

Review

Review of compression stocking in sports market

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Abstract: Sport companies offer a diversity in compression garments according to its purpose. Athletes use these garments to recover/improve their performance. However, literature shows controversy at their results and companies offer a wide range of products. The aim of this study was to analyse the current sport compression stockings market in compression, size, and properties. Seventeen commercial brands offering compression sport stockings were examined and the principal claims were to improve performance ($n = 43$), recovery ($n = 10$) and combination of performance and recovery ($n = 13$). Sizes, compression values, and type of compression (gradual or uniform) varies among brands, and between different models at the same brand. The most reported properties in the sport compression market are protection, followed by comfort, blood flow and breathability. While the least claimed properties in the sport compression market are delayed onset muscle soreness mitigation, thermoregulation (freshness-preserving and warmth-retaining insulation), and risk of injury reduction. The lack of information observed in the compression stockings market and the heterogeneity in test procedures, types, and levels of compression in the literature makes the comparison between products difficult. Greater rigor when analysing garments and their effects is required at the claims of the companies in their products.

Keywords: Garments; brands; accessories; running; recovery; performance.

1. Introduction

The popularity of compression stockings has grown during the recent years. These are garments that exert a mechanical force through an elastic component until the desired compression is achieved, which, accompanied by a passive containment, opposes the increase of the volume in the region (Alcolea et al., 2018). Traditionally, compression stockings were developed for therapeutic purposes (Cambronero Resta, 2017). Medical compression stockings are

related to counteract the effect of gravity, which is a determining factor in the disturbances of the venous and lymphatic return of the lower extremities such as varicose veins, venous ulcers or lymphedema (Evans & Ratchford, 2021; Partsch, 2012). Their usage has been expanded to the sports field due to the benefits observed in that medical context (Mota et al., 2020). In sport science, the use of compression garments on the lower limbs (e.g., compression stockings) stands out as a strategy to improve



performance and recovery during or after sport events (Brophy-Williams *et al.*, 2021; Carvalho *et al.*, 2021; Gil-Calvo *et al.*, 2016; Mota *et al.*, 2020). Specifically, these types of garments have become popular in endurance sports, such as cycling and running (Cambronero Resta, 2017; Oficial-Casado *et al.*, 2020).

The pressure exerted by the different compression stockings allows to classify them according to standards. The most common is the German Standard RAL-GZ 387:2000 (Molina Carrillo & Rozas Martín, 2020), which establishes different compression classes (CCL) based on the pressure applied to the minimum circumference of the ankle: (1) CCL1: 18-21 mmHg; (2) CCL2: 23-32 mmHg; (3) CCL3: 34-46 mmHg; (4) CCL4: >49 mmHg and graduated compression, supporting the theory of increased blood flow with higher compression at the ankle decreasing towards the calf (Brophy-Williams *et al.*, 2021). Other norms that refer to compression are: British Standard BS 6612:1985 and French Standard ASQUAL (Molina Carrillo & Rozas Martín, 2020). Nevertheless, compression stockings offered in the sports market do not have to be certified by the medical community, thus they are not subject to regulations.

The efficacy of compression garments for improving sport performance and recovery presents some discrepancies throughout the literature (Pérez-Soriano *et al.*, 2019). In this sense, the differences observed between studies could be due to the lack of consensus in the compression levels and the heterogeneity of the experimental protocols (Pérez-Soriano *et al.*, 2019). Currently, the usage of compression stockings in the sport field focuses on

recovery after physical exercise (McDonnell *et al.*, 2018), although no previous studies have clarified the mechanisms of action which makes them to be considered as an ergogenic aid (Carvalho *et al.*, 2021; O'Riordan *et al.*, 2023). Different studies suggest that certain benefits can be observed: better muscle function or fatigue indicators (e.g., CMJ, specific physical tests) (Mota *et al.*, 2020) and reduced perceived muscle pain during recovery periods (McDonnell *et al.*, 2018; Mota *et al.*, 2020), increased venous return (Evans & Ratchford, 2021; O'Riordan *et al.*, 2023), improvements in muscle oxygenation during rest time (O'Riordan *et al.*, 2023), greater injury prevention (Franke *et al.*, 2021), increased comfort due to its influence in physical sport performance (Oficial *et al.*, 2016), better skin thermoregulation (Gil-Calvo *et al.*, 2016) and increased perception of somatosensory information in the lower extremities (Woo *et al.*, 2021).

On the contrary, the literature review carried out by Mota *et al.* (2020) stated that only a small number of studies (3 out of 21) found an improvement in sport performance. Carvalho *et al.* (2021) found that sport compression stockings (gradual with an average of 21-24 mmHg) had no effect between exercise sessions on running kinematics, skin surface temperature, heart rate, or comfort and recovery perception. In addition, Oficial-Casado *et al.* (2020) assured that sport compression stockings with different compression levels (high and medium, without further specifications of the commercial brand) would not increase the return volume of venous blood through the popliteal vein, emphasizing that venous flow volume is greater after the race because

physical exercise increases the perfusion of the muscle bundles involved in the movement.

In summary, the characteristics that must be considered for the analysis and choice of compression garments could be organized into three large categories. Compression, which involves aspects exclusively related to the pressure exerted by the garment (e.g., gradual or uniform compression). Comfort, which refers to variables that directly influence the comfort of the athlete (e.g., thermoregulation). Performance, where specific physiological and biomechanical variables that influence the athlete are taken into account (e.g., venous return).

Therefore, there has been an increase in the number and type of compression stockings offered, but also certain controversy by the different commercial brands, since some stockings designed for opposed purposes (e.g., performance or recovery) show similar properties. For this reason, the main objective of the study was to carry out a descriptive analysis of the characteristics, technical specifications and properties of all current compression sports stockings on the market. A specific objective set was to gather and group the interest factors of stockings, reported by sports companies, in the categories of compression, comfort and performance to optimize the analysis and choice of compression garments.

2. Materials and Methods

The methodology followed in this work shows the information that the user can have of the brand. The review provides contrasted information between compression

companies and in discussion provides evidence on the properties that are shown in the literature together with the sport compression garments in the company.

Data collection —The study was organized in different parts:

1. Analysis of the websites of the most popular commercial brands of sport compression stockings currently available in the market were examined. Inclusion criteria were, toes to the knee sport compression stockings (which brands name socks), from national and international commercial brands, as well as for physical activity in general and for specific sports. In terms of exclusion criteria, garments used exclusively for travels or relaxing aims. The information regarding the seams and weight of the stockings was also omitted.

2. Sport compression stockings were listed according to the eligibility criteria. Sizes, technical specifications, and properties from each website brand were examined.

3. Together with the previous phase, research for additional information was carried out. Those brands that did not announce the specific pressure of the stocking (mmHg or kPa) were contacted via email in order to have the exact information. However, in some cases it was not provided due to confidentiality, lack of knowledge by the brand or lack of response. In the case of no response, they were included in the results table (Table 2) with the information available on the web.

3. Results

Seventeen commercial brands offering compression sport stockings were examined (Table 1): 226ERS, BV Sport, Compressport,

Danish Endurance, Endura, Enforma, FitBee, Gococo, Lurbel, McDavid, Nike, Physix Gear Sport, Scott, Smartwool, Sportlast, Thuasne Sport and X -Socks by X-Bionic. Sixty-six stockings were analyzed in total (Table 2). Likewise, the usage of the examined

stockings was classified as follows: improved performance in sport practice (n = 43) (PF), recovery after sport practice (n = 10) (RC) and combination of performance and recovery (n = 13) (PF and RC).

Table 1. Number of stockings offered by the commercial brands according to their usage.

Brands	Stockings		
	PF	RC	PF & RC
Compressport	6	2	2
Enforma	7	1	2
BV Sport	3	2	2
Sportlast	6	1	-
X-Socks de X-Bionic	6	-	-
Gococo	2	-	3
Lurbel	4	1	-
McDavid	2	2	-
Danish Endurance	-	-	2
Scott	2	-	-
Thuasne Sport	-	1	1
226ERS	1	-	-
Endura	1	-	-
FitBee	-	-	1
Nike	1	-	-
Physix Gear Sport	1	-	-
Smartwool	1	-	-

PF: physical and/or sportive practice usage; RC: recovery usage.

Table 2. Characteristics of sports compression stockings available in the market.

Brand	Name and/or model	Sizes	Activities	Properties
226ERS	226ERS Compression Stockings; Ref. 5424	EU: S: 37 – 39 M: 40 – 42 L: 43 – 45	PF.	Uniform COMP 21 mmHg. > Muscle growth, development and relaxation. Bioceramic fabric (FIR): AIS.
BV Sport	Chaussette de ski Slide Expert; Ref. 236/003S	Calf region (cm): S: < 30 – 34 M: > 34 – 38 L: > 38 – 43 XL: > 44 – 48	PF. Activity: ski.	COMP 15 – 20 mmHg (calf). CNF y PRT (leg, tendon that covers the malleolus and Achilles tendon).
BV Sport	Chaussettes de ski Slide Elite Compression; Ref. 232/010S		PF and RC. Activity: ski.	Gradual COMP 15 – 20 mmHg (calf region).
BV Sport	Chaussettes de ski Slide EVO Compression; Ref. 233/014S		PF and RC. Activity: ski.	Gradual COMP 15 – 20 mmHg (calf region). PRT.
BV Sport	Trek compression EVO chaussettes Randonnée; Ref. 245/002S		PF. Activity: walking and trekking.	COMP 15 – 20 mmHg (calf region). AIS, CNF, ETB, FT (> calf CO ₂ and free radicals' elimination and < DOMS), LES (Achilles tendon inflammation and shin splints), MOL (heavy legs), POS, PRT (pretibial structures, Achilles tendon, ankle nerves and tendons, forefoot, toe and heel), RV, VENT and VIB.
BV Sport	Chaussettes de compression XLR EVO; Ref. 256/104S		PF.	COMP 15 – 20 mmHg (calf region). AIS, CIR (> muscle, tendon and ligament oxygenation), CNF, ETB, FT (> calf toxins elimination and < DOMS), LES (periostitis), MOL (stiffness), POS, PRT (pretibial structures, nerves and tendons of the ankle, forefoot and shoe closure area), RV, VENT and VIB.
BV Sport	Chaussettes de récupération - Recovery EVO; Ref. 158/002S		RC.	COMP 15 – 20 mmHg (calf region). AIS, CNF, ETB (> calf stabilizers tone), FT (> toxins elimination and < DOMS), LES (periostitis and Achilles tendon inflammation), MOL (heavy legs and stiffness), POS, PRT (pretibial structures, nerves and tendons of the ankle, forefoot and heel), RV, VENT and VIB.

Brand	Name and/or model	Sizes	Activities	Properties
BV Sport	Chaussettes de récupération - PRORECUP Elite EVO; Ref. 151/002S	Calf region (cm) / size (cm): S: <30-34/<175 S+: <30-34/>175 M: >34-38/<175 M+: >34-38/>175 L: >38-43/<175 L+: >38-43/>175 XL: >34-38/>192 XL+: >38-43/>192 XXL: >43-48/>175 XXL+: >43-48/>192	RC.	COMP 25 mmHg (calf region). FT (> toxins elimination and < DOMS), LES (periostitis and Achilles tendon inflammation), MOL (heavy legs), POS, PRT (pretibial structures and Achilles tendon), RV and VIB.
Compressport	Full socks Recovery	Calf circumference (cm) / EU: 1S: 22-30/35-38 1M: 30-38/35-38 2M: 30-38/39-41 3M: 30-38/42-44 4M: 30-38/45-48	RC. Activity: trail running, running, triathlon and trips.	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. CIR, CNF, ETB, FRES, FT (> toxins elimination and < inflammation and DOMS), POS (> proprioception), PRT (arch, sole and Achilles tendon), RV (until +20%), TRANS and VENT.
Compressport	Full socks Race & Recovery	2L: 38-46/39-41 3L: 38-46/42-44 4L: 38-46/45-48	PF (competition) and RC. Activity: any that requires protection such as cycling, trail running and running.	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. CIR, CNF, ETB, FRES, FT (> toxins elimination), LES (ankle), MOL (pain, edema, inflammation and muscle cramps), POS (> proprioception), PRT (shin, arch, sole, toes and Achilles tendon), RV, TRANS, VENT and VIB.
Compressport	Full socks Detox Recovery	EU: T1: 35 – 38 T2: 39 – 41 T3: 42 – 44 T4: 45 – 47	RC. Activity: trail running, running, triathlon and trips or during long moments with static position.	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. CIR, CNF, ETB, TRANS, FRES, FT (> toxins elimination), MOL (muscle and joint pain and inflammation), POS (> proprioception), PRT (shin, arch, sole, toes and Achilles tendon), RV and VENT.

Brand	Name and/or model	Sizes	Activities	Properties
Compressport	Full socks Race & Recovery - UTMB 2021	EU / Calf circumference (cm): T1: 35-38/30-40 T2: 39-41/32-42 T3: 42-44/34-44 T4: 45-47/36-46	PF (training) and RC. Activity: trail running, triathlon and running.	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. CIR, CNF, ETB, FRES, FT (> toxins elimination), LES (ankle), MOL (pain, edema, inflammation and muscle cramps), POS (> proprioception), PRT (arch, sole, toes and Achilles tendon), RV, TRANS, VENT and VIB.
Compressport	Skimo full socks		PF (competition). Activity: sports like trail running and ski mountaineering.	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. AIS, CIR, CNF, ETB, FT (> toxins elimination), POS (> proprioception), PRT (shin, dorsum, arch and Achilles tendon), RV, VENT and VIB.
Compressport	Ski Touring full socks		PF (training). Activity: sports like trail running and ski touring.	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. AIS (toes and heel), CIR, CNF, ETB, FT, POS (> proprioception), PRT (shin, dorsum, arch and Achilles tendon, toes and heel), RV, TRANS and VENT.
Compressport	Alpine Ski Racing full socks camo		PF (competition). Activity: alpine ski	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. AIS (toes and heel), CIR, CNF, ETB, FT (>toxins elimination), LES, MOL (pain), POS (> proprioception), PRT (shin, dorsum, arch and Achilles tendon), RV, TRANS, VENT and VIB.
Compressport	Alpine Ski Merino full socks		PF (training). Activity: sports like trail running and alpine ski.	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. AIS, CIR (< toe numbness), CNF, ETB, FT, MOL (pain), POS (> proprioception), PRT (shin, dorsum, arch and Achilles tendon), RV, VENT and VIB.
Compressport	Full socks Run	EU: T1: 35 – 38 T2: 39 – 41 T3: 42 – 44 T4: 45 – 47	PF (training). Activity: trail running, triathlon and running.	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. CIR, CNF, ETB, FRES, FT, POS (> proprioception), PRT (arch, sole and Achilles tendon), RV, TRANS, VENT and VIB.

Brand	Name and/or model	Sizes	Activities	Properties
Compressport	Full socks Oxygen - black edition 2021	EU: T1: 35 – 38 T2: 39 – 41 T3: 42 – 44 T4: 45 – 47	PF (competition). Activity: trail running, triathlon and running.	Medically Inspired Gradual COMP (Class 1): ankle region - 15 mmHg and calf region - 10 mmHg. Bioceramic fabric (FIR): > skin surface microcirculation, AIS, velocity and < VO ₂ . CIR (> muscle oxygenation), CNF, ETB, AIS, FT, LES, MOL (muscle cramps), POS (> proprioception), PRT (arch, sole and Achilles tendon), RV, TRANS, VENT and VIB.
Danish Endurance	Compression socks	EU: 35 – 38 39 – 42 43 – 47	PF and RC. Activity: sport, flight trips and standing up for long periods of time.	Gradual COMP Class 2: ankle region - 24 mmHg and calf region - 18 mmHg. AM (antibacterial), CIR, CNF, MOL (pain and swelling) and TRANS. Certified OEKO-TEX®.
Danish Endurance	Organic cotton compression socks		PF and RC. Activity: sport, daily life, flight trips and standing up for long periods of time.	Gradual COMP: ankle region - 18 mmHg and calf region - 14 mmHg. CIR, CNF and MOL (pain and swelling). Certified OEKO-TEX®.
Endura	Compression Sock (twin pack); Ref. E0089	EU: S: 37 – 39.5 M: 40 – 42 L: 42.5 – 44.5 XL: 45 – 47 XXL: 47.5 – 49.5	PF. Activity: road cycling.	COMP 18 mmHg, light. CIR and PRT (arch).
Enforma	Aspen		PF. Activity: ski.	COMP medium. AM (antibacterial), AO, CIR, PRT (dorsum and ankle), TERM, TRANS and VENT.
Enforma	Melbourne	EU: S: 36 – 38 M: 39 – 41 L: 42 – 44 XL: 45 – 47	RC.	Gradual Medium COMP. AM (antibacterial), AO, CIR (> force production), CNF, PRT (dorsum and Achilles tendon, forefoot and heel), TRANS and VENT.
Enforma	Gran Canaria		PF.	Gradual high COMP. AM (antibacterial), AO, CIR, CNF, FT, PRT (dorsum and Achilles tendon, forefoot and heel) and TRANS.

Brand	Name and/or model	Sizes	Activities	Properties
Enforma	Madrid	EU: S: 36 – 38 M: 39 – 41 L: 42 – 44 XL: 45 – 47	PF.	Gradual medium COMP. Bioceramic fabric (FIR): FT and TRANS. AM (antibacterial), AO, CIR, CNF y PRT (sole, dorsum and Achilles tendon, forefoot and heel).
Enforma	Vancouver		PF. Activity: ski.	High COMP. AIS, AM (antibacterial), AO, CIR, CNF, PRT (ankle, dorsum and Achilles tendon, forefoot and heel) and TRANS.
Enforma	Tibial Stress		PF and RC.	High COMP, medically tested. It helps lift the plantar arch: < pronation at each impact. AM (antibacterial), CIR, CNF, ETB (ankle), FRES, LES (recovery: tibial periostitis and tibialis anterior and soleus overload), POS, PRT (gastrocnemius) and TRANS.
Enforma	Calf Protection		PF and RC.	High COMP, medically tested. It helps lift the plantar arch: < pronation at each impact. AM (antibacterial), CIR, CNF, ETB (ankle), FRES, LES (such as tendonitis, it recovers gastrocnemius and soleus contractures an overload), POS, PRT (gastrocnemius and Achilles tendon) and TRANS.
Enforma	Los Andes		PF. Activity: ski mountaineering.	Medium COMP. Zinc regenerative properties: recommended for diabetics. AM (antifungal due to the copper), AIS, AO due to the copper), CIR, CNF, PRT (dorsum, Achilles tendon, forefoot and heel) and TRANS.
Enforma	Pirineos	EU: S: 36 – 38 M: 39 – 41 L: 42 – 44 XL: 45 – 47	PF. Activity: competitive alpine ski.	High COMP. Bioceramic fabric (FIR): FT and TRANS. AM (antibacterial), CIR, CNF and PRT (ankle, dorsum, Achilles tendon, forefoot and heel).
Enforma	Los Alpes		PF. Activity: ski.	Medium COMP. AM (antibacterial), CIR, CNF, PRT (ankle, dorsum, Achilles tendon, forefoot and heel), TERM and TRANS.

Brand	Name and/or model	Sizes	Activities	Properties
FitBee	FitCompres – Compression stockings for women	EU / Calf circumference (cm): S-M: 36-39/23-38 L-XL: 40-44/38-48	PF and RC. Activity: people who spend long periods of time sitting or standing, i.e. nurses, travellers, pregnant women, athletes.	Gradual COMP: ankle region - 20 mmHg and calf region - 15 mmHg. CIR, FT (> toxins elimination), MOL (pain, edema, swelling, heavy legs, varicose veins fluid retention and cramps), RV and TRANS.
Gococo	Compression; Ref. SCS001403	EU / Calf circumference (cm): S: 27-32/37-42 M: 33-39/38-43 L: 40-45/39-45	PF and RC.	Gradual COMP Class 1: ankle region - 21 mmHg and calf region - 18 mmHg. Impacts absorption. AO, CIR (< blood clots), CNF, ETB (calf), FT, MOL (stiffness and swollen feet), PRT (heel and sole), TERM and TRANS.
Gococo	Compression Superior; Ref. SCSU002919		PF.	Gradual High COMP: ankle region - 27 mmHg and calf region - 15 mmHg. AO, CNF, ETB (calf), MOL (stiffness and swollen feet), PRT (arch), TERM, TRANS and VENT.
Gococo	Compression Superior Air; Ref. SCSA003207		PF.	Gradual High COMP: ankle region - 27 mmHg and calf region - 15 mmHg. AO, CIR, CNF, ETB (calf), FRES, MOL (stiffness and swollen feet), PRT (arch), TRANS and VENT.
Gococo	Compression Skiing; Ref. SCSK00271226		PF and RC. Activity: ski.	Gradual COMP Class 1: ankle region - 21 mmHg and calf region - 18 mmHg. Impacts absorption. AO, AIS, CIR (< blood clots), CNF, ETB (calf), FT, MOL (stiffness and swollen feet), PRT (arch, sole and toes), TRANS, VENT and VIB.
Gococo	Compression Wool; Ref. SCSW003011	Calf circumference (cm) / EU: S: 27-32/37-42 M: 33-39/38-43 L: 40-45/39-45 L+: 40-45/44-47	PF and RC.	Gradual COMP Class 1: ankle region - 21 mmHg and calf region - 18 mmHg. AO, AIS, CIR (< blood clots), CNF, ETB (calf), FT, MOL (stiffness and swollen feet), PRT (arch), TRANS, VENT and VIB.

Brand	Name and/or model	Sizes	Activities	Properties
Lurbel	Running Compression Stockings/ Trail Running Compression Stockings; Model: Horus; Ref. 00B1.821U / H6		PF. Activity: trail running, trekking, Nordic walking.	Gradual Medium COMP: ankle region - 15 mmHg and calf region - 10 mmHg. Bioceramic fabric (FIR): < impact at footfall. AM (antibacterial), AO, CIR (> lymphatic fluid), FT, PRT (sole, heel and Achilles tendon), POS, RV and TRANS. Certified IQNet and AENOR.
Lurbel	Running Compression Stockings; Model: Reactive; Ref. 00A1.621U / H6	EU / plantar length (cm) / calf circumference (cm) / ankle circumference (cm) S: 35-38/22-24,5/28-35/19-22 M: 39-42/25-27,5/33-39/21-24 L: 43-46/28-30/38-45/23-26	PF. Activity: running, walking and fitness.	Gradual Medium COMP: ankle region - 15 mmHg and calf region - 10 mmHg. Bioceramic fabric (FIR). AM (antibacterial), AO, CIR (> lymphatic fluid), FT (due to stress on bone structure, < lactate and toxins presence), POS, PRT (areas of higher friction, specially heel and Achilles tendon), RV, TRANS and VIB (-20%). Certified IQNet and AENOR.
Lurbel	Cycling Stockings / Triathlon Compression; Model: Recovery; Ref. 00A0.623U / H6		RC. Activity: post-exercise and long trips or relaxation.	Gradual Medium COMP: ankle region - 15 mmHg and calf region - 10 mmHg. Bioceramic fabric (FIR): > recovery. < Impact at footfall. AM (antibacterial), AO, CIR (> lymphatic fluid), FT, POS, PRT (heel), RV and TRANS. Certified IQNet and AENOR.
Lurbel	Walking Stockings; Model: Trail Plus; Ref. 00B1.800U / H6		PF. Activity: trail running, Nordic walking, trekking and fitness.	Gradual Medium COMP: ankle region - 15 mmHg and calf region - 10 mmHg. Bioceramic fabric (FIR). < Lactate and toxins, which delays muscle oxygenation. > Cushioning: < impact. AM (antibacterial), AO, CIR (> lymphatic fluid), CNF, FT (due to stress to the bone or shin splits), POS, PRT (forefoot, heel, midfoot and Achilles tendon), RV, TRANS and VIB (< gastrocnemius). Certified IQNet and AENOR.

Brand	Name and/or model	Sizes	Activities	Properties
Lurbel	Ski Stockings; Model: Alpine; Ref. 00B1.830U / H6	EU / plantar length (cm) / calf circumference (cm) / ankle circumference (cm) S: 35-38/22-24,5/28-35/19-22 M: 39-42/25-27,5/33-39/21-24 L: 43-46/28-30/38-45/23-26	PF. Activity: ski, ski touring, walking and trekking.	Gradual Medium COMP: ankle region - 15 mmHg and calf region - 10 mmHg. Bioceramic fabric (FIR). > Cushioning: < impact. AIS, AM (antibacterial), AO, CIR (> lymphatic fluid), CNF, FT, POS, PRT (forefoot, midfoot, heel and Achilles tendon), TRANS and VIB (gastrocnemius). Certified IQNet and AENOR.
McDavid	Elite Runners Stockings / Recovery Runner Stockings; Ref. 8832	Calf circumference (cm): - Elite: XS: 30.5 – 34.3 - Elite and Recovery: S: 33 – 36.8 M: 35.6 – 39.4 L: 38.1 – 41.9 XL: 40.6 – 44.5	PF / RC. Activity: running, trips, inline skating, long walks or flights.	Gradual COMP: ankle region - 18 – 21 mmHg and calf region - 12.6 – 14.7 mmHg. > Ground grip. CIR, CNF, FRES, FT, LES, MOL (pain and heavy legs), PRT and TRANS.
McDavid	Elite Recovery Compression Stockings; Ref. 8831	Calf circumference (cm): S: 33 – 36.8 M: 35.6 – 39.4 L: 38.1 – 41.9 XL: 40.6 – 44.5	RC. Activity: exercise, long walks or flights.	Gradual COMP: ankle region - 18 – 21 mmHg and calf region - 12.6 – 14.7 mmHg. AM, CIR, CNF, FT, PRT y TRANS.
McDavid	Multisport Compression Stockings; Ref. 8841	L: 38.1 – 41.9 XL: 40.6 – 44.5	PF. Activity: exercise or sport, long walks or flights.	Gradual COMP: ankle region - 18 – 21 mmHg and calf region - 12.6 – 14.7 mmHg. > Ground grip. AM, CIR (feet and calf), CNF, FRES, PRT and TRANS.
Nike	Nike Spark Lightweight: Over-The-Calf Compression Running Stockings; Ref. DB5471-100	EU: 36 – 38 38.5 – 40.5 41 – 43 44 – 45.5 46 – 48 48.5 – 50.5	PF. Activity: running.	PRT (arch and heel), TRANS and VENT.

Brand	Name and/or model	Sizes	Activities	Properties
Physix Gear Sport	Compression Socks	EU / calf circumference (cm): S-M: 36-40 women and 37.5-42.5 men / 23-38 L-XL: 39-45 women and 41.5-49 men / 35.5-48 XXL: 41.5-48 women and 46-53 men / 45-61	PF. Activity: running, walking, flights and pregnant women.	Gradual COMP: ankle region - 30 mmHg and calf region - 20 mmHg. FT (> impacts absorption and < swelling) and TRANS.
Smartwool	Athlete Edition Mountaineer Over The Calf Socks; Model: SW001095	EU: S: 34 – 37 M: 38 – 41 L: 42 – 45 XL: 46 – 49	PF. Activity: Winter and mountaineering sports.	Gradual COMP: ankle region - 30 mmHg and calf region - 20 mmHg. Nylon® in the outer shell and merino wool in contact with the skin: > strength. > cushioning. CNF, POS (flexible fabric in the ankle area), PRT (Achilles tendon), TRANS and VENT.
Scott	Scott Merino Camo Socks; Ref. 278423	EU: S: 36 – 38 M: 39 – 41	PF.	AIS (winter), AO, CIR, CNF, FRES (winter), PRT (arch, heel, and forefoot) and TRANS.
Scott	Compression Stockings Scott RC; Ref. 289489	L: 42 – 44 XL: 45 – 47	PF.	AM (antibacterial), CIR, CNF and PRT (arch, heel, and forefoot).
Sportlast	Large Compression Stockings Running PRO; Ref. TP320	Calf (cm) / ankle (cm) perimeter XS: 30-33/19-21 S: 33-36/21-23 M: 36-39/23-25	PF (training). Activity: running.	Gradual COMP: ankle region - 25 mmHg and calf region - 20 mmHg. CIR (< blood flow restriction), CNF, LES, MOL (< cramps sensation and numbness), PRT (gastrocnemius), RV (< VO ₂ , exhaustion and > lactate tolerance) and TRANS.
Sportlast	Compression Stockings Recovery; Ref. P313	L: 39-42/25-27 XL: 42-45/27-29	RC.	Uniform COMP: ankle region - 20 mmHg and calf region - 25 mmHg. CIR (< blood flow restriction), FT (< lactic acid, other toxins and DOMS) and MOL (< cramps sensation and numbness).

Brand	Name and/or model	Sizes	Activities	Properties
Sportlast	Premium Compression Stockings Running Century; Ref. P390		PF.	Gradual High COMP: ankle region - 25 mmHg and calf region - 20 mmHg. AM, CIR (< blood flow restriction), CNF, MOL (< cramps sensation and numbness), PRT (gastrocnemius), TERM, TRANS and VIB (gastrocnemius).
Sportlast	Compression Stockings PRO football Everest; Ref. P360	Calf (cm) / ankle (cm) perimeter XS: 30-33/19-21 S: 33-36/21-23 M: 36-39/23-25 L: 39-42/25-27 XL: 42-45/27-29	PF. Activity: football.	Gradual High COMP: ankle region - 25 mmHg and calf region - 20 mmHg. CIR (< blood flow restriction), CNF, MOL (< cramps sensation and numbness), PRT (dorsum, Achilles tendon and gastrocnemius) and RV (< VO ₂ , exhaustion and > lactate tolerance), TRANS and VIB (gastrocnemius).
Sportlast	Ski Compression Stockings; Ref. Wp330-NBG		PF. Activity: Winter sports.	Gradual High COMP: ankle region - 25 mmHg and calf region - 20 mmHg. CIR (< blood flow restriction), CNF, MOL (< cramps sensation and numbness), PRT (tibia, calf and dorsum), RV (< VO ₂ , exhaustion and > lactate tolerance) and TRANS.
Sportlast	Athletics Compression Stockings lady; Ref. D321	Calf (cm) / ankle (cm) perimeter: S: 30-32/19-20 M: 33-35/21-22 L: 36-38/23-24 XL: 39-42/25-26	PF (training and competition).	Gradual High COMP: ankle region - 25 mmHg and calf region - 20 mmHg. > Support surface: > strength. CIR (< blood flow restriction), CNF, LES, MOL (< cramps sensation and numbness), PRT (calf and sole), TRANS and VIB (calf).
Sportlast	Running Start Compression Stockings; Ref. TS320-1	Calf (cm) / ankle (cm) perimeter: XS: 30-33/19-21 S: 33-36/21-23 M: 36-39/23-25 L: 39-42/25-27	PF.	Gradual High COMP: ankle region - 20 mmHg and calf region - 15 mmHg. CIR (< blood flow restriction), CNF (< rating of perceived effort), MOL (< cramps sensation and numbness), PRT (gastrocnemius), RV (< VO ₂ , exhaustion and > lactate tolerance) and TRANS.

Brand	Name and/or model	Sizes	Activities	Properties
X-Bionic: X-Socks	Ski Energizer Light 4.0; Ref. XS-SSNGW19U-B053-35-38	EU: 35 – 38 39 – 41 42 – 44 45 – 47	PF. Activity: Winter sports.	Gradual COMP: ankle region - 18 mmHg and calf region - 14 mmHg. > Force transfer: > efficiency. CIR, CNF, ETB, FT (> nutrients to the muscles), LES (< ankle overload), POS, PRT (forefoot, sole, heel, shin and Achilles tendon), TRANS and VENT.
X-Bionic: X-Socks	Run Energizer 4.0; Ref. XS-RS09S19U-A007-35-38		PF.	Gradual COMP: ankle region - 18 mmHg and calf region - 14 mmHg. AIS, CNF, PRT (Achilles tendon), RV and VENT.
X-Bionic: X-Socks	Ski Patriot 4.0; Ref. XS-SS45W19U-T018-35-38		PF. Activity: ski.	Gradual COMP, smaller compared with other stockings of the brand. AIS, CIR, CNF, ETB, FT (> nutrients to the muscles), LES (toes, heel, ankle and shin), MOL (weary feet), POS, PRT (forefoot, sole, heel, shin and Achilles tendon), TRANS and VENT.
X-Bionic: X-Socks	Run Triple Helix Long (Puma by X-Bionic); Ref. PU-RS04W19U-B065-39-41		PF.	Gradual COMP. CIR (< thrombosis risk), CNF, FRES, FT (> nutrients to the muscles), PRT (sole), RV, TRANS and VENT.
X-Bionic: X-Socks	Marathon Helix Retina 4.0; Ref. XS-RSR3S20U-G205-35-38		PF. Activity: endurance runners.	Gradual COMP: ankle region - 18 mmHg and calf region - 14 mmHg. FRES, LES, PRT (heel, ankle and Achilles tendon), TRANS and VENT.
X-Bionic: X-Socks	Effektor Competition 4.0; Ref. EF-RS04S21U-E027-43-46S	Calf size / EU: S/ 35 – 38 S/ 39 – 42 S/ 43 – 46 M/ 35 – 38 M/ 39 – 42 M/ 43 – 46 L/ 39 – 42 L/ 13 – 46	PF (competition). Activity: long competitions.	CIR (skin blood circulation could be compromised by COMP, although blood flow through the veins and capillaries remains unimpeded in areas free of COMP), CNF, ETB, FRES, FT (> nutrients to the muscles), PRT y VIB.

Brand	Name and/or model	Sizes	Activities	Properties
Thuasne Sport	Chaussettes longues UP ACTIV RUNTRAIL (femme); Ref. 0344 01	- Ankle circumference (cm): S: 19 – 22 M: 22 – 25 L: 25 – 28 XL: 28 – 31	PF and RC. Activity: running and trail running.	Gradual COMP Class 2: ankle region - 20 mmHg and calf region - 15 mmHg. Impact absorption. CNF, ETB (ankle), PRT (ankle) and TRANS.
Thuasne Sport	Chaussettes longues UP RECOVERY; Ref. 034601	- Leg length (cm): Normal: ≤ 44 Large: > 44 - Size (EU): 35 – 38 39 – 42 43 – 46	RC. Activity: running, trail running and sitting or standing up for long periods of time.	Gradual COMP Class 2: ankle region - 20 mmHg and calf region - 15 mmHg. CNF, MOL (heavy legs) and TRANS.

AIS: insulating thermoregulation that preserves warmth; AM: antimicrobial; AO: anti-odor; CIR: stimulation of blood circulation improving blood flow; CNF: comfort; COMP: compression; DOMS: delayed onset muscle soreness; ETB: stabilization; EU: European sizing; FRES: thermoregulation that preserves freshness; FT: fatigue reduction and/or delay due to muscle damage limitation; LES: risk injury reduction; MOL: relief of discomfort such as pain, muscle cramps, swelling or heavy legs feeling; PF: physical and/or sportive practice usage; POS: healthy foot position or anatomical adjustment; PRT: protection; RC: recovery usage; RV: venous return improvement; TERM; thermal regulation to achieve a constant ordinary temperature; TRANS: transpirable; VENT: ventilated; VIB: limitation or reduction of harmful muscular vibrations or oscillations.

4. Discussion

Sport compression garments are a common strategy to improve performance and recovery in sport practice (Brophy-Williams et al., 2021; Gil-Calvo et al., 2016; Mota et al., 2020; Pérez-Soriano et al., 2019). Nevertheless, the studies carried out so far present some discrepancies, which could be due to the lack of consensus in the regulations and the differences between products of the commercial brands. For this reason, the objective of the present study was to analyse the compression values, sizes, and properties of the sport compression stockings available in the market.

This article takes into account both the information provided by the brands (available to the athlete) and the scientific evidence of the benefits of these compression properties (scientific research). Since there are multiple characteristics to be considered, compression stockings have been organized into three large categories: compression, comfort, and performance.

On the one hand, the main benefit of compression garments claimed by the commercial brands analysed is the increase in sports performance. In line with Mota et al. (2020), this could be related to their popularity since they are a simple and low-cost aid. In this sense, most of the stockings offered in the market are for running, which is one of the activities that has most popularized their use (Cambronero Resta, 2017; Oficial-Casado et al., 2020).

The commercial brands included in the study also highlight the recovery properties after physical exercise. That is why, despite the fact that the brands propose each product for one use (PF or RC), their purpose cannot

be differentiated based on the characteristics of the garment. In fact, all the commercial brands are using the benefits reported in the scientific community about the effectiveness of the compression stockings. However, we know that there is some controversy around these benefits, since there are many dissenting opinions (McDonnell et al., 2018; Pérez-Soriano et al., 2019).

Compression - This category includes type of compression, value of compression (mmHg), compression stocking size, medical classification and elasticity of materials. Two types of compression were observed in the compression garments analyzed: gradual and uniform. Forty-six stockings presented gradual compression (BV Sport, Compressport, Danish Endurance, Enforma, FitBee, Gococo, Lurbel, McDavid, Physix Gear Sport, Smartwool, Sportlast, Thuasne Sport and X-Bionic:X-Socks) and two stockings had uniform compression (226ERS and Sportlast). The difference in the type of compression exerted may be due to the gradual decreasing compression found in the garments with therapeutic purposes, highlighting the influence of medical stockings on sports stockings (Cambronero Resta, 2017). However, a lack of specification in the type of compression has also been observed, since eighteen stockings do not provide information regarding this characteristic.

Another relevant aspect in the compression stockings design is the specific value of compression (mmHg) exerted. The commercial brands with uniform compression analysed expressed similar pressure values: 226ERS (21 mmHg) and Sportlast (mean 20-25 mmHg). However, the measurement region of the pressure exerted

by the compression stocking is not included. Gradual compression stockings report different pressures on the ankle and calf region, from some garments with a minimum compression of 15 mmHg on the ankle and 10 mmHg on the calf (most offered, 15 stockings), up to a maximum of 30 mmHg on the ankle and 20 mmHg on the calf. Note that the gradual garments offer decreases in with higher pressures exerted.

Not all sport compression stockings with specific compression details reach the pressure values required for medical stockings according to the German Standard RAL-GZ 387:2000 (Molina Carrillo & Rozas Martín, 2020). Therefore, it is not possible to compare their effects in many cases. Some of the commercial brands available in the market do not provide information regarding the pressure exerted by their compression stockings (Enforma, Nike, Scott and the Ski Patriot 4.0, Run Triple Helix Long and Effektor Competition 4.0 socks from X-Socks by X-Bionic) (16 stockings). In some cases, they provide alternative characteristics related to the pressure exerted. For instance, Enforma ranked compression as medium or high, or X-Socks by X-Bionic mentioned that the Ski Patriot 4.0 stockings had lower compression compared to the rest of the same brand. BV Sport only refers to calf compression in its products despite having specific pressure data.

Another parameter studied in this review was compression stockings size, being shoe's EU the most common measure method used by thirteen commercial brands, followed by calf circumference (cm), also expressed as area or perimeter, used by nine brands. In several cases, the same brand employs different sizing measurements

depending on the compression stocking. BV Sport uses the calf area (cm) on its products, but includes the size or length of the sole (cm) in the Chaussettes de récupération – PRORECUP Elite EVO. Taking into account that most stockings have gradually decreasing compression, the use of a single measurement method for sizing would be limited given the individual variability. Only eight commercial brands employed different measurement methods to guarantee an optimal usage, even when previous studies have already exposed the risks of inadequate adaptation, discomfort and even pressure necrosis when using the wrong compression garments size (Molina Carrillo & Rozas Martín, 2020). In this sense, the most complete brand is Lurbel because it uses EU, sole length (cm) and both calf and ankle circumference (cm). Also, Thuasne Sport considers EU, ankle circumference (cm) and leg height (cm). Other method to optimize compression garment fitting for the user is taking 3D scans of subjects' legs (Brown et al., 2022), since custom fitted compression garments have been shown to provide the benefits inherent to compression, such as improved strength recovery and indices of muscle damage, compared to controls and standard size garments (e.g., Small, Medium, Large).

Some commercial brands claim that their stockings follow the medical classification: Compression stockings by Danish Endurance (CCL2) and Compression, Compression Wool and Compression Skiing by Gococo (all CCL1). However, sport compression stockings offered by these brands have not been manufactured for medical usage, and employing this classification may be a marketing strategy.

Commercial brands draw the attention of the consumers using the German Standard RAL-GZ 387:2000 and providing prestige and rigor to the product since medical efficacy is not in question. In contrast, Thuasne Sport brand does offer regulated medical devices that receive the CE certificate, and their sport compressive stockings are correctly classified as CCL2.

Although Compressport also uses the medical classification, it specifies the pressure of the product to the customer. This brand stockings state that their compression is simply medically inspired (CCL1). Likewise, Enforma does not employ medical terminology but reports that Tibial Stress and Calf Protection stockings are medically tested (high compression). These examples show the influence of medical stockings effectiveness on sport stockings marketing, increasing the popularity of the latter (Mota et al., 2020). Nevertheless, the inconsistency observed in the compression characteristics of the stockings offered by Compressport should be considered. This brand, despite reporting the same gradual pressure on each stocking, promises different compressions depending on the product on a 1 to 3 scale (1 = light, 3 = high). For example, Full Recovery stockings claim a level 3 compression while Full Race & Recovery stockings claim a level 1 compression, although both have 15 mmHg at the ankle and 10 mmHg at the calf. This could again be a marketing strategy to make the customer think that different levels of compression garments are available.

Finally, eight stockings did not include the materials information: Trek compression EVO – chaussettes Randonnée, Chaussettes de recovery blanches PRORECUP Elite EVO (both from BV Sport) and all the ones from

Sportlast except for Running PRO long compression stockings. All the other stockings were made out of elastic materials and the pressure was applied through an adjustable fabric, according to the inherent characteristics of the compression garment material of manufacture (Molina Carrillo & Rozas Martín, 2020). Additionally, these products showed different compositions and the wide range of materials used to produce them can be an obstacle for clothing recommendation in a therapeutic context. Furthermore, it can also confuse sport consumers when choosing a product. The most complete brand, which includes the most information regarding compression, comfort and performance variables, is Lurbel.

Comfort - Some properties produced by the different materials, the spinning technology or the weaving type are related to comfort perception (CNF). Likewise, variables like TERM, AIS, FRES, TRANS, VENT, AM, AO, MOL and PRT will be briefly defined to discuss in this section as they contribute to achieve different comfort levels. Therefore, not only the CNF property should be considered but also those mentioned above, since they also have an impact on this parameter. It has been observed that commercial brands are currently using the conventional stockings characteristics because the variables mentioned are not compression exclusive. The most innovative properties in the textile industry, such as the ionized silver yarn benefits on thermal insulation and infections, have also been observed.

Compression garments materials can influence the comfort perceived by consumers. The information available claims

that compression stockings have synthetic fibers made from synthetic polymers such as polyamide, Nylon® (a type of polyamide), spandex (elastane) or Lycra® (patented elastane), thus they are produced with non-renewable raw materials (García Ovejero, 2014). However, some commercial brands include more sustainable and high-quality products like OEKO-TEX® certificate (by Textile Industry Research Association [AITEK]) on their materials: Danish Endurance, Lurbel and the Vancouver stocking from Enforma. The commercial brand Lurbel has the IQNet and AENOR certificate.

Fifty-two stockings make explicit reference to CNF. Therefore, most of the commercial brands promise greater comfort, in line with the improvement in general comfort (~66%) reported by the runners who used this type of stockings in comparison with the athletes who did not wear them (Oficial et al., 2016). On the contrary, another study did not observe any significance in comfort perception due to the compression effect when it was measured after 24h using different compression stockings (Carvalho et al., 2021). These results indicate that comfort perception is a valuable parameter for commercial brands.

TERM is a property allows the foot to remain thermally normal since the stocking is not a barrier in the temperature transfer to the environment. The ordinary temperature will depend on the environment where the activity is carried out, and it should be recommended to specify whether it preserves warmth (AIS) or freshness (FRES). Seventeen AIS garments claim to have benefits in terms of comfort when practicing sport in cold environments because they

prevent the transmission of the heat outside the garment (Gil-Calvo et al., 2016).

The heat retained by compression garments is related to a discomfort perception expressed by consumers (Evans & Ratchford, 2021; Molina Carrillo & Rozas Martín, 2020; Oficial et al., 2016). For this reason, fifteen FRES stockings affirm benefits in comfort perception, so they can avoid problems in TRANS and VENT. However, in the study by Gil-Calvo et al. (2016), the stocking with a cold effect, which could be linked to the FRES property, did not produce any changes on skin surface temperature after the race. Furthermore, Carvalho et al. (2021) found no significant differences on skin surface temperature when these compression garments were used. The evaluation was carried out after 24 hours between exercise sessions in athletes who performed consecutive running exercises.

Fifty stockings include the TRANS property, which allows the skin to remain dry thanks to the distillation of the water through the pores of the garments, which determines its wicking capacity (Daggett et al., 2019). Previous studies show that stockings with merino wool are rated as cooler, less humid, and more comfortable compared to polypropylene stockings (Bogerd et al., 2012). On the contrary, commercial brands that contain this type of wool in their stocking's composition claimed the AIS property. Despite being a characteristic no related to pressure, it is a compression garment model recommended for skiing or physical activities in cold environments.

Another fabric to highlight and related to thermal comfort is the stocking with bioceramic fabric. This fabric incorporates

far-infrared (FIR) chemical fibers (Stygiené et al., 2022) which provides better AIS, according to commercial brands. Previous studies found improved heat retention capacity (1.5 °C) and increased foot microclimate temperature (2 °C) (Stygiené et al., 2022). Stygiené et al. (2022) claim that stockings with this characteristic and those containing yarn with silver and copper, are optimal for thermal insulation in cold climates and for improving health in indoor environments.

Ventilated property (VENT) is offered by commercial brands (26 stockings) through a special yarn, mesh fabric or air channels. As previously mentioned, VENT is related to TRANS, AIS and FRES and these variables influence the development of infections by athletes (Daggett et al., 2019). Daggett et al. (2019) affirm that, some of the preventive measures against infections, especially onychomycosis because its prevalence increases 2.5 times in athletes, are: keeping dry feet, use of synthetic stockings to eliminate moisture and wear good ventilation clothing. In this sense, copper and silver use produce positive effects against infections, both of fungal and bacterial origin, even becoming antiviral.

The ability to prevent microbial growth (AM) is also particularly relevant in terms of perceived comfort and different commercial brands include this property in twenty stockings. Another interesting property related to comfort is anti-odor (AO), which eliminates the unpleasant odor. Some infections, such as onychomycosis which presents fungal origin and smelly nails can be related to feet odor (Frazier, W.T. et al., 2021). In fact, there are seventeen AO stockings and some of them coincide with those reported by

AM. However, odor is part of the normal skin flora, so there will always be microorganisms that are part of the resident flora on our skin. For all these reasons, AO also coincides on many times with VENT and TRANS.

Traditionally, physical discomfort such as pain, or heavy legs feeling (MOL) is a common property that has been associated with sport compression stockings (Bovenschen et al., 2013), and twenty-nine garments can be found with this property. However, Bovenschen et al. (2013) examined MOL through standardized questionnaires completed before, immediately after, after 30 minutes and after 2 days of running a 10 km track race as a maximal exercise test. Compression stockings were compared to no compression stockings and the variables analyzed were pain in extremities, heaviness feeling, fatigue, blistering, swelling, muscle pain, exhaustion, feet slip, tightness, muscle vibrations, tingling, numbness feeling, comfortable run, easy run, and fast recovery, but no reduction in subjective muscular discomfort on the lower extremities was observed.

Finally, PRT is especially a relevant property because it provides protection to certain anatomical regions by adding a reinforcement (e.g., padded heel) or a fastening method (e.g., calf anchors through patterns on the fabric) that allow for a better leg support in the desired muscle areas. Commercial brands include PRT in fifty-eight stockings, claiming to fight against overheating or friction that can produce blisters, which decrease comfort perception. Some authors relate these mechanisms to stockings breathability, although after 80 years of research there are still no prevention strategies for these events using updated and

quality methodologies (Worthing et al., 2017).

Performance - The specific variables that relate performance and compression garments are CIR, RV, FT, VIB, DOMS, LES, PRT, POS, ETB and will be briefly defined to discuss in this section. Fifty-one compression stockings promise the stimulation of blood circulation or improving blood flow (CIR). These commercial brands that include CIR refer to the benefits of non-numb toes, increased force production, protection against blood clots and reduced risk of thrombosis. Cambronero (2017) stated that the first therapeutic compression garments were developed to improve blood circulation, which could be the reason why the CIR property can be found in most products. On the contrary, X-Socks by X-Bionic exposes that skin's blood circulation could be negatively affected by compression, despite CIR can be found among their garments. This statement could be related to the risks of wrong sizing (Molina Carrillo & Rozas Martín, 2020) since no harmful effects have been found in the literature (Pérez-Soriano et al., 2019).

Cambronero (2017) highlights the relationship between CIR and sport recovery processes, since an improvement in peripheral blood circulation is achieved with compression garments. This benefit includes better venous return (RV), an improvement in lactate clearance and other muscle damage markers (FT), and muscle oscillation reduction (VIB). Similarly, O'Riordan et al. (2023) suggested that these properties improved muscle blood flow, venous return, and muscle oxygenation at rest in basketball players.

Other authors demonstrated that compression stockings did not improve exercise performance and no changes in strength, resistance, or combined protocols have been found (Pérez-Soriano et al., 2019). However, Pérez-Soriano et al. (2019) claimed that compression garments may have a positive effect in recovery, which could be due to the improvement in performance and muscular damage perception in subsequent resistance tests. The review by Mota et al. (2020) found few studies affirming an improvement in performance related to sport compression stockings. Despite this fact, the authors report that compression stockings have positive effects on function indicators and perceived muscle pain during recovery periods (Mota et al., 2020).

Given the discrepancy in the performance field, commercial brands take advantage of these properties to create attractive offers to the athletes. Specifically, thirty-five stockings can be found in the market with FT benefits. However, no differences in perceived fatigue and recovery have been observed between compression stockings group (pressure mean 23 ± 11 mmHg at maximum calf circumference, 22 ± 8 mmHg at the top of the ankle, and 19 ± 8 mmHg at the bottom of the ankle) and the control group without compression stockings on a Visual Analogue Scale (VAS, 10 cm) (Brophy-Williams et al., 2017).

No changes in blood lactate concentration were neither found, although it is a property associated with FT (Brophy-Williams et al., 2017). Nevertheless, post-exercise performance improved when participants had strong beliefs in sport compression stockings efficacy for improving recovery between exercise bouts

(Brophy-Williams et al., 2017). Participants with a strong belief, measured by a Total Quality Recovery scale, had better post-run performance when wearing compression stockings (mean $\Delta = -3.6 \pm 19.2$ s) compared with neutral or negative perceptions (mean $\Delta = 17.9 \pm 17$ s). Other studies stated that there is no evidence about the decrease of lactate concentration neither in physical practice nor in recovery (Pérez-Soriano et al., 2019). Therefore, the potential benefits could be attributed to the placebo effect which influence performance when wearing compression garments (Brophy-Williams et al., 2017; Mota et al., 2020).

The RV property is supposed to help return venous blood from lower extremities to the heart. However, according to Evans and Ratchford (2021), this mechanism is already carried out by calf muscles when walking and it is called skeletal muscle pump in the scientific literature. The skeletal muscle pump refers to the mechanism during dynamic exercise where rhythmic contractions of muscles squeeze blood back towards the heart. Likewise, Oficial-Casado et al. (2020) suggested that venous flow volume is greater after running because exercise itself increases muscle bundles perfusion involved in the movement. Despite these studies, twenty-five compression stockings with RV can be found in the market.

On the other hand, six compression stockings that prevent Delayed Onset Muscle Soreness (DOMS) were found and it is associated to other properties like FT. Based on the study by McDonnell et al. (2018), forty-six gradual compression stockings were able to mitigate DOMS effect after low-intensity exercises compared to the control group, and

the 2 uniform compression stockings alleviated it to a greater extent after moderate-intensity exercise compared to the gradual stockings. No improvements after high-intensity exercise were reported. These garments should be classified as RC since their benefits are observed during recovery periods (McDonnell et al., 2018). In this sense, the only uniform garment that could provide benefits in DOMS after moderate exercise would be the Uniform Recovery compression stocking (Sportlast), although its great variability in the pressure data (20-25 mmHg) could challenge that statement.

Similarly, the best compression stockings to improve DOMS after a low intensity would be gradual RC or PF garments and RC garments with 21 ± 0.7 mmHg at the ankle and 13.2 ± 1.9 mmHg at the calf. Some examples are: Recovery Runner Socks and Recovery Elite Compression Socks (McDavid). It is important to highlight that the commercial brand McDavid offers the same stockings as two different ones (Stockings for elite runners and Recovery runner stocking) although both have identical details and reference number. Therefore, although elite runner stockings are for PF, they would also be valid for DOMS if they are used during recovery periods. Nevertheless, these products also have great variability in pressure (ankle: 18-21 mmHg and calf: 12.6-14.7 mmHg) so their effectiveness can be questionable. The gradual RC or PF stockings and RC stockings from FitBee and Thuasne Sport (both with 20 mmHg in the ankle and 15 mmHg in the calf) have practically the most effective pressure values.

In terms of muscular efficiency, reduction of harmful muscular oscillations

(VIB) is closely related to the risk of injury (LES) and feet protection (PRT), and twenty stockings can be found in the market. Compressport, Lurbel, Scott and Smartwool are the commercial brands that explicitly state an improvement in cushioning, which refers to the action of minimizing the deceleration produced each time the foot impacts the ground. Previous studies reported a protective effect during running provided by compression stockings due to the impact attenuation observed regardless the degree of pressure (Oficial *et al.*, 2016). Similarly, Pérez-Soriano *et al.* (2019) suggested that compression garments increased attenuation and reduced impact accelerations while running, reducing the risk of overload injuries due to cumulative impact shock. VIB is also closely related to the anatomical garment fit (POS), since it contributes to the maintenance of a natural foot posture in spite of the fatigue. A total of twenty-four compression stockings can be found with POS, claiming to limit unnecessary muscle activity. However, although a reduction in muscle activity has been confirmed, greater efficiency does not mean better performance (Pérez-Soriano *et al.*, 2019).

Some of the stockings with POS mention proprioception as a benefit, which is directly related to stabilization (ETB), included in twenty-four stockings. Previous research has demonstrated the improvement in proprioception in older adults (65 to 80 years old) caused by POS and ETB properties (Woo *et al.*, 2021). However, medical compression stockings (20-30 mmHg at the ankle) were more effective than non-medical compression stockings (8-15 mmHg at the ankle) (Woo *et al.*, 2021). Normally,

compression stockings with ETB and POS report an ankle pressure equal to or greater than 15 mmHg.

Currently, a total of seventeen garments have been found with LES property. In this sense, Franke *et al.* (2021) concluded that wearing compression garments during training and competition is significantly associated with a lower injury prevalence in lower extremities. The cited study showed that almost half of the athletes (47.5%) used compression stockings to prevent injuries or to reduce symptoms of a current sport injury, being the shin (23.8%) and calf (17.8%) the most common ones, which are also related to recovery (Franke *et al.*, 2021).

Finally, protection and stability are positive aspects that have traditionally been associated with compression garments. However, these properties are already considered in compression stockings since their main function is to protect the foot from chafing, blisters or harmful friction. Similarly, these garments provide efficient ankle support and have a positive influence on injuries prevention. For this reason, despite the fact that a reinforcement of these properties can be expected when a certain compression is added, most of the properties evidenced without controversy in the literature are typical characteristics of conventional stockings.

The most popular sport commercial brands such as Adidas or Asics stopped including compressive stockings in the 2022 catalogue. Likewise, Nike has only one stocking with limited information available regarding the compression and properties. It is possible that this response from the most popular brands in the sport industry is due to

the contradictions found in the scientific literature.

It is also interesting to note that the difference in the stocking-specific pressure could lead to obtain different results or physiological adaptations (Brophy-Williams et al., 2021). This could be the main reason why discrepancies in the literature regarding compression garments and their effects can be observed. A lack of information has been shown in the analyzed sport compression stockings, which is in line with many studies published in this field.

5. Limitations

The review study selected the 17 compression stockings offered in the catalog of the most popular commercial brands in this field. However, there are significantly more compression stockings available which were not included in the review. Other limitations are methodological as there is no previous research on commercial brands.

6. Practical Applications

Affirming the effectiveness of compression stockings in the sports context is difficult because of the lack of information provided by the brands. In order to benefit from the advantages of compression in sports, it is advisable to carefully examine your own characteristics as an athlete and those of the stockings.

As a solution, the development of mathematical models that predict compression stockings pressure are one of the later trends (Siddique et al., 2020). Another novel approach is the development of smart compression garments, with sensor-based activity recognition technology to

accurately assess movement, muscular and skeletal positions (Xiong & Tao, 2018). In this sense, the real challenge could be the application of these novel methods and offer them in the market in an affordable way.

7. Conclusions

Sport compression stockings are offered by the commercial brands as an ergogenic aid, especially for running, since they provide benefits associated with performance or recovery. On webs, most of the compression stockings offered in the current market are used during sport practice, followed by both practice and recovery as indistinct use and the use for recovery is a minority. The lack of information observed in the compression stockings market and the heterogeneity in test procedures, types and levels of compression in the literature makes the comparison between products difficult. Greater rigor when analysing garments and their effects is required. There is a need to include more measures in the compression stockings offer in order to estimate the size due to the high within-subject variability and to avoid the risks of inadequate adaptation.

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References

- Alcolea, J. M., Alonso Álvarez, B., Arroyo Bielsa, A., Domingo, P., Galindo García, A., Gracia Graells, M., Iglesias Urraca, C., Insua Nipoti, E., Martín Castillo, E., Martínez Álvarez, J. R., Novoa Rodríguez, M., Río-González, A., & Villarino Marín, A. L. (2018). Documento de consenso Lipedema 2018 (p. 52). Spanish

- Chapter of Phlebology & Lymphology y Sociedad Española de Angiología y Cirugía Vascular.
- Bogerdt, C. P., Niedermann, R., Brühwiler, P. A., & Rossi, R. M. (2012). The effect of two sock fabrics on perception and physiological parameters associated with blister incidence: A field study. *The Annals of Occupational Hygiene*, 56(4), 481-488. <https://doi.org/10.1093/annhyg/mer127>
- Bovenschen, H. J., Booij, M. T., & van der Vleuten, C. J. M. (2013). Graduated compression stockings for runners: Friend, foe, or fake? *Journal of Athletic Training*, 48(2), 226-232. <https://doi.org/10.4085/1062-6050-48.1.26>
- Brophy-Williams, N., Driller, M. W., Kitic, C. M., Fell, J. W., & Halson, S. L. (2017). Effect of Compression Socks Worn Between Repeated Maximal Running Bouts. *International Journal of Sports Physiology and Performance*, 12(5), 621-627. <https://doi.org/10.1123/ijspp.2016-0162>
- Brophy-Williams, N., Fell, J. W., Halson, S. L., Kitic, C. M., & Driller, M. W. (2021). Pressure gradient differences between medical grade and sports compression socks. *The Journal of The Textile Institute*, 112(2), 187-191. <https://doi.org/10.1080/00405000.2020.1730664>
- Brown, F., Jeffries, O., Gissane, C., Howatson, G., van Someren, K., Pedlar, C., Myers, T., & Hill, J. A. (2022). Custom-Fitted Compression Garments Enhance Recovery From Muscle Damage in Rugby Players. *The Journal of Strength & Conditioning Research*, 36(1), 212. <https://doi.org/10.1519/JSC.0000000000003408>
- Cambronero Resta, M. (2017). Efectos de las medias compresivas graduales sobre el organismo tras su uso prolongado [Universidad de Alicante]. <http://rua.ua.es/dspace/handle/10045/77128>
- Carvalho, J., Kunzler, M. R., Priego-Quesada, J. I., Aparicio, I., Pérez-Soriano, P., Machado, Á. S., & Carpes, F. P. (2021). Effects of 24 h Compression Interventions with Different Garments on Recovery Markers during Running. *Life*, 11(9), Article 9. <https://doi.org/10.3390/life11090905>
- Daggett, C., Brodell, R. T., Daniel, C. R., & Jackson, J. (2019). Onychomycosis in Athletes. *American Journal of Clinical Dermatology*, 20(5), 691-698. <https://doi.org/10.1007/s40257-019-00448-4>
- Evans, N. S., & Ratchford, E. V. (2021). Vascular Disease Patient Information Page: Compression therapy. *Vascular Medicine*, 26(3), 352-355. <https://doi.org/10.1177/1358863X211002263>
- Franke, T. P. C., Backx, F. J. G., & Huisstede, B. M. A. (2021). Lower extremity compression garments use by athletes: Why, how often, and perceived benefit. *BMC Sports Science, Medicine and Rehabilitation*, 13(1), 31. <https://doi.org/10.1186/s13102-020-00230-8>
- Frazier, W.T., Santiago-Delgado, Z.M., & Stupka, K.C. (2021). Onychomycosis: Rapid Evidence Review—PubMed. 104(4), 359-367. <https://pubmed.ncbi.nlm.nih.gov/34652111/>
- García Ovejero, R. (2014). Estudio del comportamiento de materiales textiles en relación con la electricidad estática [Universidad de Salamanca]. <https://doi.org/10.14201/gredos.127367>
- Gil-Calvo, M., Jiménez Pérez, I., Sellés, O., Priego Quesada, J. I., Aparicio Aparicio, I., Lucas Cuevas, Á. G., Llana Belloch, S., & Pérez Soriano, P. (2016). Evaluación de las medias compresivas con efecto: Frío/calor sobre la temperatura cutánea durante la carrera. *Actas del XXXIX Congreso de la Sociedad Ibérica de Biomecánica y Biomateriales: SIBB 2016*, 2016, ISBN 978-84-9773-855-2, pág. 61, 61.
- McDonnell, A., Cooper, D., Mlinar, T., & Mekjavic, I. (2018). The effect of post-exercise application of either graduated or uniform compression socks on the mitigation of delayed onset muscle soreness. *Textile Research Journal*, 89, 004051751878000. <https://doi.org/10.1177/0040517518780002>
- Molina Carrillo, R., & Rozas Martín, J. M. (2020). Revisión bibliográfica de las recomendaciones de las Guías de Práctica Clínica para la prescripción de Medias de Compresión Médica. *Revista de Enfermería Vascular*, 3(6), Article 6. <https://doi.org/10.35999/rdev.v3i6.81>
- Mota, G. R., Simim, N. A. M., dos Santos, I. A., Sasaki, J. E., & Marocolo, M. (2020). Effects of wearing compression stockings on exercise performance and associated indicators: A systematic review. 11, 29-42. <https://doi.org/10.2147/OAJSM.S198809>

- Oficial, F. J., Aparicio, I., Gil-Calvo, M., Gisbert, M. J., & Pérez-Soriano, P. (2016). Efectos del uso de medias compresivas en corredores sobre la acelerometría y el confort. (p. 54) [Libro de actas de congreso]. XXXIX Congreso de la Sociedad Ibérica de Biomecánica y Biomateriales.
- Oficial-Casado, F., Aparicio, I., Julian-Rochina, I., Blanes, M., & Perez-Soriano, P. (2020). Effects of a fatiguing run in popliteal vein flow using sports compression socks. *Journal of Industrial Textiles*, 49(7), 967-978. <https://doi.org/10.1177/1528083718804202>
- O’Riordan, S. F., McGregor, R., Halson, S. L., Bishop, D. J., & Broatch, J. R. (2023). Sports compression garments improve resting markers of venous return and muscle blood flow in male basketball players. *Journal of Sport and Health Science*, 12(4), 513-522. <https://doi.org/10.1016/j.jshs.2021.07.010>
- Partsch, H. (2012). Compression Therapy: Clinical and Experimental Evidence. *Annals of Vascular Diseases*, 5(4), 416-422. <https://doi.org/10.3400/avd.ra.12.00068>
- Pérez-Soriano, P., García-Roig, A., Sanchis-Sanchis, R., & Aparicio, I. (2019). Influence of compression sportswear on recovery and performance: A systematic review. 48(9), 1505-1524. <https://doi.org/10.1177/1528083718764912>
- Siddique, H. F., Mazari, A. A., Havelka, A., & Kus, A. (2020). Performance Characterization and Pressure Prediction of Compression Socks. 21(3), 657-670. <https://doi.org/10.1007/s12221-020-9420-z>
- Stygienė, L., Krauledas, S., Abraitienė, A., Varnaitė-Žuravliova, S., & Dubinskaitė, K. (2022). Thermal Comfort and Electrostatic Properties of Socks Containing Fibers with Bio-Ceramic, Silver and Carbon Additives. *Materials (Basel, Switzerland)*, 15(8), 2908. <https://doi.org/10.3390/ma15082908>
- Woo, M. T., Davids, K., Chow, J. Y., & Jaakkola, T. (2021). Acute effects of wearing compression knee-length socks on ankle joint position sense in community-dwelling older adults. *PloS One*, 16(2), e0245979. <https://doi.org/10.1371/journal.pone.0245979>
- Worthing, R. M., Percy, R. L., & Joslin, J. D. (2017). Prevention of Friction Blisters in Outdoor Pursuits: A Systematic Review. *Wilderness & Environmental Medicine*, 28(2), 139-149. <https://doi.org/10.1016/j.wem.2017.03.007>
- Xiong, Y., & Tao, X. (2018). Compression Garments for Medical Therapy and Sports. *Polymers*, 10(6), Article 6. <https://doi.org/10.3390/polym10060663>