Sports Compression Garments: Application Guide

Mr Daniel Chi-Wo LEE

May 21, 2019 (Tuesday), 1930-2130, HKSI
Sports Compression Garment (CG)??

https://www.fancydress-factory.co.uk/

Definition of CG

• A piece of garment that *applies mechanical pressure* to the body surface hence compressing and stabilizing the underlying tissues;

• Available in various designs:
  • Lower-body from the ankle up to the waist;
  • Upper-body and;
  • Cover the limbs, fully or partially e.g. sleeves and stockings.

(MacRae et al., 2011)

https://www.2xu.com.hk/
Sports Compression Garment (CG)

• Popular among competitive and recreational athletes;

• Compression Wear and Shapewear Market is expected to reach US$5,576 million by 2022;

Allied Market Research, 2016

https://www.chinadailyhk.com/articles/161/184/184/1550388375573.html

History of CG application

- Clinical Application:

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(Agu et al., 1999; O'Meara et al., 2012; Partsch, 2014)

Burn scar management

Treatment of Deep vein thrombosis patient

(https://www.healthpartners.com/hospitals/regions/specialties/burn-center/scar-management/)
Clinical application of CG

Venous Disease A-Z series: no. 7

Thigh compression

H Partsch* and G Mosti†
*Private Practice, Vienna, Austria; †Department of Angiology and Cardiology, Casa di cura Barbantini, Lucca, Italy


Figure 1 (a) Magnetic resonance image cross-section at mid-thigh level in a patient with massive varicose veins and a dilated great saphenous vein (GSV) in supine position. (b) A thromboprophylactic stocking exerting a pressure of 6 mmHg on the thigh leads to a reduction of the cross-section of the GSV and of the femoral vein. This low pressure is enough to make the contour of the thigh look more circular. (c) Planimetry shows a reduction of the cross-section area of both GSV and femoral vein with the stocking
Clinical application of CG

Impact of compression stockings on calf-vein diameters and on quality of life parameters in subjects with painful legs

Christina Jeanneret\(^1\), Konstantinos Karatolios\(^1\), and Irene von Planta\(^2\)

\(^1\)Kantonsspital Baselland, Department of Angiology, University Clinic of Internal Medicine, Bruderholz, Switzerland
\(^2\)Vascular Laboratory, St. Johann, Switzerland

Conclusions: Intra-individually tested the calf muscle vein diameters decrease under compression, more pronounced in the prone than in the standing position. In the ankle area the PTV does not decrease in standing subjects. Quality of life assessed increases for both compression stockings.

Figure 2: Duplexsonography imaging of gastrocnemius veins in standing and prone position, with and without compression, indication of measurement

ap = antero-posterior, lm = latero-medial
Clinical application of CG

High Compression Pressure over the Calf is More Effective than Graduated Compression in Enhancing Venous Pump Function

G. Mosti a, b,*, H. Partsch b

WHAT THIS PAPER ADDS

- This study emphasises the importance of high compression pressure over the calf to enhance venous pumping function in patients with severe venous insufficiency, independently from the pressure profile. In our study, this high pressure was applied by wrapping inelastic material with a ‘negative gradient’; the compression pressure was stronger over the calf compared to the ankle. This concept is in disagreement with the usual belief that compression should always have a reducing graduated pressure profile from ankle to calf. In the future clinical practice, this means that we do not need to follow dogmatic rules to distribute the pressure of the bandage along the leg but should be guided by the wish to obtain optimal efficacy.
Any benefits of wearing CG in healthy individuals?!
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Current findings on CG in sports
Claimed benefits of CG in sports

**Background**

- 30 male participants RCT into different group
- Compression tights (15 mmHg)
- Stockings (15 mmHg)
- CON (&lt;5 mmHg at calf and thigh)
- 120 mins running uphill @55% VO\(_{2\text{max}}\)
- 60 and 180 mins after run (Mb: Myoglobin)
- Rest with normal garment

**Current Findings**

**CUHK Studies**

**Messages**

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**Wearing Compression Tights on the Thigh during Prolonged Running Attenuated Exercise-Induced Increase in Muscle Damage Marker in Blood**

Sahiro Mizuno, Mari Arai, Fumihiko Todoko, Eri Yamada and Kazushige Goto

Citation:

\[\text{Mb concentration} = 3,370 \text{ pg/mL} \text{ at } 180 \text{ min, } P = 0.03\]  

**Conclusion:** Wearing compression garment on the thigh significantly attenuated the increase in serum Mb concentration after exercise, suggesting that exercise-induced muscle damage was attenuated.

Keywords: compression gear, prolonged running, exercise-induced muscle damage, jump performance, maximal muscular strength
Claimed benefits of CG in sports

**Background**

- 8 male participants
- **High tights** (thigh: 26.8 mmHg, calf: 29.2 mmHg)
- **Med tights** (thigh: 16.1 mmHg, calf: 17.9 mmHg)
- **Low tights** (thigh: 4.4 mmHg, calf: 3.0 mmHg)
- 120 mins running uphill @60% VO_{2max}
- Jump performance after run

**Current Findings**

Wearing lower-body compression garment with medium pressure impaired exercise-induced performance decrement during prolonged running

Sahiro Mizuno¹, Mari Arai²*, Fumihiro Todoko²*, Eri Yamada²*, Kazushige Goto³*

PLOS ONE | https://doi.org/10.1371/journal.pone.0178620 | May 31, 2017 | 1 / 12

**CUHK Studies**

**Messages**

**Conclusion**

Wearing a lower body CG exerting medium pressure (approximately 15 mmHg) significantly attenuated decrease in jump performance than that with high pressure (approximately 30 mmHg). Furthermore, exercise-induced increases in HR and the inflammatory response were significantly smaller with CG exerted 15 mmHg than that with garment exerted < 5 mmHg.

Decision to publish, or preparation of the manuscript.

**Competing interests:** Three authors (Arai M, Todoko F, Yamada E) are affiliated to DESCENTE Ltd, which made garments for the present experiment. Although they contributed to conducting the present experiment (e.g., preparing custom-made garments, evaluating pressure levels), they were not involved in manuscript writing or drawing conclusion from the results.
## Claimed benefits of CG in sports

### Background

Current Findings

CUHK Studies

Messages

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**RESEARCH ARTICLE | Control of Coordinated Movements**

Effects of a compression garment on sensory feedback transmission in the human upper limb

© Trevor S. Barss,1,2,3 Gregory E. P. Pearcey,1,2,4 Bridget Munro,4 Jennifer L. Bishop,4 and E. Paul Zehr1,2,3,5

- 13 participants (M: 5)
- Neurologically intact participants
- Custom-made, non-medical-grade compression sleeve, silicone at the proximal and distal ends
- **10 and 20 mmHg across forearm and upper arm**
- Afferent Transmission during a static Task and movement

Compression apparel modulates spinal cord excitability across multiple sensory pathways and movement tasks. Interestingly, there was a significant improvement in reaching accuracy while wearing the compression sleeve. Taken together, the compression sleeve appears to increase precision and sensitivity around the joint where the sleeve is applied. Compression apparel may function as a “filter” of irrelevant mechanoreceptor information allowing for optimal task-related sensory information to enhance proprioception.

**NEW & NOTEWORTHY** Wearing a customized compression sleeve was shown to alter the excitability of multiple pathways within the central nervous system regardless of conditioning input or movement task and was accompanied by improved accuracy of reaching movements and determination of movement end point. Compression apparel may assist as a type of “filter function” of tonic and non-specific mechanoreceptor information leading to increased precision and movement sensitivity around the joint where compression is applied.
Claimed benefits of CG in sports

INFLUENCE OF A COMPRESSION GARMENT ON REPETITIVE POWER OUTPUT PRODUCTION BEFORE AND AFTER DIFFERENT TYPES OF MUSCLE FATIGUE

WILLIAM J. KRAEMER*, JILL A. E NOEL D. DUNCAN®, JEFF S. VOL PAUL CANAVAN*, JOHN JOHNSTON and WAYNE J. SEB

customized software used to determine jump power. Ten consecutive maximal counter-movement jumps with arms held at waist level were performed. The compressive garment had no effect on the maximal power of the highest jump in either men or women. The compressive garment significantly enhanced mean power output in the jump test both before and after different fatigue tasks. The compressive garment enhanced joint position sense at the hip at 45° and 60° of flexion. A compression garment also significantly reduced the vertical velocity of muscle movement upon landing. These data indicate that compression shorts do not improve maximal jump power output. However, an enhanced mean power output during the repetitive maximal jump test was observed when wearing a compression garment. The performance improvement observed may be due to reduced muscle oscillation upon impact, psychological factors, and/or enhanced joint position sense.
Claimed benefits of CG in sports

**Effect of an Ankle Compression Garment on Fatigue and Performance**

NEMANJA ŠAMBAHER, SAIED J. ABOODARDA, DUSTIN B. SILVEY, DUA DAVID G. BEHM

*Journal of Strength and Conditioning Research*
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- 15 healthy, active participants (M: 7)
- Ankle CG: below knee to over ankle
- WU: Bicycling 5 min at 10 rpm, 1kP and 20 calf raise & 30 hops
- Test: ankle half-relaxation time
- Continuous drop jump @ 50cm
- MVC force

Heights), continuous drop jump (30 cm), time to fatigue (TTF), and blood lactate concentration were measured pre- and post-warm-up and postfatigue. Compared with control condition, ankle CG condition had significantly reduced half-relaxation times (p = 0.043) and higher skin temperatures at post-warm-up and post-fatigue protocol (p < 0.001, Δ3.2 and Δ4%, respectively). Participants also exhibited significantly lower ground reaction forces (GRFs) for 50-cm drop jumps (p = 0.044, Δ9.9%) with ankle CG at post-warm-up. There were no significant differences between conditions for muscle contractile properties, MVC force or EMG, jump height, take-off velocity, contact time, and jumping TTF. Independent of group, there was a threefold increase in blood lactate (p < 0.001) from pre-warm-up to post-fatigue and a significant decrease in MVC force (p = 0.048, Δ8.1%) from post-warm-up to postfatigue. Results suggest that ankle CG increased and maintained skin temperature during recovery, decreased twitch half-relaxation times, and reduced GRF from a 50-cm drop height. However, ankle CG did not improve other performance measures, aid in recovery, or affect blood lactate clearance.
Claimed benefits of CG in sports

- 20 healthy women (non-strength trained)
- Compression sleeves for 5 days
- Worn immediately after exercise
- Non-compression group
- Upper arm circumference
- Creatine Kinase (CK)
- Subjective soreness perception
- Test: 2*sets (50 arm curl), 60°/s
Claimed benefits of CG in sports

**Compression Stockings Used During Two Soccer Matches Improve Perceived Muscle Soreness and High-Intensity Performance**

**Background**

Current Findings

CUHK Studies

Messages

S. Valencia Gimenes,1 M. Marocolo,2 L. Neves Pavin,1 Leandro Mateus Pagoto Spigolon,3,4 O. Barbosa Neto,1 Bruno Victor Correa da Silva,6 Rob Duffield,6 and Gustavo Ribeiro da Mota1

Journal of Strength and Conditioning Research
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CG and control groups. Although total distance covered did not differ (p > 0.05) between groups, CS increased distances (effect size [ES] = 0.9–1.32) in higher-speed zones (>19 km·h⁻¹ CS ~550 m vs. control ~373 m) alongside an increased number of accelerations (~50.0 to ~3.0 m·s⁻²) than control (CS: 33.7 ± 11.2 vs. control: 23.8 ± 7.9; p = 0.003; ES = 1.04). Perceived recovery did not differ (p > 0.05) between groups for either match but was worse in the second match for both groups. Perceived muscle soreness increased in control after match 2 (from 3.1 ± 1.9 to 6.3 ± 1.6 AU; p < 0.0010) but did not in CS (from 2.8 ± 1.4 to 4.1 ± 1.9 AU; p = 0.6275; ES = 1.24 CS vs. control after match). Accordingly, CS use during 2 soccer matches with 72-hour recovery reduces perceived muscle soreness in the second match and increases higher-speed match running performance.

- 20 outfield players (5 km run time ~19:29)
- Compression stockings (20-30 mmHg)
- CON garment (regular socks)
- 2 matches with match loads
- Running distance of the matches
- Perceived muscle soreness
Claimed benefits of CG in sports

Effect of Pressure Intensity of Compression Short-Tight on Fatigue of Thigh Muscles

NAOKAZU MIYAMOTO¹ and YASUO KAWAKAMI²

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DOI: 10.1249/MSS.00000000000009330

Methods: Two groups of 11 male subjects performed treadmill running at 12 km/h in three conditions in each of experiment 1 (short-tights with a compression intensity of the thigh of 8 mm Hg (LOW) and 15 mm Hg (MID) and non-compression shorts as control (CON)) and experiment 2 (short-tights with 20 mm Hg (MID-HIGH) and 25 mm Hg (HIGH) and CON2). Before and immediately after the running exercises, T2-weighted magnetic resonance images of the right thigh were obtained without testing garments. From the images, skeletal muscle proton transverse relaxation time (T2) of each muscle in the thigh was calculated. Results: T2 was significantly increased after the treadmill running in all conditions in the hamstring and adductor muscles. In experiment 1, after the running, T2 elevation was significantly smaller in MID than that in CON1 for the biceps femoris, semimembranosus, adductor longus, and adductor magnus muscles. In experiment 2, after the running, T2 elevation was significantly lower in MID-HIGH than that in CON2 and HIGH for the biceps femoris, semimembranosus, and adductor longus. Conclusions: The findings suggest that wearing compression short-tights with a pressure intensity of 15-20 mm Hg at the thigh can reduce development of fatigue of exercising muscles during submaximal running exercise in healthy adult males. Key Words: MAGNETIC RESONANCE IMAGING, TRANSVERSE RELAXATION TIME, TREADMILL RUNNING, HAMSTRING, HIP ADDUCTORS, MALE ADULTS
Claimed benefits of CG in sports

- 23*elite male rugby player
- Competition rugby
- Lower-body compression garment (~12 hrs)
- Passive recovery (9 mins bench sitting, etc.)
- Active recovery (7 mins spinning)
- Contrast water therapy 3*(1 mins 8-10 °C + 2 mins 40-22 °C)
- CK transdermal (36, 84 hrs)

**Background**

**Current Findings**

**CUHK Studies**

**Messages**

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**Effectiveness of post-match recovery strategies in rugby players**

N D Gill, C M Beaven, C Cook

Objectives: To examine the effectiveness of four interventions on the rate and magnitude of muscle damage recovery, as measured by creatine kinase (CK).

Methods: 23 elite male rugby players were monitored transdermally before, immediately after, 36 hours after, and 84 hours after competitive rugby matches. Players were randomly assigned to complete one of four post-match strategies: contrast water therapy (CWT), compression garment (GAR), low intensity active exercise (ACT), and passive recovery (PAS).

Results: Significant increases in CK activity in transdermal exudate were observed as a result of the rugby match (p<0.01). The magnitude of recovery in the PAS intervention was significantly worse than in the ACT, CWT, and GAR interventions at the 36 and 84 hour time points (p<0.05).

Conclusions: An enhanced rate and magnitude of recovery was observed in the ACT, CWT, and GAR treatment groups when compared with the PAS group. Low impact exercise immediately post-competition, wearing compression garments, or carrying out contrast water therapy enhanced CK clearance more than passive recovery in young male athletes.
Claimed benefits of CG in sports

**Background**

Wearing compression socks during exercise aids subsequent performance.

**Current Findings**

- 12 male runner (5 km run time ~19:29)
- Compression socks (calf: ~37 mmHg, upper ankle: ~31 mmHg, lower ankle: ~23 mmHg)
- Test: Run WU, (5K TT, 60 mins recovery) with/without CG, then 5K TT again
- TT performance

**CUHK Studies**

**Messages**

(TT1), a one hour recovery period, then a repeat of the warm-up and 5 km time trial (TT2). One session required the use of sports compression socks during the first warm-up and time trial (COMP), while the other did not (CON).

**Results:** The decline in run performance in CON from TT1 to TT2 was moderate and significantly greater than that experienced by runners in COMP (9.6 s, d = 0.67, p < 0.01). No difference was found between experimental conditions for oxygen consumption, blood lactate or calf volume (p = 0.61, 0.54, 0.64, respectively). Perceptual measures of muscle soreness, fatigue and recovery were also similar between trials (p = 0.56, 1.00 & 0.61, respectively).

**Conclusions:** Wearing sports compression socks during high intensity running has a positive impact on subsequent running performance. The underlying mechanism of such performance enhancement remains unclear, but may relate to improved oxygen delivery, reduced muscle oscillation, superior running mechanics and athlete beliefs.
Sport CG enhance sport performance and recovery!!
Other recent study of CG in sports

THE EFFECT OF GRADUATED COMPRESSION STOCKINGS ON RUNNING PERFORMANCE

AJMOL ALI,1 ROBERT H. CREA SY,2 AND JOHANN A. EDGE3

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25(5)/1385–1392
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Ali, A, Creasy, RH, and Edge, JA. The effect of graduated compression stockings on running performance. J Strength Cond Res 25(5): 1385–1392, 2011—The aim of this study was to examine the effects of wearing different grades of graduated compression stockings (GCS) on 10-km running performance. After an initial familiarization run, 9 male and 3 female competitive runners (Vo2max 88.7 ± 5.8 ml·kg−1·min−1) completed 4 10-km time trials on an outdoor 400-m track wearing either control (0 mm Hg; Con), low (12–15 mm Hg; Low), medium (18–21 mm Hg; Med), or high (23–32 mm Hg; Hi) GCS in a randomized counterbalanced order. Leg power was assessed pre and postrun via countermovement jump using a jump mat. Blood-lactate concentration was assessed GCS. There were no significant differences in performance time between trials (p = 0.99). The change in pre to postexercise jump performance was lower in Low and Med than in Con (p < 0.05). Mean heart rate (p = 0.99) and blood lactate (p = 1.00) were not different between trials. Participants rated Con and Low as more comfortable than Med and Hi (p < 0.01). Med and Hi were rated as tighter than Low (p < 0.01), all GCS were rated as lighter than Con (p < 0.01), and Hi was associated with the most pain (p < 0.01). In conclusion, GCS worn by competitive runners during 10-km time trials did not affect performance time; however, Low and Med GCS resulted in greater maintenance of leg power after endurance exercise.
Other recent study of CG in sports

The Use of Compression Stockings During a Marathon Competition to Reduce Exercise-Induced Muscle Damage: Are They Really Useful?

- 34 recreational runners (M: 17)
- Marathon race
- Performance time & pace of marathon
- Pre- and post-CK, CMJ, CK, serum myoglobin
- Compression stockings (foot to below-knee: 25-20 mmHg)
- Conventional socks

OBJECTIVES: To examine the efficacy of wearing compression stockings to prevent muscle damage and to maintain running performance during a marathon competition.

BACKGROUND: Exercise-induced muscle damage has been identified as one of the main causes of the progressive decrease in running and muscular performance found during marathon races.

METHODS: Thirty-four experienced runners were pair-matched for age, anthropometric data, and best race time in the marathon, and randomly assigned to a control group (n = 17) of runners who wore conventional socks or to a group of runners who wore foot-to-knee graduated compression stockings (n = 17). Before and after the race, a sample of venous blood was obtained, and jump reductions in leg muscle power (−19.8% ± 177%) versus −24.8% ± 18.4%, respectively; P = .37) and jump height (−25.3% ± 14.1% versus −32.5% ± 20.4%, respectively; P = .27) were similar. At the end of the race, there were no differences between the control group and the compression stockings group in serum myoglobin (568 ± 347 ng·mL⁻¹ versus 573 ± 270 ng·mL⁻¹, respectively; P = .97) and creatine kinase concentration (390 ± 166 U·L⁻¹ versus 487 ± 227 U·L⁻¹, respectively; P = .16).

CONCLUSION: The use of compression stockings did not improve running race and did not prevent exercise-induced muscle damage during the marathon. Wearing compression stockings during long-distance running events is an ineffective strategy to avoid the deleterious effects of muscle damage on running performance.
Other recent study of CG in sports

Born et al. BMC Sports Science, Medicine, and Rehabilitation 2014, 6:21
http://biomedcentral.com/2052-1847/6/21

A novel compression garment with adhesive silicone stripes improves repeated sprint performance – a multi-experimental approach on the underlying mechanisms

Dennis-Peter Born1,2, Hans-Christer Holmberg3, Florian Goernert1 and Billy Sperlich1,3

- 12 recreational runners (M: 17)
- 30*30m repeated sprints with 1 min rest
- Compression tights (silicon strips): Rectus femoris: 19.0 mmHg/Gastrocnemius medialis: 21.7
- Physiological monitoring, haemoglobin and RPE measurements
- Speed camera and record on muscle activation

Revised sprint performance is determined by explosive production of power, as well as concerted efforts by the athletes, and there is evidence that compression garments and sports taping can

Each of two sub-studies, female athletes performed two sets of 30 30-m sprints (one wearing compression garments with adhesive silicone stripes (CGSS) intended to mimic normal clothing, in randomized order. Sub-study 1 (n = 12) focused on cardio-respiratory and perceptual responses, while neuronal and biomechanical parameters were

Both sub-studies the CGSS improved repeated sprint performance during the final 30 m. None of the cardio-respiratory or metabolic variables monitored were altered (P = 0.06, d = 0.71). Also during the final 10 sprints, rating of perceived exertion reduced (P = 0.01, d = 1.1), step length increased (P = 0.01, d = 0.91) and activation (P = 0.01, d = 1.24), while the hip flexion angle was lowered throughout the 2.28 s and step frequency (best P = 0.34, d = 0.2) remained unaltered.

Although physiological parameters monitored were unchanged, the CGSS improved repeated sprint performance during the final 30 m. None of the cardio-respiratory or metabolic variables monitored were altered (P = 0.06, d = 0.71). Also during the final 10 sprints, rating of perceived exertion reduced (P = 0.01, d = 1.1), step length increased (P = 0.01, d = 0.91) and activation (P = 0.01, d = 1.24), while the hip flexion angle was lowered throughout the 2.28 s and step frequency (best P = 0.34, d = 0.2) remained unaltered.

Through the course of 30 30-m repeated sprints by reducing perceived exertion and altering stride flow, clothing, Oscillation, Oxygenation, Oxygen uptake, Textile, Tissue satiety, Video analysis
Other recent study of CG in sports


Compression stockings do not improve muscular performance during a half-ironman triathlon race

Juan Del Coso · Francisco Areces · Juan José Salmero · Cristina González-Millán · Javier Abián-Vicén · Lidon Soriano · Diana Ruiz · César Gallo · Beatriz Lara · Julio Calleja-Gonzalez

- 36 experienced triathlete
- 19*CG group & 17*CON group
- Half ironman triathlon
- Compression stockings or regular socks
- Performance time, CMJ, CK, blood myoglobin, RPE muscle soreness

Purpose This study aimed at investigating the effectiveness of compression stockings to prevent muscular damage and preserve muscular performance during a half-ironman triathlon.

Methods Thirty-six experienced triathletes volunteered for this study. Participants were matched for age, anthropometric data and training status and placed into the experimental group (N = 19; using ankle-to-knee graduated compression stockings) or control group (N = 17; using regular socks). Participants competed in a half-ironman using validated scales.

Results Total race time was not different between groups (315 ± 45 for the control group and 310 ± 32 min for the experimental group; P = 0.46). After the race, jump height (0.5 ± 0.0 vs. 0.3 ± 0.0; P = 0.01) was different between groups after the race.

Conclusion Wearing compression stockings did not represent any advantage for maintaining muscle function or reducing blood markers of muscle damage during a triathlon event.
Other recent study of CG in sports

The Effects of Wearing Lower Body Compression Garments During a Cycling Performance Test

Matthew W. Driller and Shona L. Halson

International Journal of Sports Physiology and Performance, 2013, 8, 300-306
© 2013 Human Kinetics, Inc.

Purpose: Compression garments have been commonly used in a medical setting as a method to promote blood flow. Increases in blood flow during exercise may aid in the delivery of oxygen to the exercising muscles and, subsequently, enhance performance. The aim of the current study was to investigate the effect of wearing lower body compression garments during a cycling test. Methods: Twelve highly trained cyclists (mean ± SD age 30 ± 6 y, mass 75.6 ± 5.8 kg, VO2peak 66.6 ± 3.4 mL · kg⁻¹ · min⁻¹) performed two 30-min cycling bouts on a cycle ergometer in a randomized, crossover design. During exercise, either full-length lower body compression garments (COMP) or above-knee cycling shorts (CON) were worn. Cycling bouts involved 15 min at a fixed workload (70% of VO2peak power) followed by a 15-min time trial. Heart rate (HR) and blood lactate (BL) were measured during the fixed-intensity component of the cycling bout to determine the physiological effect of the garments. Calf girth (CG), thigh girth (TG) and perceived soreness (PS) were measured preexercise and postexercise. Results: COMP produced a trivial effect on mean power output (ES = .14) compared with CON (mean ± 95% CI 1.3 ±1.0). COMP was also associated with a lower HR during the fixed-workload section of the test (~2.6% ± 2.3%, ES = -.38). There were no differences between groups for BL, CG, TG, and PS. Conclusion: Wearing compression garments during cycling may result in trivial performance improvements of ~1% and may enhance oxygen delivery to the exercising muscles.

- 12 highly trained cyclists (VO2peak 66.6 ± 3.4 mL · kg⁻¹ · min⁻¹)
- 15mins (70% VO2), then 15mins TT
- Lower-body compression tights during cycling
- Above knee cycling shorts (CON)
- Blood lactate, calf girth, thigh girth, perceived soreness
Other recent study of CG in sports

Calf Compression Sleeves Change Biomechanics but Not Performance and Physiological Responses in Trail Running

Hugo A. Kerhervé, Pierre Samozino, Fabrice Descombes, Matthieu Pinay, Guillaume Y. Millet, Marion Pasqualini and Thomas Rupp

- 14 male participants
- 3 laps on moderately flat terrain (MFT)
- 2 laps technical and hilly terrain (THT)
- Calf compression sleeves (23±2 mmHg)
- CON (full tights: <4 mmHg)
- Speed, distance, HR, skin temp. delay onset of muscle soreness (VAS)

Results: Muscle oxygenation increased significantly in CS compared to CON at baseline and immediately after exercise (p < 0.05), without any difference in deoxygenation kinetics during the run, and without any significant change in run times. Wearing CS was associated with (i) higher aerial time and leg stiffness in running at constant rate, (ii) with lower ground contact time, higher leg stiffness, and higher vertical stiffness in all-out running, and (iii) with lower ground contact time in hopping. Significant DOMS were induced in both CS and CON (>5 on a 10-cm scale) with no difference between conditions. However, Achilles tendon pain was significantly lower after the trial in CS than CON (p < 0.05).

Discussion: Calf compression did not modify muscle oxygenation during ~2 h 30 of trail running but significantly changed running biomechanics and lower limb muscle functional capabilities toward a more dynamic behavior compared to control session. However, wearing compression sleeves did not affect performance and exercise-induced DOMS, while it minimized Achilles tendon pain immediately after running.
Other recent study of CG in sports

Pressure and coverage effects of sporting compression garments on cardiovascular function, thermoregulatory function, and exercise performance

Braid A. MacRae · RaecheL M. Laing · Brian E. Niven · James D. Cotter

- 14 male recreationally trained cyclist
- 60min (65% VO₂) followed by 6km TT
- Whole-body CG: 11-15 mmHg, over-sized CG: 8-13 mmHg, gym-shorts (CON)
- Exercise cardiac output (CO), Stroke volume (SV), Heart rate (HR)
- Covered skin temp. and core temp.
- TT performance

Mixed-road cycling at ~ 65% VO₂max and a 6-km time trial. Wearing CG (CSG or OSG) did not mitigate cardiovascular strain during mild orthostatic stress at rest (p = 0.20–0.93 for garment effects). During exercise, cardiac output was ~ 5% higher in the CG conditions (p < 0.05), which appears to be accounted for via non-significant higher end-exercise heart rate (~ 4–7%, p = 0.30; p = 0.06 for greater heart rate drift in CSG); other cardiovascular variables, including stroke volume, were similar among conditions (p = 0.23–0.91). Covered-skin temperature was higher in CG conditions (p < 0.001) but core (oesophageal) temperature was not (p = 0.79). Time-trial performance (mean power, time taken) was similar with or without CG (p = 0.24–0.44). In conclusion, any demonstrable physiological or psychophysical effects of full-body CG were mild and seemingly reflective more of surface coverage than pressure. No benefit was evident for exercise performance.
Other recent study of CG in sports

Long-term effects of graduated compression stockings on cardiorespiratory performance

AUTHORS: Priego JJ1,2, Lucas-Cuevas AG1, Aparicio I1, Giménez JV1, Cortell-Torres JM3, Pérez-Soriano P1

ABSTRACT: The use of graduated compression stockings (GCS) in sport has been increasing in the last years due to their potential positive effects for athletes. However, there is little evidence to support whether these types of garments actually improve cardiorespiratory performance. The aim of this study was to examine the cardiorespiratory responses of GCS during running after three weeks of regular use. Twenty recreational runners performed three tests on different days: test 1) – a 5-min maximal effort run in order to determine the participants’ maximal aerobic speed; and tests 2) and 3) – a fatigue running test of 30 minutes at 80% of their maximal aerobic speed with either GCS or PLACEBO stockings at random. Cardiorespiratory parameters (minute ventilation, heart rate, relative oxygen consumption, relative carbon dioxide production, ventilatory equivalents for oxygen and carbon dioxide, and oxygen pulse) were measured. Before each test in the laboratory, the participants trained with the randomly assigned stockings (GCS or PLACEBO) for three weeks. No significant differences between GCS and PLACEBO were found in any of the cardiorespiratory parameters. In conclusion, the present study provides evidence that running with GCS for three weeks does not influence cardiorespiratory parameters in recreational runners.

- 20 recreational runner (M: 13)
- GCS (ankle:24 mmHg and Knee: 21 mmHg; manufacturer information)
- 3 weeks of training with GCS or placebo garment (Randomly assigned)
- 5 mins max effort run
- Ventilation per min
- Heart rate (HR)
- VO₂ per kg
- VCO₂ per kg
Other recent study of CG in sports

- 15 well-trained cyclists (Maximal power output 339 ± 39 W)
- Loose fitting shorts
- Low compression tights
- Med compression stockings
- 3*intervention trials: (30, 50, 70, 85% PPO Loading, 5-min recovery, then 4km TT)
- Stroop test at each stage
- MAP, cerebral blood flow, lactate, etc.

Compression garments and cerebral blood flow: Influence on cognitive and exercise performance

Brittany A. Smale, Joseph M. Northey, Disa J. Smee, Nathan G. Versey & Ben Rattray

Abstract
This study aimed to describe the effect of compression garments on middle cerebral artery blood flow velocity (MCA) in relation to cognitive and exercise performance whilst cycling. In a randomised-controlled-cross-over design, 15 well-trained male cyclists were recruited to participate in three identical trials wearing loose fitting shorts (control), low-grade, or medium-grade compression garments. The protocol involved four 8 min increments of cycling at 30%, 50%, 70%, and 85% maximal power output and a 4 km time-trial. Participants undertook a cognitive Stroop task at baseline and at the midpoint of each increment. MCA was monitored with Transcranial Doppler Ultrasonography. Mean arterial pressure (MAP) and partial pressure of end-tidal CO₂ (PₐCO₂) were measured throughout. MCA, MAP, PₐCO₂, and reaction time of the complex Stroop task were influenced by exercise intensity, but not compression garments. Compression garments significantly affected cognitive accuracy in the complex Stroop task such that low-grade compression appeared to enhance cognitive accuracy in comparison to the control condition at the highest intensity (p = .010). Time-trial performance did not differ between the control (338.0 ± 17.3 s), low-grade (338.7 ± 18.7 s), or medium-grade (342.2 ± 19.3 s) conditions (p = .114). Compression garments did not affect MCA, during exercise or time-trial performance, but compression may be beneficial for improved cognitive accuracy during high-intensity exercise. Further research is required to elucidate the potential impact on cognitive performance.
Other recent study of CG in sports


Different types of compression clothing do not increase sub-maximal and maximal endurance performance in well-trained athletes

BILLY SPERLICH¹, MATTHIAS HAEGELE¹, SILVIA ACHTZEHN¹, JOHN LINVILLE², HANS-CHRISTER HOLMBERG³, & JOACHIM MESTER¹

- 15 well-trained athlete \( \text{VO}_{2\text{max}} \ 63.7 \pm 4.9 \ \text{mL} \cdot \text{kg}^{-1} \cdot \text{min}^{-1} \)
- Compression socks
- Compression tights
- Whole-body compression
- No exerted pressure provided
- 15 mins running at ~70% \( \text{VO}_{2\text{max}} \), then run to volitional exhaustion (fixed velocity)

Three textiles with increasing compressive surface were compared with non-compressive conventional clothing on physiological and perceptual variables during sub-maximal and maximal running. Fifteen well-trained endurance athletes (mean ± SD: age 27.1 ± 4.8 years, \( \text{VO}_{2\text{max}} \ 63.7 \pm 4.9 \ \text{mL} \cdot \text{min}^{-1} \cdot \text{kg}^{-1} \)) performed four sub-maximal (~70% \( \text{VO}_{2\text{max}} \)) and maximal tests with and without different compression stockings, tights, and whole-body compression suits. Arterial lactate concentration, oxygen saturation and partial pressure, pH, oxygen uptake, and ratings of muscle soreness were recorded before, during, and after all tests. In addition, we assessed time to exhaustion. Sub-maximal (\( P = 0.22 \)) and maximal oxygen uptake (\( P = 0.26 \)), arterial lactate concentration (\( P = 0.16 \; 0.20 \)), pH (\( P = 0.23 \; 0.46 \)), oxygen saturation (\( P = 0.13 \; 0.26 \)), and oxygen partial pressure (\( P = 0.09 \; 0.20 \)) did not differ between the types of clothing (effect sizes = 0.00–0.45). Ratings of perceived exertion (\( P = 0.10 \; 0.15 \)), muscle soreness (\( P = 0.09 \; 0.10 \)) and time to exhaustion (\( P = 0.16 \)) were also unaffected by the different clothing (effect sizes = 0.28–0.85). This was the first study to evaluate the effect on endurance performance of different types of compression clothing with increasing amounts of compressive surface. Overall, there were no performance benefits when using the compression garments.
The effectiveness of CG in sports application?!
### Claimed benefits

<table>
<thead>
<tr>
<th>Pros (did)</th>
<th>Cons (did not)</th>
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<tbody>
<tr>
<td>• Reduce perceived muscle soreness;</td>
<td>• Improve performance time</td>
</tr>
<tr>
<td>• Enhance neurotransmission;</td>
<td>(Ali et al., 2011)</td>
</tr>
<tr>
<td>• Attenuate muscle oscillation;</td>
<td>• Improve running pace</td>
</tr>
<tr>
<td>• Improve joint awareness;</td>
<td>(Arcecs et al., 2015)</td>
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<tr>
<td>• Mitigate swelling;</td>
<td>• Prevent exercise-induced muscle damage</td>
</tr>
<tr>
<td>• Enhance subsequent exercise performance;</td>
<td>(Arcecs et al., 2015)</td>
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<tr>
<td>• Improve sub-maximal oxygen usage;</td>
<td>• Improve blood biomarkers e.g. CK, lactate, blood myoglobin during exercise</td>
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<tr>
<td>(Brophy-Williams et al., 2019; Gimenes et al., 2019)</td>
<td>(Arcecs et al., 2015; Born et al., 2014; Del Coso et al., 2014; Kerherve et al., 2017)</td>
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<td>• Alter local blood flow/metabolite clearance;</td>
<td>• Improve cycling performance</td>
</tr>
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<td>(Bringard et al., 2006; Dascombe et al., 2011)</td>
<td>(Driller et al., 2013; MacRae et al., 2012; Smale et al., 2018)</td>
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<tr>
<td>• Attenuate exercise-induced muscle damage blood biomarkers.</td>
<td>• Have training effects on cardiorespiratory parameters</td>
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<td>(Mizuno et al., 2017)</td>
<td>(Priego et al., 2015)</td>
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<tr>
<td>(Barss et al., 2018)</td>
<td>• Affect middle cerebral blood flow</td>
</tr>
<tr>
<td>(Kraemer et al., 1998)</td>
<td>(Smale et al., 2018)</td>
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<tr>
<td>(Šambaher et al., 2016)</td>
<td>• Improve endurance performance</td>
</tr>
<tr>
<td>(Kraemer et al., 2001)</td>
<td>(Sperlich et al., 2010)</td>
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<td>(Gill et al., 2006)</td>
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</table>
Systematic review and meta-analysis
Recent published studies

Compression Garments and Exercise: No Influence of Pressure Applied

Samuel Beliard 1,2,3, Michel Chauveau 4, Timothée Moscatiello 4, François Cros 4, Fiona Ecarnot 2, and François Becker 5

Is There Evidence that Runners can Benefit from Wearing Compression Clothing?

Florian Azad Engel 1, Hans-Christer Holmberg 2, Billy Sperlich 3
Review and Meta-Analysis on sports CG

- Relatively *few* ergogenic effects;  
  (Born et al., 2013; Brown et al., 2017; Engel et al., 2016)

- *Small effects* on improving short duration sprints (10-60 m), vertical-jump height;  
  (da Silva et al. 2018)

- *Large positive effects* on post-exercise leg soreness, strength recovery and attenuate the concentration of Creatine Kinase.  
  (Hill et al., 2014; MacRae et al., 2011)

- *No apparent relation* between the effects of CG.......and the pressures applied;  
  (Beliard et al., 2015)
Factors affecting effectiveness of CG
Consumer Council report (15/05/2019)

• 消委會測試壓力襪：部分有反效果，阻血液上流

• https://www.youtube.com/watch?v=rVsN-Sh_piM
Compression pressure from CG

The variation in pressures exerted by commercially available compression garments

Jessica A. Hill · Glyn Howatson · Ken A. van Someren · Stuart Davidson · Charles R. Pedlar
Published online: 28 January 2015

Abstract Commercially available compression garments (CGs) demonstrate the enhanced recovery from exercise in some, but not all studies. It is possible that in some cases the degree of compression pressure (ComP) exerted is not sufficient to produce any physiological benefit. The aim of this investigation was to identify the levels of ComP exerted by commercially available CGs. This study was composed of two parts. In part A 50 healthy, physically active individuals (n = 26 male, n = 24 female) were fitted with CGs according to manufacturer’s guidelines. ComP was measured in standing then compared to ideal ComP. In part B there was a significant difference (P < 0.05) between observed pressure and ideal pressure at the quadriceps for males and females and in the calf for the female population. There was no significant difference (P > 0.05) between observed and ideal pressures in the calf of the male population. No significant differences in pressure (P > 0.05) were observed between CG brands at the quadriceps or calf. In conclusion, a large number of individuals may not be experiencing an adequate ComP from CG, and this is true for all the three major brands of CGs that were investigated.

50 healthy individuals (M: 24)
- Fitted with CG according to manufacturer’s guidelines
- Exerted ComP was measured in standing then compared to ideal ComP

COMP: compression pressure
Compression pressure from CG

Confounding compression: the effects of posture, sizing and garment type on measured interface pressure in sports compression clothing

NED BROPHY-WILLIAMS¹,², MATTHEW WILLIAM DRILLER²,³, CECILIA MARY SHING², JAMES WILLIAM FELL² & SHONA LOUISE HALSON¹,²

Abstract
The purpose of this investigation was to measure the interface pressure exerted by lower body sports compression garments, in order to assess the effect of garment type, size and posture in athletes. Twelve national-level boxers were fitted with sports compression garments (tights and leggings), each in three different sizes (undersized, recommended size and oversized). Interface pressure was assessed across six landmarks on the lower limb (ranging from medial malleolus to upper thigh) as athletes assumed sitting, standing and supine postures. Sports compression leggins exerted a significantly higher mean pressure than sports compression tights ($P < 0.001$). Oversized tights applied significantly less pressure than manufacturer-recommended size or undersized tights ($P < 0.001$), yet no significant differences were apparent between different-sized leggings. Standing posture resulted in significantly higher mean pressure application than a seated posture for both tights and leggings ($P < 0.001$ and $P = 0.002$, respectively). Pressure was different across landmarks, with analyses revealing a pressure profile that was neither strictly graduated nor progressive in nature. The pressure applied by sports compression garments is significantly affected by garment type, size and posture assumed by the wearer.
Compression pressure (COMP) measurement
PicoPress® (MICROLAB ELETTRONICA S.a.s. di Bergamo Giorgio & C.)
## Compression Level Chart

<table>
<thead>
<tr>
<th>Range</th>
<th>EU standard</th>
<th>UK standard</th>
<th>US standard</th>
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<tbody>
<tr>
<td><strong>Extra mild</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>(&lt;14 mmHg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mild</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(14-17 mmHg)</td>
<td></td>
<td>EU Class 1 (14-17 mmHg)</td>
<td>UK Class 1 (14-17 mmHg)</td>
</tr>
<tr>
<td><strong>Moderate</strong></td>
<td>EU Class 1 (18-21 mmHg)</td>
<td>UK Class 2 (18-24 mmHg)</td>
<td>US Class 1 (15-20 mmHg)</td>
</tr>
<tr>
<td>(18-24 mmHg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Strong</strong></td>
<td>EU Class 2 (23-32 mmHg)</td>
<td>UK Class 3 (25-35 mmHg)</td>
<td>US Class 2 (20-30 mmHg)</td>
</tr>
<tr>
<td>(25-35 mmHg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Very strong</strong></td>
<td>EU Class 3 (34-46 mmHg)</td>
<td></td>
<td>US Class 3 (30-40 mmHg)</td>
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<tr>
<td>(&gt;35 mmHg)</td>
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(O'Meara et al, 2012)
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<tr>
<th>Background</th>
<th>Current Findings</th>
<th>CUHK Studies</th>
<th>Messages</th>
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Research gap of CG?!
Research gap of CG in healthy individuals

Existing evidences of wearing sports CG

- Inconsistency in results due to discrepancies in pressure applied, type of CG, sex, etc., between studies; (Brophy-Williams et al., 2015; Hill et al., 2015)

- Limited data on morphological changes (vessels and muscles) of the human leg with CG application; (Lee et al. 2018; MacRae et al., 2012; Wang et al., 2012; Wang et al., 2013)

- Conflicting findings on local and systemic hemodynamic responses i.e. CO, HR, SV, MAP, SVR; (Ibegbuna et al., 2003; Platts et al., 2009; Stenger et al., 2010; Stenger et al., 2013; Stenger et al., 2014; Watanuki et al. 1994;)

- A lack of study monitoring hemodynamic responses during recovery. (Avril et al., 2010; Bringard et al., 2006)

CG: sport compression garment; CO: cardiac output; HR: heart rate; SV: stroke volume; MAP: mean arterial pressure; SVR: systemic vascular resistance.
Research gap of CG in healthy individuals

Wearing of sports CG

- Efficacy of CG wearing in *hemodynamic responses* during exercise and recovery;
  (Lee et al., 2018; MacRae et al., 2011; MacRae et al., 2012)

- Leg tissue (muscles and SAT) responses to compression pressures;
  (Lee et al., 2018; Wang et al., 2012; Wang et al., 2013)

- Applied pressure and the associated hemodynamic responses;
  (Chan et al., 2016; O'Meara et al., 2012; Rohan et al., 2013)

- Practical recommendation for CG wearing in exercise and recovery.
  (Ali et al., 2010; Avril et al., 2010; Del Coso et al., 2014)

CG: sport compression garment; SAT: subcutaneous adipose tissue.
<table>
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<tr>
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<th>CUHK Studies</th>
<th>Messages</th>
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CG researches of the CUHK
Sports CG and Hemodynamic Responses

- 33 healthy college student (M: 18)
- Without history of unexplained syncope
- Sports compression tights (CT: 7.2 - 18.6 mmHg)
- Loose-fitting track pants (CON: <2 mmHg)
- Monitoring of cardiac output (CO), stroke volume (SV), heart rate (HR), systemic vascular resistance (SVR) and mean arterial pressure (MAP) with USCOM
- At supine and an head up tilt test (HUT)

Results: The SV and CO was lower at 70° head-up tilt than in supine but wearing CT attenuated the decline in SV (25.9 ± 11.6 cm³ CT vs. 35.9 ± 11.4 cm³ CON, p < 0.001), CO (1.1 ± 0.7 L min⁻¹ CT vs. 1.4 ± 0.6 L min⁻¹ CON, p < 0.05), HR (8.8 ± 8.4 beat min⁻¹ CT vs. 15.9 ± 9.7 beat min⁻¹ CON, p < 0.001) and SVR (740 ± 504 d s cm⁻³ CT vs. 961 ± 560 d s cm⁻³ CON, p < 0.005). The mean arterial pressure (3.3 ± 4.1 mmHg CT vs. 3.6 ± 4.5 mm Hg CON, p > 0.05) was similar in both trials.

Conclusions: Healthy individuals wearing low-pressure sports compression tights experienced less severe haemodynamic disturbance such as decreases in CO, SV, HR and SVR during an orthostatic challenge.

USCOM: ultrasound cardiac output monitor
Take home message

In physically active and healthy population, wearing sports CG according to manufacturer guidelines could have:

• Relatively few ergogenic effects;  
  (Born et al., 2013; Brown et al., 2017; Engel et al., 2016)

• Small effects on improving short duration sprints (10-60 m), vertical-jump height;  
  (da Silva et al. 2018 )

• Large positive effects on post-exercise leg soreness, strength recovery and attenuate the concentration of Creatine Kinase;  
  (Hill et al., 2014; MacRae et al., 2011)

• No detrimental effects on exercise performance.  
  (MacRae et al., 2011)
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References


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References


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Tanaka, Kunihiiko, Tokumiya, Shiori, Ishihara, Yumiko, Kohira, Yumiko, & Katafuchi, Tetsuro. (2014). Compression stocking length effects on arterial blood pressure and heart rate following head-up tilt in healthy volunteers. *Nursing Research, 63*(6), 435-438. doi: 10.1097/NNR.0000000000000062


• The authors DCWL declares that he has no competing interests to declare in relation to this seminar.
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