_2) was monitored by oximetry. Apneas were defined as ≥90% reduction in airflow or thoracoabdominal motion from baseline, respectively, lasting ≥10 s. Hypopneas were defined as ≥30% reduction airflow lasting ≥10 s, associated with a ≥3% desaturation or an arousal from sleep [9]. They were classified as obstructive if there was out-of-phase thoracoabdominal motion or flow limitation on the nasal pressure tracing, and central if there was absent thoracoabdominal motion, or in-phase thoracoabdominal motion without evidence of airflow limitation, during apneas and hypopneas, respectively. Signals were recorded on a computerized sleep recording system and scored by technicians blind to the randomization of the patient and to measurement of NFV and LFV. The AHI and the frequency of oxygen desaturations of ≥3% per hour of sleep (oxygen desaturation index, ODI) were quantified.

2.3. NFV and LFV and neck and calf circumferences

Weight was measured before going to bed and within 30 min of awakening the next morning before urinating. Leg edema was assessed before sleep on a scale of 0–3 [10]. With subjects instrumented for sleep studies, lying awake and supine, LFV and NFV were measured simultaneously using a bioelectrical impedance spectrum analyzer (MP150, Biopac Systems Canada, Inc., Montreal, Canada). This well-validated technique uses impedance to electrical current within a body segment to measure the fluid content [11]. For NFV, electrodes were placed behind the right ear and at the base of the right side of the neck. For LFV, electrodes were placed on the ankle and upper thigh of both legs in order to capture reductions in LFV due to both edema reduction in the lower leg and increased venous return throughout the whole leg following the use of compression stockings. Electrodes were secured in place with adhesive tape and the distance between them measured to ensure they were placed the same distance apart at baseline and follow-up. Neck circumference and calf circumferences were measured as previously described [3]. Measurements of LFV, NFV, and neck and calf circumferences were repeated the next morning after awakening before subjects got out of bed and the overnight changes calculated. Measurements were made before the polysomnograms were scored such that the experimenter was blind to the AHI.

2.4. Upper-airway cross-sectional area

Intraluminal UA-XSA before and after sleep was measured by acoustic pharyngometry (Eccovision, Hood Laboratories, Pembroke, MA, USA), with the patient lying supine and the head in the neutral position as previously described [12,13].

2.5. Assessment of sleepiness, sitting time, and physical fitness

Before polysomnography, patients completed the Epworth Sleepiness Scale (ESS) and the short form of the Functional Outcomes of Sleep Questionnaire (FOSQ-10) [13–15]. They performed the psychomotor vigilance task (PVT; PVT-192, CWE Inc., Ardmore, PA, USA), a validated test of alertness that involves reacting as quickly as possible to the appearance of a light by pressing a button on a handheld device [16]. Results obtained included the mean reaction time and the number of false reactions (response to no signal) and lapses (reaction time >500 ms). Patients completed a diary of the number of hours spent sitting during that day and, at baseline, the Duke Activity Status Index, a measure of physical fitness [17].

2.6. Compression stockings

Patients were fitted with appropriately sized, off-the-shelf, below-the-knee compression stockings that apply a pressure of 20–30 mmHg at the ankle. Patients were instructed to wear them every day, commencing the morning after the baseline polysomnogram, putting them on immediately after awakening and removing them just before getting into bed. Patients completed a daily diary of the times the stockings were worn.

2.7. Study design

This was a 2-week randomized controlled trial. Prior to the baseline polysomnogram, patients were randomized according to a computer-generated random schedule in permuted blocks of two and four to either wear compression stockings during the study period or to a control group, with no intervention. Measurements were taken at baseline and at the end of the 2-week study period. Patients received a telephone call after 1 week to enquire about any changes in their health or medications and, for the compression stockings group, to determine that the stockings continued to fit well and to check for any side effects. No patients were treated for OSA by CPAP or any other intervention during the study period.

2.8. Outcome measures

The primary outcome was the change in AHI from baseline to follow-up. Secondary outcomes were changes in ODI, fluid volumes, UA-XSA, ESS, FOSQ-10, PVT results, and sleep structure.