



# The effect of compression stocking on leg edema and discomfort during a 3-hour flight: A randomized controlled trial

Joachim H.H. Olsen\*, Stina Öberg, Jacob Rosenberg

Center for Perioperative Optimization, Department of Surgery, Herlev Hospital, University of Copenhagen, Copenhagen, Denmark

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## ABSTRACT

**Background:** Compression stockings reduce the risk of thromboembolic complications, leg edema, and edema-related pain and discomfort during long-haul flights. The aim of this study was to assess if compression stockings reduce leg edema, pain, and discomfort during a three-hour flight.

**Methods:** This randomized controlled trial had a paired design as participants were randomized to wear a compression stocking on one leg during a three-hour flight with the other leg acting as control. Eligibility criteria were adults aged 18–60 years living in Denmark without medical indication for wearing compression stockings during flights. The primary outcome was the change in difference of ankle circumference between legs with and without compression stocking pre- and post-flight. Secondary outcomes were changes in difference of calf circumference, pain, and discomfort pre- and post-flight. All outcomes were self-reported with measurements and questionnaires.

**Results:** A total of 34 participants, median age 31 years (range 25–54), were randomized with complete follow-up. Difference in ankle circumference was median 5 mm larger post-flight compared with pre-flight (interquartile range (IQR) = 0–9,  $p = .001$ ) and the corresponding change in calf circumference difference was median 5 mm (IQR = 1–12,  $p < .001$ ). Ankle- and calf circumferences decreased in the leg wearing compression stocking and increased in the other leg. There was no change in difference of pain and discomfort and no adverse events.

**Conclusion:** Compression stockings reduced edema formation in young healthy passengers during a three-hour flight. Passengers experiencing edema-related discomfort during short-haul flights may benefit from wearing compression stockings during air travel.

**Trial registration:** [clinicaltrials.gov: NCT03546725](https://clinicaltrials.gov/ct2/show/study/NCT03546725).

## 1. Introduction

The use of compression stockings during short-haul flights can be recommended if they have benefits such as reducing ankle- and calf edema formation and decrease edema-related pain and discomfort. Approximately 3.8 billion passengers travel by flight each year, globally [1], and long-haul flights longer than four hours are a known risk factor for leg edema [2–5], deep venous thromboembolism [6–8] and superficial vein thrombosis [3,5]. As age is a general risk factor for leg edema [9,10], younger passengers may develop lesser edema during flights. Compression stockings have a prophylactic effect on edema and venous thromboembolic complications during flights longer than four hours [11] and low-ankle-pressure graduated compression tights reduce edema formation and edema-related discomfort during flights longer than five hours [12]. No studies have investigated the prophylactic

effect of compression stockings during flights shorter than four hours.

The aim of this study was to assess if compression stockings used during a 3-h flight decreased leg edema and discomfort in young healthy passengers.

## 2. Methods

This was a randomized controlled trial with a paired design where each participant was randomized to wear a compression stocking on only one leg. In this way, participants acted as their own control. The study is reported according to the Consolidated Standards of Reporting Trials (CONSORT) statement [13] with a statistical analysis plan and registration at [clinicaltrials.gov](https://clinicaltrials.gov/ct2/show/study/NCT03546725) before inclusion of the first participant (NCT03546725).

Eligibility criteria were adult men and women aged 18–60 years. All

\* Corresponding author at: Department of Surgery, Herlev Hospital, Herlev Ringvej 75, 2730 Herlev, Denmark.

E-mail address: [hjalde.o@gmail.com](mailto:hjalde.o@gmail.com) (J.H.H. Olsen).

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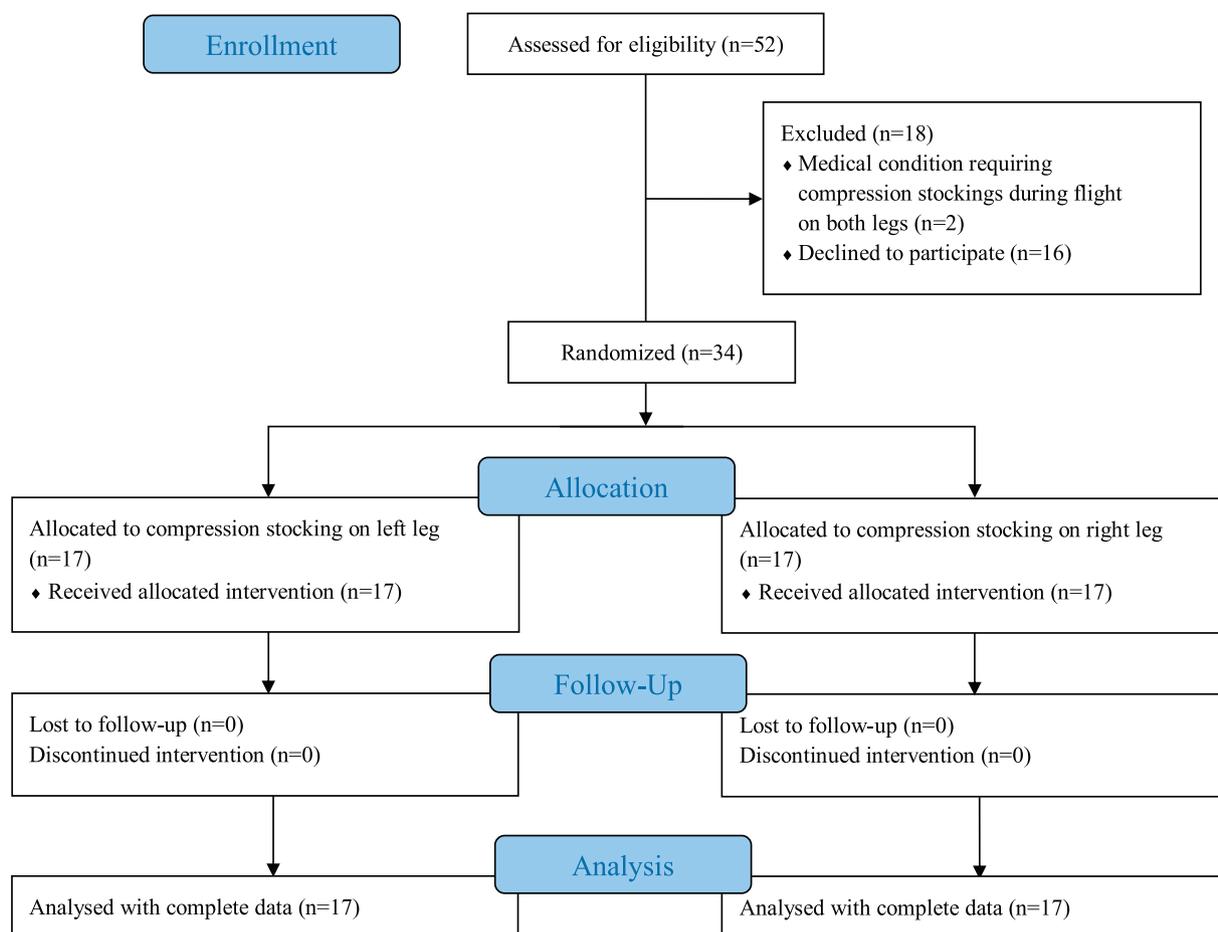


Fig. 1. Flow diagram of the trial process. n: number.

participants signed a written informed consent. Exclusion criteria were any conditions requiring compression stockings during flights or symptomatic arterial insufficiency in the lower extremities. All participants were adult medical researchers living in Denmark going on a planned group travel with a 3-h flight from Denmark to Turkey in May 2018. Participants were enrolled in the study at a meeting prior to the trial.

Participants were randomized to wear an individually fitted compression stocking on the left or the right leg (Sigvaris Medical Cotton, St. Gallen, Switzerland) with a length to below the knee and a class II compression level, corresponding to 23–32 mmHg compression at the ankle. Participants put on the compression stocking on the randomized leg in the airport just prior to the flight. The compression stocking was kept on until all participants were simultaneously instructed to remove the stocking in a bus departing from the airport. Measurements were done just prior to putting on and within few minutes after removing the stocking. The exact time was noted.

The primary outcome in this study was the change in differences of ankle circumference post-flight and pre-flight. We calculated the difference in ankle circumference as the circumference of the leg without compression stocking subtracted the circumference of the leg with compression stocking. This difference was calculated pre-flight and post-flight. The difference between the pre- and the post-flight differences was the primary outcome of the trial. Predefined areas for measurement at the smallest circumference at the ankle and the widest circumference at the calf were marked with a permanent marker. Each participant received verbal instructions and face-validated written instructions to take three measurements and report circumferences in centimeters (cm) with one decimal in a face-validated case report form.

The mean of the three measurements was used as the final measurement.

Secondary outcomes were the change in pre- and post-flight differences of calf circumference, and pain and discomfort between legs treated with and without compression stockings (the same procedure as for the primary outcome). A questionnaire was handed out to all participants with face-validated instructions for pain and discomfort assessment, using a horizontal 100 mm visual analogue scale. All participants were asked to report consumption of oral analgesics up to four hours prior to the flight as well as during the flight, and to specify the type of drug (paracetamol, ibuprofen, etc.) and dose in milligrams. Participants received verbal and written instructions to act as they would normally do during flights. All data were self-reported by participants. There were no changes to trial methods, eligibility criteria, or outcomes after commenced trial.

Sample size was calculated in the statistical program G\*power 3.1.9.2. The calculation was based on the detection of a relevant difference of the primary outcome i.e. change in pre- and post-flight differences in ankle circumference. A previous study found a mean decrease in ankle circumference of 0.19 cm in passengers wearing compression tights compared with passengers not wearing compression tights during flights longer than five hours [12]. As we expected a similar change, we set the mean difference in ankle circumference to 0.19 cm, with a standard deviation of 0.3 cm (as in the previous study) [12], 5% alpha, and 80% power. This yielded a sample size with a paired design of 23 participants. For practical reasons, we included all available individuals wishing to participate.

The randomization sequence of participants was performed the day before the trial by the second author (SÖ) using a computerized random

number generator with a 1:1 ratio, created at <http://www.randomization.com>. The second author also performed the allocation procedure, sending a short text message (SMS) immediately after randomization. The second author who performed the randomization and allocation had not examined participants before randomization, and was unaware of the participants' leg size, venous factors such as varicose veins, and any other potential differences between the two legs. Consequently, we considered concealing of the allocation irrelevant in this study. The study had a single blinded design, as participants self-registered the outcomes and could not be blinded due to the type of intervention. The first author was blinded for the randomized side during electronic data entry.

Data analysis was performed in IBM SPSS Statistics for Windows, Version 24.0 (IBM Corp., Armonk, NY). Distribution of data was assessed for normality with histograms. Data were analyzed with the Wilcoxon signed-rank test.

Approval was retrieved from the Danish Data Protection Agency (j.no. VD-2018-08-6141). According to Danish law, approval was not required by a local ethics committee for this type of study with non-invasive intervention in healthy volunteers (j.no. 17040074).

### 3. Results

We included 34 participants (18 females) with a median age of 31 years (range 25–54). All participants completed the full trial with 100% complete data. For flow of participants, see Fig. 1. The flight had a duration of approximately three hours with takeoff at 7:39 PM and landing at 10:34 PM Central European Time (CET) +1. Participants put on the compression stockings on the randomized leg median 70 min before the flight and removed the compression stocking median 47 min after landing, resulting in a median duration of wearing compression stockings of four hours and 55 min. Data pre-flight (baseline) and post-flight are summarized in Table 1.

The difference in ankle circumference was median 5 mm larger post-flight compared with the corresponding difference pre-flight, IQR = 0–9,  $p = .001$  (Table 2). The legs wearing compression stockings had a median decrease in ankle circumference of 2 mm ( $p = .004$ ) during flight, while the legs without compression stockings had a median increase of 2 mm ( $p = .01$ ) (Table 3).

The difference between pre- and post-flight calf circumference differences was median 5 mm, IQR = 1–12,  $p < .001$  (Table 2). After flight, legs wearing a compression stocking had a median reduction in calf circumference of 3 mm ( $p = .007$ ), while calf circumference had increased in legs without compression stockings with a median of 3 mm

**Table 1**

Objective and subjective measures pre- and post-flight. Median values of ankle- and calf circumference, pain, and discomfort for legs with compression stockings and legs without compression stockings. Measurements were taken before the compression stocking was put on and after the compression stocking was removed. n: number; IQR: interquartile range; cm: centimeters; mm: millimeters; VAS: visual analogue scale (range 0–100 mm).

	Compression (n = 34)		Non-compression (n = 34)	
	Median	IQR	Median	IQR
<b>Pre-flight</b>				
Ankle circumference, cm	22.6	21.5–24.0	22.5	21.7–23.8
Calf circumference, cm	38.2	36.1–40.9	37.7	36.0–40.3
Pain, mm (VAS)	0	0–0	0	0–1
Discomfort, mm (VAS)	0	0–2	0	0–3
<b>Post-flight</b>				
Ankle circumference, cm	22.3	21.4–23.5	22.8	22.0–24.2
Calf circumference, cm	38.0	34.9–40.3	38.2	36.2–40.9
Pain, mm (VAS)	0	0–1	0	0–1
Discomfort, mm (VAS)	2	0–11	0	0–6

**Table 2**

Change in pre- and post-flight differences between legs. Ankle and calf circumference, pain, and discomfort were measured pre- and post-flight and differences were calculated between legs with and without compression stockings. A change in pre- and post-flight differences was calculated as the post-flight difference subtracted the corresponding pre-flight difference. \*: Wilcoxon signed-rank test was used; IQR: interquartile range; mm: millimeters; VAS: visual analogue scale (range 0–100 mm).

	Median	IQR	p*
Ankle circumference, mm	5	0–9	0.001
Calf circumference, mm	5	1–12	< 0.001
Pain, mm (VAS)	0	0–0	0.86
Discomfort, mm (VAS)	0	–6–0	0.09

**Table 3**

Change in edema, pain, and discomfort for legs with and without compression stockings, separately. Changes in ankle circumference, calf circumference, pain, and discomfort were calculated as post-flight values subtracted corresponding pre-flight values. Differences were calculated separately for legs wearing and not wearing compression stockings. \*: Wilcoxon signed-rank test was used; n: number; IQR: interquartile range; mm: millimeters; VAS: visual analogue scale (range 0–100 mm).

	Compression (n = 34)			Non-compression (n = 34)		
	Median	IQR	p*	Median	IQR	p*
Ankle circumference, mm	–2	–6–0	0.004	2	0–5	0.01
Calf circumference, mm	–3	–9–1	0.007	3	–1–5	0.02
Pain, mm (VAS)	0	0–0	0.44	0	0–0	0.64
Discomfort, mm (VAS)	1	0–7	0.005	0	0–3	0.12

( $p = .02$ ) (Table 3).

There was no significant change in the difference in pain or discomfort between legs post-flight compared with the difference pre-flight (Table 2). While median visual analogue scale for pain did not increase during the flight, there was an increase in the median visual analogue scale for discomfort of 1 mm in legs with compression stockings ( $p = .005$ ) (Table 3). There were no adverse events. One participant had taken oral analgesics (1000 mg paracetamol and 600 mg ibuprofen) within four hours pre-flight. None of the participants took analgesics during the flight.

### 4. Discussion

In this randomized controlled trial, we found a positive effect of wearing compression stockings on ankle and calf circumference during a 3-h flight in healthy young volunteers. There was no difference in pain or discomfort between legs with and without compression stockings.

The difference in ankle and calf circumference was explained partly by edema formation in legs not wearing compression stockings and partly due to a reduction in volume of the legs wearing compression stockings. A similar difference solely due to increasing volume in legs not wearing compression stockings might result in even more pain and discomfort, which was absent in this study. As age is a risk factor for leg edema [9,10], older passengers may have more pronounced edema formation and consequently a greater benefit of wearing compression stockings, even during short-haul flights. The finding of reduced edema formation in the leg wearing the compression stocking is in accordance with previous studies that found a similar effect during long-haul flights [2–5].

We found a slight increase in discomfort with a visual analogue scale of 1 mm in legs with compression stockings. As most participants were young and not used to wear compression stockings, discomfort might reflect pressure from the stocking itself and may be unrelated to

edema. A class I compression level stocking may cause less discomfort. However, an increase in visual analogue scale of 1 mm is not clinically significant [14,15] and there was no difference in pain or discomfort when comparing legs with and without compression stockings. Our results differ from results of a previous study that found a larger mean decrease in ankle circumference of 0.19 cm in a group using compression tights during flights longer than five hours, who also had less pain and discomfort compared with the control group [12]. This finding of a smaller difference in ankle circumference, but a significant change in pain and discomfort may reflect a longer flight duration, as edema would persist for a longer time. Another explanation could be differences in relation to age i.e. that older patients could be more sensitive to edema formation or less sensitive to the compression from the stocking.

A strength of this study was the paired design with passengers acting as their own control consequently reducing the risk that findings were influenced by differences in baseline characteristics. While the visual analogue scale has not been validated specifically in respect of edema-related pain and discomfort after a flight, it has been validated as an accurate and reproducible scale for measurement of acute pain in patient groups with heterogeneous characteristics of age, gender, and causes of pain [14,15,16]. This study was limited by the lack of blinding of participants and self-reported measures of ankle- and calf circumference, which could introduce detection bias with the possibility of both over- and underestimation of outcomes. Since we based our sample size on detection of a change in ankle circumference difference, this study may be underpowered to detect changes in differences of pain and discomfort. As we only had a few exclusion criteria, the findings of this study have a high external validity. However, the participants were generally young and had a high socioeconomic status, which may limit the external validity in respect of older and comorbid passengers.

Current guidelines recommend compression stockings for passengers with risk factors for venous thromboembolism on long-haul flights, but not for flights with a duration of less than six hours due to the absolute risk of venous thromboembolism being low [17,18]. We found reduced edema formation in legs wearing compression stockings during a 3-h flight in a sample of young healthy volunteers. These findings do not demand the use of compression stockings for all passengers during short-haul flights, but passengers experiencing leg edema with coherent pain or discomfort would probably benefit from compression stockings. Future studies should investigate the effect of compression stockings on leg edema in passengers with increased risk of edema formation, for instance older passengers, as they may benefit even more from compression stockings during flights shorter than four hours.

In conclusion, compression stockings reduced ankle and calf edema formation during a short-haul flight of three hours but did not reduce pain or improve comfort in young healthy passengers. Passengers who experience edema with coherent pain and discomfort during short-haul flights would likely benefit from wearing compression stockings.

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#### Conflicts of interest

Olsen reports no potential conflicts of interest.

Öberg reports no potential conflicts of interest.

Rosenberg reports no potential conflicts of interest.

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