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Review

Classification, Structure and Construction of Functional Orthopaedic Compression Knits for Medical Application: A Review

Daiva Mikucioniene [1,*], Liudmyla Halavska [2], Liudmyla Melnyk [2], Rimvydas Milašius [1], Ginta Laureckiene [1] and Svitlana Arabuli [2]

1 Faculty of Mechanical Engineering and Design, Kaunas University of Technology, Studentu str. 56, LT51424 Kaunas, Lithuania; rimvydas.milasius@ktu.lt (R.M.); ginta.laureckiene@ktu.lt (G.L.)
2 Faculty of Arts and Fashion, Kyiv National University of Technologies and Design, Mala Shyianovska str. 2, 01011 Kyiv, Ukraine; galavska.ly@knutd.com.ua (L.H.); melnik.lm@knutd.com.ua (L.M.); arabuli.si@knutd.com.ua (S.A.)
* Correspondence: daiva.mikucioniene@ktu.lt

Abstract: Analysis of functional products for medical textiles indicates that there are plenty of different classifications of this group. Requirements for compression generated by compression garments differ depending on the application area, and even more, sometimes are contradictory and can be fulfilled in very different ways. The effectiveness of such products depends on mechanical and physical properties as well as psychological barriers. Currently, there is no uniform classification of compression classes, furthermore, there is no uniform standard, test method or technic for evaluation of the product' compression. Knitted compression fabrics are made by knitting together at least two types of yarns: a ground yarn which ensures stiffness and thickness and an elastomeric yarn which generates compression. Knitted compression products can be produced on both flat and circular knitting machines, though parameters and usage of production are different. Additional elements used in the structure of the compression product can significantly change the generated compression. Purposes and number of additional details depend on the application and functionality of the compression support, nevertheless, all rigid elements must be taken into account at the designing stage. Additional functionality like antimicrobial activity or thermal therapy can also be provided for compression knits. It is highly important to ensure the longevity of all functional properties.

Keywords: compression; medical application; orthopaedic support; compression cover; knit; structure; antimicrobial activity; thermal therapy

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1. Introduction

One of the most important fields of functional textiles is textiles for medical applications, the importance of which is caused by its relation to human health. Medical textile products may be classified into four main sectors: implantable materials, non-implantable materials, extracorporeal devices, and hygiene and healthcare products [1]. According to the classification, a variety of medical and preventive compression supports, and other compression garments are assigned to the non-implantable medical textile group. Many different functional textile products for limb supporting or compression therapy are usually ascribed as medical textiles. The use of compression textile products for medical purposes has increased significantly since 1970. Originally, these products were used to exert pressure along the human body for the treatment of scars resulting from burns, and treatment of post-surgical conditions. Today, the uses of compression products have expanded to applications for venous and lymphatic systems, bone and muscle injury healing, muscle control, etc. The area of medical textiles is very extensive. Medical textiles embrace products from first aid blankets to high-technology products like man-made vessels or surgical meshes.

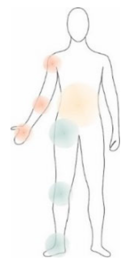
Medical textiles for the care of amputated limbs in the postoperative period, used at the stage of rehabilitation and prosthetics, are divided into separate groups. The need for such textile products appears due to the fact that when using prostheses and orthoses, certain areas of human skin, due to amputation of a limb and circulatory disorders, experience a strong load for which they were not designed by nature. In this case, pressure on the amputation site of the limb, friction, sweating and other sensations of physical discomfort led to the user experiencing severe pain in the areas of contact of the stump with the prosthesis or orthosis.

The aim of this review was to analyse and summarise the classification, structure, construction, requirements, testing methods, and additional functionality of compression products for medical applications and to highlight specific problems that may be taken into consideration when developing new products.

2. Classification of Compression Garments and Specific Requirements

Compression textile products may be defined as compression products for a special purpose that could be medicine [2,3], sport [4–7] or body formation purposes [8]. There are a number of well-known commercial brands such as Sigvaris (Switzerland), Orliman (Spain), Otto Bock (Germany), Bauerfeind (Germany) and others in the world market of orthopaedic compression supports. The main attention is given to the compression properties of these products; however, aesthetic, comfort and end-use properties are not less important for consumers. The analysis of textiles for medical applications indicated that there are different classifications of these groups. Firstly, medical and preventive supports, or compression garments may be classified by the position of the human body (Table 1).

Table 1. Classification of orthopaedic supports according to the position on the body.

Body Part		Position of Support
Arm	Wrist Elbow Shoulder	
Leg	Tarsus/ankle Knee Hip	
Other	Belly (pregnancy) Back/waist	

Classification according to the position on the body is essential for primary identification. However, the most important is the classification of medical textiles according to their purpose or special function. Compression garments generate compression to a particular body part. Compression may be defined as the normal force acting on a body in the perpendicular direction of the applied tensile force [9]. Recent medical compression garments are individually designed and manufactured for a particular part of the body: medical compression stockings for vascular diseases, compression bodysuits, face masks, medical orthopaedic supports, prevention compression supports, etc. (Table 2). All of these products have the same explicit purpose of compression; however, the variety of these function applications is wide [10].

Table 2. Main groups of wearable compression products.

Group	Purpose
Medical orthopaedic compression supports	Prevention, functional or rehabilitation compression supports are designed for a particular part of the body—knee, ankle, elbow, shoulder, etc. Compression supports or braces are applied for post-operative or traumatic irritations, swelling of joints and articular capsules, weak or instable ligaments, chronic instability, etc. [2,11].
Medical compression stockings	Vascular diseases prevention and treatment. The controlled pressure compresses veins surface, keeping them small and forcing blood to deeper veins in the legs, accelerating the velocity of blood flow to the heart and ends pooling of the blood, thus assuring healthier feet and legs [12].
Post-operative compression stockings	Applied for compression therapy after leg operations, (e.g., vein, abdominal, pelvic or orthopaedic surgery) as an alternative to compression bandages. The product may include understocking for securing wound dressings and waist attachment for better fixation [13].
Compression bandages	Compression bandages for venous diseases or post-trauma treatment for venous leg ulcers, phlebology, lymphological diseases, lymphedema, after vein surgery, after sclera-therapy, for wound care, post-trauma, etc. [14]. Different compression bandages and different number of layers may be applied.
Vest orthopaedic garments	Compression for lymphedema. Usually, compression sleeves are used for lymphedema treatment, but they can also be beneficial to apply compression to the entire upper body, particularly in the cases of scars or oedemas in the shoulder area [15].
Post-surgical garments	Post-surgical garments for compression therapy after medical or plastic surgeries. The products may be indicated for arm and upper back liposuction and lipoplasty, mastopexy, augmentation and reduction mammoplasty, abdominoplasty, buttock implants, procedures of the abdomen or back, upper body lift and liposuction, etc. [16].
Compression stump shrinkers	Compressive stump shrinkers promote wound healing after leg or arm amputation and stump shaping [15]. The soft, smooth inner surface of the fabric ensures the stump shrinker, is comfortable to wear. Stump socks normally have conical shape to fit best to the limb [17].
Sockets	Sockets ensure a high level of safety and wearer comfort in direct contact between the residual limb and prosthesis. Product has to be adapted to the user's specific requirements. To achieve appropriate sensitive areas protection against pressure and impacts during knee flexion, additional materials are applied. It ensures the user's residual limb is securely connected to the prosthesis [18].
Compression masks	Compression masks maintain the decongestive state following manual lymph drainage and protects from lymphedema to form in the face after operations or during tumour treating. Facial compression can also assist in the treatment of scars, e.g., after burns or scalding [15,17,19]. The average pressure level applied to the treated tissues is about 25 mmHg [17].
Compression sleeves and gloves	May be used for an arm lymphedema to form after breast surgery due to damage to the lymph vessels and the removal of lymph nodes. The uniform surface pressure helps heal the scar area and leads to a reduction in scar thickness [15].
Maternity products	Maternity products are recommended in the second half of the pregnancy to support the abdomen and to reduce back pain, distributing the weight on the back evenly and preventing muscle strain. Post-partum products may also be indicated for inter-vertebral disc injuries, ascites, neurological disorders, following abdominal surgery, for abdominal hernia support [20].
Compression garments for body formation	Improving body forms and lines to achieve lower body size or better representation. The most common products for body formation are vests, shorts, leggings or different occupation bodysuits—shapers [16,19].

Compression garments are beneficial for the recovery of several markers of exercise-induced muscle damage, accelerate recovery of muscle function, and may also assist athletes following exercise, but the findings are often isolated or inconclusive [21,22]. However, it is proven that some kind of compression sportswear may affect muscle performance or prevent injuries [23]. It is found that swelling, power, and strength are improved during recovery with compression garments [4,22], and the efficiency of compression garments is affected by garment construction, fabric properties, garment fit and positioning on the body. All these factors play a significant role in the predictive pressure value generated by the compression garment and may undermine its functionality [24].

Functional products for medical purposes have to fulfil the following requirements: (a) to match individual characteristics of the product, size and duration of usage; (b) to perform appropriate physical, chemical, medical properties to ensure compliance with the required functions; (c) to preserve geometrical dimensions and shape as well as functional and physio-mechanical properties under the influence of the biological environment; (d) not to cause skin irritation, pain, discomfort, etc.; (e) not to decay and thus not release any harmful toxic substances; (f) to maintain the geometrical shape and dimensions after sterilisation and washing; (g) to maintain physical, mechanical and additional functional properties in long-term usage. The listed requirements are applied to all kinds of medical products, however, there are additional specific requirements for only orthopaedic compression products. Medical orthopaedic supports must also comply with the following requirements: (1) to match individual limb dimensions; (2) to evaluate the biomechanical state of muscle; (3) to ensure the required compression; (4) to preserve the geometrical shape and compressive properties during long-term usage; and (5) to preserve dimensions and compressive properties after washing [25,26].

Compression therapy is usually applied for bandaging, compression stockings and orthopaedic compression supports. According to previous studies, it is proved that the blood flow is faster under gradual compression with an average compression rate of 25 mmHg [25–27]. Properly used compression therapy may result in a promotion of healing of leg veins, injuries, and burn wounds and increase the life quality. Improperly applied compression therapy may cause long-term (delayed) healing, pain, traumatic ailments, or even loss of the limbs [28]. In the case of untreated venous diseases, it progresses and pain develops, and dangerous complications such as inflammation of the veins, eczema, thromboembolism, ulcers, or varicose vein thrombosis bleeding may appear [28,29].

Compression garments for venous diseases are among the best-known and the largest application areas of compression therapy for medical purposes. Venous diseases are very common in developed countries—about half of the adult population consults their doctors about problematic leg veins at some stage during their lives, and 10–20% of the population suffer from varicose veins [2,17,30,31]. In the case of medical requirements, it has to ensure the required compression level. In European countries, compression garments are classified into four groups according to the compression intensity. The lowest compression values are used for prevention or marginal ailments, while higher compression values are applied for patients complaining of major diseases. The differences between compression groups' valuations in different countries are presented in Table 3. Different scientific papers and standards refer to the different recommended values of compression at the ankle [32–36] (compression measurement at the ankle describes the compression class of compression socks, it ranges from 10 mmHg (according to the French standard ASQUAL [37]) to 21 mmHg (according to the German standard RAL-GZ 387/1: 2008 [38])). However, it is recommended that the compression should not exceed 40–50 mmHg. Moreover, the highest compression has to be applied to the ankle and calf and, rising to the top of the product, compression has to decrease gradually: ankle zone—100%, calf zone—70%, above the knee—50%, thigh zone—40% [30].

There are different technologies for manufacturing compression stockings that determine the compression class of the product. Compression stockings produced on a flat knitting machine can reach a higher compression class (3–4 classes) than that knitted on a circular knitting machine (1–3 classes) [17]. However, circular knitting is able to propose seamless products.

Table 3. Compression class standards [39,40].

Standard	Compression Class			
	I	II	III	IV
	Generated Compression, mmHg			
Great Britain BSI [34]	14–17	18–24	25–36	>36
Germany RAL-GZ-387/1:2008 [38]	15–21	23–32	34–46	≥49
France AS-QUAL [37]	10–15	15–20	20–36	>36
Unified European CEN [35]	15–21	23–32	34–36	>49
USA (based on European Standards) [36]	15–20	20–30	30–40	>40
USA HCPCS [36]	18–30		30–40	40–50

Similar to compression stockings, knitted orthopaedic compression supports can be divided by purpose: prevention, rehabilitation or postoperative supports [41]. Compression support is defined as a corrective or orthopaedic item intended to grip or support any movable part of the body in the correct position and allow movement of that body part. The main difference between these groups is the intensity of compression generated by the support. Preventive compression support may assist both as sportswear and as a textile for medical applications. Nevertheless, medical supports may be applied for the same body part, though not for compression therapy purposes. The compression rate of the orthopaedic compression support is usually in the range of 20–25 mmHg [42]. Conventionally, all these products have various distinct applications.

The range of orthopaedic supports is very wide. This group includes supports for neck, shoulder, wrists, elbows, hips, thighs, wrists, back, knees, legs, ankles and feet. Such supports not only fix the limb, but also hold, heat, stabilise, reduce pain, and play a different role, depending on the cause of the problem.

The knee joint is the largest joint of the human body in terms of joint surface area and capsule size. Usually, it gets very heavy workloads. Regardless of its size, this joint is structurally weak. Because of its joint anatomy, large external forces and high function demands, the knee is one of the most commonly injured joints [43,44]. Knee supports are generally divided into three groups: functional preventive supports, post-trauma supports, and post-operative supports. Information from different manufacturers was compared and the results of the analysis are presented in Table 4. Differently from the previous classification, in this case the similar application (e.g., knee support) but different purposes of the indications of products were analysed.

Table 4. Analysis of applications and purposes of knee supports and braces.

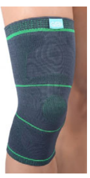
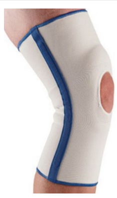
Support	Description	Functionality
Functional Prevention		
 [20]	Compression knee support	The brace does not prevent movement, reduces the risk of injuries and is designed to be used during motion. Indicated for knee joint stabilisation, arthrosis of the knee joint, arthritis, osteoarthritis, synovitis, chondrites, etc. [20,45].
 [45]	Compression knee support with silicon ring	Viscoelastic insert improves blood circulation and ensures knee patellar fixation and stabilisation in the correct position [20,46]. Indicated for cartilage disease, deficient knee patella position of the knee joint ligaments and muscle strains, arthrosis, osteoarthritis, and injury prevention [11,20].

Table 4. *Cont.*

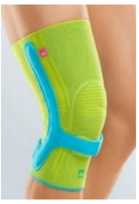
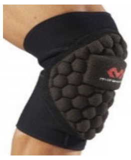
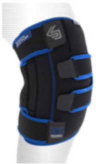
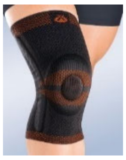
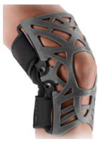
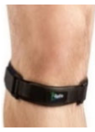
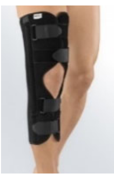
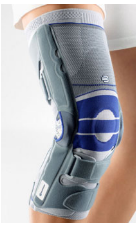
Support	Description	Functionality
	Functional Prevention	
 [46]	Compression knee support with patellar strap	Combination of a knee support and a patellar support strap for reliable guidance and stabilisation of the knee joint, thus relieving tension on the patellar (tendon) insertion. Indicated for patellar tendinitis, Osgood–Schlatter disease, patellofemoral pain syndrome, chondropathia, retro patellar arthrosis, etc. [46].
 [47]	Knee support for knee joint protection from injury	Protects knee joint from injury during a variety of contact sports. Especially used for sport activities like volleyball, handball, etc. Some special inserts can be used such as padded inserts or other additional elements for shock absorption [47].
	Functional post-trauma supports	
 [13]	Ice/heat recovery compression knee wrap	Ice therapy helps to reduce swelling and pain with gentle compression. Indicated for sprains, strains, tendonitis and post activity soreness and swelling. Can be used as a heat therapy to loosen stiff muscles and to relieve arthritis and muscle spasm pain [13].
 [45]	Knee support with integrated silicon pad	The structure with a silicone ring increases knee patellar fixation and stabilisation in the correct position. Indicated for patellar ligament looseness, strain, tear or immersion, tendomyopathy and after the patellar ligament plastic surgery [20,45].
 [48]	Web reaction knee brace	It is a distinct alternative to basic knee sleeves. Indicated for general anterior knee pain, chondromalacia patella, Osgood–Schlatter disease, quadriceps and patella tendonitis strain [48].
 [11]	The patella tendon support	Improves proprioceptive performance that reinforces muscular support of the knee joint. Used to decrease pain associated with patellofemoral malalignment or mild instabilities of the knee joint [11,13].
	Functional post-operative supports	
 [46]	Knee immobiliser	Indicated for temporary post-operative immobilisation at 0 degrees or pre-operative pain conditions, also can be used for following patella dislocations and after ligament injuries [11,46].
 [47]	Hinged knee brace for post-operative rehabilitation	Indicated to reduce pain and speed recovery after major ligament surgeries, cartilage (meniscus) repair, patella realignment, stable femoral fracture and regenerative chondroplasty [47].

Table 4. *Cont.*

Support	Description	Functionality
	Functional post-operative supports	
 [49]	Hinged knee support for post-operative rehabilitation	Prevents hyper-extension and limits the range of motion with adjustable physio glide hinges; has different extension, flexion and immobilisation angles. Supports are indicated for treatment of mild to moderate unilateral, after the anterior cruciate ligament rupturemedial or lateral osteoarthritis of the knee and permanent long-term care where surgery is contra-indicated [46,49].
 [11]	Knee support with flexible side locks and stiffening strips	Recommended for knee joint ligament strain or tear. Four flexible metal retainers (two on each side) ensure enhanced stabilisation of the joint [11].

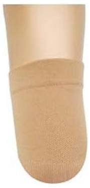
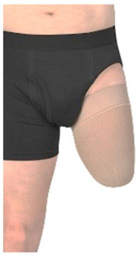
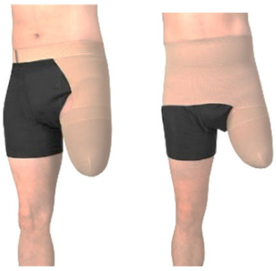
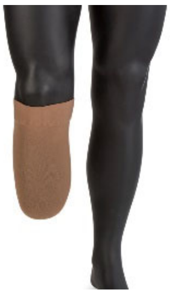
After various injuries, the joints of the knee must be immobilised by a certain constrictive force that restricts movements. The aim of immobilisation is to prevent the overextension of reconstructed or resilient tissues. It must be a stiff or partially stiff mean of implement that is used to strengthen the weak or deformed part of the body or to restrict movement in an unhealthy or injured body part [50]. After knee injury, the joints are immobilised at an angle of 30–45°. This position is optimal for operated linings and meniscus. Functional post-operative/rehabilitation supports are indicated for short-term use (about 2–8 weeks) [5,50]. However, the average immobilisation time is 2–3 weeks. Other functional knee supports can be worn from 6 to 12 months [5,50,51]. Long-term immobilisation can be the result of atrophic knee processes. If immobilisation takes too long, its effect may be harmful [28,52].

It is very important to notice that the means of orthopaedic devices should be selected individually. It should not disturb blood circulation due to pressure on the limb, it should not be too loose and should not slip away, and it should not have sharp corners. It is necessary to constantly monitor the condition of the skin at the site of application, especially if the sensitivity of the patient is abnormal. The patient should be informed about possible skin damage and perform skin care properly. In case of the possibility of the restricted function of the limb, the patient has to be informed about precisely determined terms of usage, otherwise it may cause damage, for example, the legs can alter the dynamic stereotype of the gait, which later can be hardly resolved [53–55].

When amputating a limb, compression covers are used to prevent post-traumatic oedema, improve blood supply to the stump and prevent the formation of oedema after removal of the prosthesis. Such covers are an important auxiliary means of prosthetics in the postoperative period. With their help, uniform pressure is ensured, decreasing in the direction from distal to proximal. The advantages of using compression sheaths compared to elastic bandages are, first of all, ease of use, good fixation on the amputated limb, rapid elimination of swelling, high wearing comfort, sufficient air and vapour permeability, moisture absorption by the textile product combined with a compression effect.

The range of stump covers is determined by the level of amputation of the limb and the physical activity of the user. Compression sleeves for amputated limbs are available with standard compression for safety and effectiveness. Their main purpose is to prevent swelling and restore blood supply. A more detailed presentation of an assortment of these garments is presented in Table 5.

Table 5. Analysis of the use and purpose of stump covers.

Section of Amputated Limb	Description	Functionality
 [56]	Compressive support of the arm stump	The arm stump compression sleeve is seamlessly bonded with standard compression for safety and effectiveness, designed to prevent swelling and restore blood flow [56].
 [57]	Compressive support of the femoral stump	Compression cover for the stump of the 1st and 2nd compression classes of different lengths depending on the level of amputation, produced by using three types of raw materials (polyester, environmentally friendly cotton yarns, and X-Static silver yarns with antibacterial effect) for comfortable use. Designed for regular wear to prevent and treat swelling, restore blood supply and form a stump [57].
 [57]	Compression support for the femoral stump	Compression cover for the stump of the 1st and 2nd compression classes with a holder on the belt, used after amputation closer to the thigh, produced from three types of raw materials (polyester, environmentally friendly cotton yarns, and X-Static silver yarns with antibacterial effect) for comfortable use. Designed for regular wear to prevent and treat swelling, restore blood supply and form a stump [57].
 [58]	Compression support for the shin stump	Compression cover with standard compression for below-knee amputees with Clima Comfort function. Designed to control swelling and relieve phantom pain. The functionality of the product is ensured through the use of special fibre yarns that quickly remove moisture from the surface of the skin, avoiding the unpleasant feeling of dampness, provide good breathability, prevent the colonisation of bacteria and microorganisms inside the textile material, which minimises or eliminates the possibility of unpleasant odours. At the same time, the product retains its functional properties after repeated washing [58].

According to the level of amputation of the leg limb, there are compression covers for the stump of the lower leg of the first and second compression classes (and also two types of sizes in length: used in the case of amputation at the level above the ankle; used in the case of amputation at the level below the knee) and, also, covers for the thigh stump of two compression classes (two sizes of length: for amputation above the knee; for amputation below the groin). It should be noted that compression covers for the stump used in the case of amputation below the groin have an additional fastening system on the patient's belt.

According to the knowledge of manufacturers of orthopaedic compression supports [11,20,25,50], orthopaedic supports must also be comfortable, ergonomic, and easy to put on and remove. Due to the knee supports being worn continually and in direct contact with the skin, the importance of comfort features is high, and also it has to ensure that patients can wear the support for a specified amount of time. Materials used for the production of orthopaedic supports must perform appropriate properties: good thermal conductivity, good water vapour transmission properties, appropriate durability and elasticity. The main primary purpose of stump covers is to protect the skin, absorb sweat, and prevent friction, redness and temperature changes. The main types of raw materials used to produce covers are cotton and woollen yarns, as well as new-generation synthetic yarns with a sweat-removal effect and temperature regulation. It should also be noted that stump covers for daily use are made with one, three or even five layers to ensure proper fit of the stump in the prosthesis socket. The production of covers of different thicknesses is due to the loss or increase in the volume of the stump. Such covers ensure the ideal integration of the residual limb with the prosthesis. Properly chosen raw materials for the manufacturing of stump covers ensure a decrease in temperature by one or two degrees as well as the ability to remove moisture, providing comfort throughout the day.

3. Systems and Methods of Compression Measurement

Orthopaedic compression is the direct application of pressure to a limb, which is usually expressed in mmHg or Pa. Currently, there is no uniform classification of compression classes. Furthermore, there is no uniform standard for measuring product compression. Some countries have national standards or use other countries' national standards; for example, the United States Health Services and other pharmaceutical retailers in Europe use British standards [59]: [32,40,60,61].

There are three different ways to determine the compression: (a) direct in vivo method, (b) indirect in vitro method and (c) control of treatment therapies [62].

The essential principle of the direct in vivo measurement method is that the pressure measurement is carried out directly on the affected limb. During this kind of test, a person wears gradual elastic compression stockings, and the pressure sensor measures the contact pressure along a leg [27,31,61,63]. The SIGG-test (SIGaT-Sigvaris, Germany) and PicoPress (MediGroup, Stafford, Australia) are two of the well-known devices used for in vivo measurement of compression. There are a number of drawbacks to the direct in vivo measurement method—it is quite difficult to achieve appropriate precision, especially when a person breathes, moves or is tired. This measurement method is not suitable for the repeatable evaluation of product parameters, because the same person may not be able to test the product for a long time. In addition, dimensions of the same human limb change over time [64].

The basic principle of the indirect in vitro method is the determination of the stretching behaviour of a knit or a woven fabric. The compression product is fastened on a special mannequin with sensors that measure compression. These measurement methods are applied to the German standard RAL-GZ 387/1:2008 and British standard BS 6612:1985 [59]. The indirect (theoretical) method of determining compression is the compression calculation according to Laplace's Law [65,66]:

$$P = \frac{2 \cdot \pi \cdot F}{S} \tag{1}$$

where P is the pressure in Pa, F is the tensile force in N, S is the area of the specimen in m^2.

In this case, compression is evaluated as a function of the tensile force and the area of the product. There are many devices used for measuring the pressure to a limb, i.e., for extrapolation of compression from tensile force measurement. The two most known devices for compression testing of stockings are HATRA (Hosiery and Allied Trades Research Association, UK), which is required for validation under the British standards (BS 6612:1985, BS 7563:1999, BS 7672:1993) [59], and HOSY (Forschungsinstitut Hohenstein, Hohenstein, Germany), which is required for validation under the German standard RAL-GZ-387/1 [38,60]. However, this method of compression measurement fails to capture compression changes resulting from complex geometry and differences in the shape of the limb.

During the design and production processes of compression products, the modelling of the product must be based on the analysis of the compression phenomenon [66–68]. The mechanical properties of the materials used and, especially, the relaxation phenomenon that occurs during long-term wear must be evaluated, too. Due to the stress relaxation, compression values, if compared the newly produced product and the same product after several hours of wearing, can differ significantly [66]. Currently, the design and production of compression products are based on an identical percentage decrease between the dimensions of the main structural perimeter compared with the corresponding values of the patient's body dimensions [19].

Moreover, it is highly important to combine appropriate compression and individual consumer parameters. Therefore, measurements of the volumes of the limb usually are executed in collaboration with doctors and manufacturers. The three-dimensional body scanning technology, used to capture anthropometric dimensions, has become a common tool for research, design and production [9,69–71]. Three-dimensional scanning allows for designing compression products and evaluating individual dimensions of the human limbs, which leads to a more accurate measurement of limb volume and more suitably designed compression products. Digitalisation of the design process ensures the creation of compression products of a given shape with an increased level of comfort and functionality due to their correspondence to the shape and size of the individual patient's limb with its characteristics of stump formation and the ability to ensure the distribution of pressure created by the product throughout the limb.

4. Structure and Construction of Compression Orthopaedic Products

Orthopaedic supports are usually produced from soft materials with an elastic structure, thus knitted materials are common and easily used for this purpose [41,72–74]. Elastic and compression-knitted orthopaedic supports are available in many forms, may contain extra elements for different functional purposes and may be indicated for various diseases. The construction of functional compression supports consists of crucial elements for particular functions that are substantial for patient health or the healing process. In this regard, the group of functional post-operative supports may be characterised as the most difficult and contains the most considerable elements.

Manufacturers of advanced textiles and medical products use new types of raw materials and special finishing to ensure functionality and to achieve the above requirements. The requirements of the modern consumer of this type of product are gradually shifting towards ensuring maximum comfort and functionality of compression products. The variety of chemical composition and physical and mechanical properties of raw materials makes it possible to obtain textile materials with predictable properties. Along with widely used natural raw materials, such as cotton and wool, increasing interest is concentrated on new types of environmentally friendly fibres obtained from eucalyptus, banana, coconut, soybean, bamboo, corn, hemp, etc. Such materials, along with antibacterial and antiseptic properties, also have a positive preventive and sometimes therapeutic effect on humans. From the point of view of tactile sensations, eco-materials do not irritate the skin, which is especially important for compression covers and supports worn next to the skin [75]. Even more, new types of materials such as shape-memory polymers, which are usually used in smart textiles, can also be used in compression orthopaedic products to ensure the possibility of self-stress control in the product and to control the pressure exerted by the product in wrapped position. Shape-memory polymers can memorise an original shape and allow recovery of the original shape from a temporary deformed shape under particular stimuli. However, in practice, the activation of the shape-memory fabric on a leg still remains a challenge and is costly [76].

There are two main types of raw materials used for the production of compression textile materials: a) traditional fibres such as cotton, viscose, polyamide, polyester, wool, and acrylic; and b) elastomeric fibres. For example, polyamide yarns are most popular for compression stockings because of high elongation and abrasion resistance, dimensional stability, possibility of making a highly transparent knitted structure. Polyester microfibers may also be used for compression stockings as they are strong, flexible, elastic, soft, and have good capillarity which is a very important comfort property [77]. The main properties of yarns used for compression orthopaedic supports have a valuable influence on the properties of the final product. Therefore, the selected yarns must ensure the following conditions: (1) sufficient elasticity of the product in the longitudinal (wale) and transversal (course) directions; (2) the minimal residual deformation of the product; (3) the durability of functional and physio-mechanical properties of the product during usage; and (4) hygienic properties, for example, good air permeability. Usually, the types of products used are: (1) polyamide yarns (plain and textured fibres); (2) polyurethane reinforced yarns; (3) vulcanised rubber yarns; (4) cotton or viscose yarns; and (5) elastomeric yarns with polyurethane or silicon core [6,78–80]. Due to neoprene's good characteristics (high elasticity, tension properties and thermal insulation, that enable neoprene to promote healing and absorb shocks), it also is widely used in medical products. However, products from neoprene might cause skin irritation in long-term usage [25,68].

Knitted compression fabrics are made by knitting at least two types of yarns—ground yarn and elastomeric yarn—together. Ground yarn ensures stiffness and thickness. To generate compression and to achieve better performance of compression support, extra elastomeric yarns are inserted into the construction of a knit as inlaid, floated or plated yarns [66,74,81,82].

Thus, taking into account what was said above, it can be summarised that the compressive properties of the orthopaedic product are ensured by the elastomer yarn, dimensional and shape stability is ensured by using synthetic yarns (polyamide or polyester) in the knitted structure, while comfort functionality can be reached by using natural yarns (they can be laid as a ground yarn in the plated or/and combined structure of the knit).

The choice of knitting pattern is determined by the functional properties and intended purpose of the compression product. Theoretically, the elastomeric yarn can be introduced into the knitted structure in the following three ways: laying it in the form of a weft inlay yarn; laying it in the form of tucks; and knitting it into loops. The properties of the compression fabric, the structure of its surface and the location of the elastomeric yarn (inside the structure or on the surface of the fabric) will depend on the method of fixing the elastomeric yarn in the knitted structure. The method for securing the elastomeric yarn in the knitted fabric structure depends on the technological capabilities of the knitting equipment, the properties of the ground pattern and the requirements for the knitted product for a specific purpose. The optimal method is that which ensures reliable fastening of the elastomeric yarn in the knitted structure, also uniformity elasticity and dimensional stability of the knitted structure. Moreover, depending on the design of the rehabilitation product, fabrics with increased unidirectional or biaxial stretchability can be used for its manufacture. Modern products are made using both warp and weft-knitted elastic fabrics. In products made from knits of limited width (like corsetry, bandages or reinforcing tapes), usually warp-knitted tapes are used, in which the elastomeric component is introduced in the form of a weft inlay yarn. Such a knitted structure is stretchable only in one direction, however, depending on the relative position of other binding elements in the structure, it can be of different tightness [83]. Circular compression products are usually made on weft-knitting machines. They can be produced on the basis of single and double knitted patterns. Products made on the single needle bar knitting machine, i.e., on the basis of single patterns (such as compression prenatal underwear, stockings, knee socks, tights, stump covers) have a lower thickness and elastomeric yarns are fixed in the knitted structure in the form of tucks and/or knitted into loops together with the ground yarn using principle of a plated knitting [84]. Typically, compression knee pads and knee supports are knitted on the basis of double knitted patterns (using double needle bar knitting machines) that allow the elastomeric yarn to be inserted into the knitted structure in the form of an inlay yarn. Moreover, since the inlay yarn is not knitted into loops, there is more flexibility in choosing its linear density (thickness) depending on the requirements for the level of compression and the rigidity of the compression product. To ensure the longitudinal elasticity of a knitted product, elastomeric yarns can also be knitted into loops separately from the ground yarn. With this method of inserting an elastomeric component into the knitted structure, the functional properties of the product appear in the transverse direction, but such products also have elasticity in the longitudinal direction. The elastomeric yarn can be knitted into the structure by creating in turn loops and floats according to some particular pattern repeat. The option of introducing an elastomeric yarn into the knitted structure has a significant impact on its properties. Thus, introducing elastomeric yarns in the knitted structure in the form of inlay yarn makes it possible to create fabrics with greater elongation, elasticity and lower raw material consumption compared to other discussed methods. However, if the elastomeric yarn is knitted into the structure creating loops, it increases the reliability of its fastening in the structure and its stretchability in two directions. When making compression stump covers, the primary requirement is to create tactile comfort. Therefore, the single-knitted structure of single patterns is used for their manufacture. In this case, the elastomeric yarn, which provides compression, can be knitted into loops on all needles or partially, according to the pattern repeat, with the formation of floats in places where it is not knitted, and can also be introduced into the ground structure in the form of tucks or inlay yarns.

Table 6 shows the knitting patterns that are used to make compression products of a given shape.

Table 6. Analysis of patterns for various compression product assortment groups.

Group	Type of Knitting Pattern
Medical orthopaedic compression supports	– Double weft-knitted pattern with elastomeric inlay yarn; elastomeric yarn can also be laid as a fleece yarn by creating tucks and floats in turn. – Warp knitted pillar stitch pattern with horizontally laid elastomeric inlay yarn.
Medical compression stockings	– Weft-knitted single plated pattern with elastomeric ground yarn; knitted on the basis of single jersey. – Single weft-knitted tuck stitch pattern with elastomeric yarn laid in the courses where tucks are created. – Single weft-knitted fleece pattern where elastomeric yarn is used as the fleece yarn, which creates tucks and floats.
Post-operative compression stockings	– Weft-knitted single plated pattern with elastomeric ground yarn; knitted on the basis of single jersey. – Single weft-knitted tuck stitch pattern with elastomeric yarn laid in the courses where tucks are created. – Single weft-knitted fleece pattern where elastomeric yarn is used as the fleece yarn which creates tucks and floats.
Compression bandages	– Warp-knitted pillar stitch pattern with horizontally laid elastomeric inlay yarn.
Vest orthopaedic garments	– Warp-knitted pillar stitch pattern with horizontally laid elastomeric inlay yarn.
Post-surgical garments	– Warp-knitted pillar stitch pattern with horizontally laid elastomeric inlay yarn.
Compression stump shrinkers	– Weft-knitted single plated pattern with elastomeric ground yarn; knitted on the basis of single jersey. – Single weft-knitted tuck stitch pattern with elastomeric yarn laid in the courses where tucks are created. – Single weft-knitted fleece pattern where elastomeric yarn is used as the fleece yarn, which creates tucks and floats.
Sockets	– Weft-knitted single plated pattern with elastomeric ground yarn; knitted on the basis of single jersey. – Single weft-knitted tuck stitch pattern with elastomeric yarn laid in the courses where tucks are created. – Single weft-knitted fleece pattern where elastomeric yarn is used as the fleece yarn, which creates tucks and floats.
Compression masks	– Warp-knitted pillar stitch pattern with horizontally laid elastomeric inlay yarn.

Table 6. *Cont.*

Group	Type of Knitting Pattern
Compression sleeves and gloves	– Weft-knitted single plated pattern with elastomeric ground yarn; knitted on the basis of single jersey. – Single weft-knitted tuck stitch pattern with elastomeric yarn laid in the courses where tucks are created. – Single weft-knitted fleece pattern where elastomeric yarn is used as the fleece yarn which creates tucks and floats.
Maternity products	– Warp knitted pillar stitch pattern with horizontally laid elastomeric inlay yarn.
Compression garments for body formation	– Warp knitted pillar stitch pattern with horizontally laid elastomeric inlay yarn. – Double weft-knitted pattern with elastomeric inlay yarn; elastomeric yarn can also be laid as a fleece yarn by creating tucks and floats in turn. – Weft-knitted single plated pattern with elastomeric ground yarn; knitted on the basis of single jersey. – Single weft-knitted tuck stitch pattern with elastomeric yarn laid in the courses where tucks are created. – Single weft-knitted fleece pattern where elastomeric yarn is used as the fleece yarn, which creates tucks and floats.

A higher level of compression is mainly achieved by increasing the thickness of the elastic core of the inlay yarn, although adjustments may also be made to the ground yarn [74,85]. The weft inlay yarns can be inserted in every single course or certain courses according to a pattern [41,86]. The level of compression is partially defined by inlay yarn properties, which are directly related to the modulus of elastic core yarn and the covering parameters. Regardless of the selected raw material of covering yarns, the tensile force of elastomeric inlay yarn exponentially increases by increasing elongation. In the area of low elongations (50% for elastomeric yarns), properties of inlay yarn's covering yarns do not have a significant influence on compression properties, whereas only elastomeric core yarn is affected by the tensile strength. It means that covering yarns may be chosen, depending on comfort, hygiene, aesthetic, etc., requirements [85]. The inlay yarn insertion density has a valuable influence on the generated compression. This influence has an exponential character. Up to 25% higher compression values were estimated in knits with the inlay yarns inserted in every single course in comparison with the knits with twice lower inlay yarn insertion density but with the same total amount of the inlay yarns [41,86,87].

In order to design suitable orthopaedic compression support, the following parameters must be appropriately selected: the type and the linear density of the base yarn, the type and the linear density of elastomeric yarn, the knitting device (warp or weft, flat or circular) and its parameters (gauge, number of working needles or diameter of the cylinder, etc.), knitting pattern and the main structural and technological parameters (loop length, loop density, density of laid-in elastomeric yarns, initial pre-tension of the elastomeric yarn, etc.) [88].

Orthopaedic supports may be knitted as seamless products or sewn from knitted and other materials (e.g., neoprene). Seamless products are usually designed for mass production, are produced of a few sizes and are usually used for prevention purposes. Sewn compression products may be produced by cutting out suitable blanks from planar material. The main disadvantage of this is the difficulty of achieving an exact anatomical fit of the bandages and a large number of connecting points, such as seams, are created. The latter connecting points partially alter the properties of the material used, and this poses in particular the risk of pressure points or chafing points of the skin.

Compression-knitted fabrics may be produced on both flat and circular knitting machines [6,17,78,80,87,89,90]. Circular knitting machines are used to produce tube-shaped products; usually, it does not contain any additional details such as strips or hooks. The diameter of the knitting machine cylinder and the number of needles are constant throughout the process of the production of knitted fabric on the circular knitting machine. However, the diameter of a product as well as the gradual change in compression through the length of the product can be changed during the knitting process by changing the pre-tension of the elastomeric yarn, the length of the loop or the knitting pattern [91]. Circular knitting machines are usually more productive in comparison with flat knitting machines. However, flat knitting machines can be used to produce finite and even spatial products [39,92]. The most advantageous method is shaped knitting on both circular and flat knitting machines [17,39].

Compression supports made on flat knitting machines are more beneficial in comparison with circular knitting because: (a) knits are spatial and better shaped (match with anatomical shape of a human body); (b) knitted products provide a compression and support effect due to the bi-directional tension construction; (c) it is possible to achieve specific properties due to the constructive pattern effects (also, jacquard knitting pattern may be used to make the product more attractive or to demonstrate a logo); and (d) it is possible insertion of viscoelastic profiles or soft pads (which provides stability, support, and massage effect) into the structure of the product which improves blood circulation, absorbs hematomas and oedema (swelling) [17,28]. Also, it ensures an anatomical shape which guarantees a perfect fitting, supporting and compressing effect due to the stretch construction, and stabilisation due to integrated viscous elastic profiles or pads.

Several trends in the research of knitted fabrics can be distinguished: structures and physical properties of knitted fabrics [80–82,90,93–95] and mechanical properties (especially elasticity and resilience properties) [78,80,88,90,91,96–101]. Mechanical properties of knitted fabrics are closely related to the structure of the knitted fabric, the properties of the yarn and the areas of use of the knitted fabric. The deformation of the knitted fabric plays an important role in the properties of further processing and use.

The compressive properties of knitted fabrics are influenced by various factors: (a) raw material, i.e., ground yarn type and linear density and elastomeric yarn type; and (b) manufacturing process, i.e., the characteristics of the knitting machine and specific parameters of production process. Compression products are worn repeatedly many times; accordingly, the properties of resilience are equally important as elastic properties [66]. The recovery power of the product is used to evaluate its response to the body's movement immediately after the impact. The higher elastomeric yarn tension results in a higher recovery power in the knitting area, which results in shorter loops formation (in comparison with the length of loops without elastomeric yarn) [90,91]. Deformation properties of elastic knits widely differ from knitted fabrics without elastomeric yarns in the structure. The higher amount of elastomeric yarn in the knitted fabric composition leads to a greater tensile force and, therefore, a human limb is affected by the higher compression [19,25,31,63,66,96,102–105].

It is important to notice that a different geometry of knitted structure generates different mechanical properties that are strongly related to the fabric structure, yarn properties and direction in which fabric is used [74,86,106]. Many studies have been published on the deformability of knitted fabrics [1,9,12,21,97,107]. Compression of the support depends on the support area, shape and knitting characteristics, such as knitting pattern, loop density, etc. The ways in which the textile material deforms under applied stresses play an important role in its processing and end-use. Alternating compression in the length of the product can be achieved by changing the knitting density, knitting pattern and/or pre-tension of a laid-in elastomeric yarn.

Knitted orthopaedic supports are often designed with additional details for different purposes. Orthopaedic supports often have added silicone or other parts for functional application and may also comprise other components, such as straps, and fasteners, including a disengage-able two-part fastener system for engaging the support with a body [9]. All the rigid elements inserted into the support can change the elasticity of the entire product and, consequently, its compression. In the area of low extensions, there is a strong linear dependence between the relative area of the rigid element and the compression generated by the knitted orthopaedic support—compression linearly increases by increasing the area of the rigid element [86]. It is not always possible to obtain the desired features of the support only with the knit, so additional parts may be inserted into the knitted product. Such parts can be one-sided or double-sided plates with special hinges and straps, foam rubber, silicone parts, metal plates, hook and loop strips (Velcro), and neoprene parts. For example, special hinges and straps may be inserted into the knee support to strengthen the sideway support from both sides of the knee and to control the degree of joint movement. These devices also are beneficial for reducing the compression forces of the joints caused by weight and the "valgus-varus" (pulling, pushing forces) load caused by contact activities. Hinges are usually made of metal alloys (titanium or aluminium) or non-metallic composite materials with a specific strength, also it must be as light as possible and ensure the comfort of the patient. The extra straps inserted into the support facilitate the attaching and removing processes of the support and provide individual compression. In this case, the patient can regulate the compression level [5]. Moreover, the structure of the support can also be modified: an opening for the kneecap can be made, and one or more additional straps and special reinforcements inserted [5,50,51]. Special reinforcements may be round-shaped, C-shaped, J-shaped or H-shaped [5,25]. Rigid elements may be classified into three main groups, which are used for (a) medical purposes (elements create the function that is relevant to the patient's health and healing process); (b) wearing comfort (straps, silicon strips, fasteners, etc., may affect compression not only according to its relative area, but also due to the different force a consumer uses); and (c) branding (labels, tags and logos). Additional elements for medical purposes are crucial, cannot be eliminated, and the relative area of these elements cannot be reduced significantly. The type and size of additional elements used for wearing comfort can be considered and their relative area may be changed. At least the inferred group is the branding type elements and in the case of this type, relevance is overt. Additional rigid elements can significantly affect compression generated by the support or can even change the compression class of the product. It was established that the rigid element, which occupies ~8% of the total area of a support, enhances the tensile force as well as compression up to 15% even in the low elongation (10%) intervals. This influence depends on the level of elongations in which the orthopaedic support is used. The compression, generated by the support with 25% relative area covered by a rigid element, increases up to approx. 17% at 10% of elongation and up to approx. 24% at 20% of elongation. However, if the area covered by a rigid element is up to 3% and such a support is used in the area of low deformations (up to 10%), it is not necessary to assess the influence of the relative rigid area on compression of the knitted support [107].

Significant changes in compression level appears due to stress relaxation. It was found that the decrease in compression during the long-term (200,000 s) stress relaxation is 20–25%, and almost a half (49%) of this decrease is observed during the first 100–120 s. The difference between compression at the initial moment and after 120 s of stress relaxation can vary from 2 mmHg to 4 mmHg depending on the compression garment construction [72]. It was also found that compression consistently decreases during the stress relaxation regardless of the pre-tension of the elastomeric yarn applied in the yarn feeder. Compression products are intended for long-term wear, so it should be understood that the effect of compression therapy will decrease after a few minutes of wearing. Therefore, the compression level of orthopaedic compression products must be evaluated after at least 120 s period of stress relaxation.

5. Additional Functionality of Medical Compression Garments

The effectiveness of compression therapy depends not only on the compression generated. Psychological and physiological barriers to wearing compression products have been researched by various scientists [18,85,88,94,108]. Noncompliance and non-usage are usually caused by the following factors: unable to specify a reason (30%), not prescribed by the primary physician (25%), did not help (14%), binding of circulation (13%), inappropriate thermal properties during wearing (8%), limb soreness (2%), poor cosmetic appearance (2%), disability to be applied without help (2%); contact dermatitis or itching (2%), and other—cost, work situation, etc. (2%) [109]. Other barriers to wearing compression garments are highlighted among teenagers and kids: the main cause is discomfort during wearing (55%), lack of understanding of their condition (45%), factors such as difficulty to apply, appearance and no perceived benefits are almost at the same level (35–38%) [110]. Lack of comfort while wearing compression garments negatively affects performance and people are not encouraged to do more activity.

Compression stockings as well as orthopaedic compression supports have to fulfil comfort requirements that are demanded for long-lasting wearable products—air permeability, perspiration absorption, antibacterial effect, in some cases additional thermal therapy or transparency, etc. It is well known that the fabric composition and yarn properties have an influence on comfort properties such as thermal conductivity, water vapour permeability and air permeability [18,111]. It is proved that thermal properties are hardly affected by the capillary structure of fibres and yarn surface geometry. Also, air in the knitted fabric structure plays a prevalent role in heat transfer [108,112]. Air permeability may be defined as a function of the loop density, tightness and thickness whilst water vapour permeability greatly depends on the raw material properties [113]. To achieve these requirements, specific fibres are used, or treatment is applied. The most "negative" effect on air permeability has elastomeric yarns, especially high linear density elastomeric inlay yarns. Elastomeric yarns not only tighten the knitted structure but also, they themselves are not permeable to air. Even more, compression products are worn in a stretched state (usually stretched at 10–30% to generate the required level of compression). This deformation of the knitted structure also has an influence on the loop geometry and size of pores between the yarns and fibres through which the air circulates. Therefore, it is recommended to test the air permeability in the stretched state of the specimen at a specific elongation.

It should also be noted that weakened blood circulation in common patients who are amputees and, as a result, lower body temperature leads to the need for additional thermal insulation, which, together with low ventilation of the micro-space, leads, in turn, to increased sweating under the compression textile product. To avoid deterioration of the thermal insulation of a textile material caused by moisture accumulation, the transfer of moisture in the form of sensitive and non-sensitive perspiration from the body to the environment must be allowed. The ability of textiles to transfer moisture in the vapour or liquid form is one of the most important factors influencing thermos-physiological comfort, which is especially important in conditions of increased sweating [106,114,115].

Indicators of ergonomics of textile materials, characterising the convenience of the product and the comfort of its operation, include two subgroups: hygienic indicators (determining the compliance of materials with the hygienic conditions of human life) and comfort indicators (determining the degree of compliance of materials with the physiological and psychological characteristics of a person). Comfort is usually described by hundreds of parameters. However, the main aspects of comfort are psychological, thermos-physiological and neurophysiological [116]. Since the assessment of the level of psychological comfort is mainly based on a person's subjective feelings, studies of the comfort of textile materials and products relate to a greater extent to issues of ensuring thermos-physiological and neuro-physiological comfort (which in other studies is called tactile or sensory) [117]. Sensory comfort is characterised by what a person experiences as a result of the interaction of clothing and skin under certain atmospheric conditions. The feeling of neuro-physiological comfort is influenced by the texture of materials, their surface roughness, rigidity, and ability to collapse and create wrinkles [118,119]. There are three main skin irritants: mechanical contact with external objects, temperature changes caused by heat flows, and chemical influences. In response to various stimuli, skin receptors can produce sensations of heat, cold, touch or pain. The neuro-physiological aspect [117] of textile clothing comfort is also influenced by such characteristics as prickliness and scratchiness, stiffness, softness, smoothness, roughness, friction, and the tendency of the material to cause itching (itchiness), as well as tactile properties and whether the material is warm or cool to the touch, whether it causes a feeling of dampness (dampness sensations). The prickliness is associated with the presence of hard fibres rising above the surface of the fabric. The degree of adhesion of a fabric is most influenced by characteristics such as the supporting surface, wettability and the area of contact of the fabric with the skin. Wet adhesion occurs due to sweating. A warmth to the touch is felt when the garment is first picked up or put on. The feeling of roughness depends both on the geometry of the surface of the fabric and on the area of contact between fabric and skin and the force interaction between them.

Because of ageing, the temperature of the deep muscles decreases, and it can profoundly change motor function and performance [95]. For example, local knee heating (up to 44 °C next to skin temperature) for young and aged, especially, adults can reduce pain and increase mobility [120]. Heating therapy helps to increase skin blood flow, blood volume and oxygen saturation, stimulates blood circulation and, therefore, reduces joint stiffness and pain release in joints, and consequently leads to the overall improvement in joint mobility during movement [121].

Various heating elements and techniques can be used to realise the heating function in orthopaedic compression supports, such as heating tubes or plates attached to the surface of the support, electro-conductive metal wire or electro-conductive yarns embroidered on the surface of the support or directly incorporated into the structure of the support by weaving or knitting. Realisation of an externally mounted heating plate or tube is technically not very difficult, however, it has an essential disadvantage—it is an additional rigid element that has a significant impact on the overall compression generated by the product. The embroidered heating element, using electrically conductive threads, also has a significant effect on the overall elasticity and compression of the product. The best solution to realise the complex compression heat therapy is to incorporate electro-conductive yarns directly into the textile structure [122].

Conductive fibres, filaments and yarns can be classified into two main groups: those that are originally conductive and others that are specifically treated in order to reduce their electrical resistance and increase their conductivity. Originally, conductive yarns were formed from electrically conductive metals, such as stainless steel, copper, aluminium, carbon, fine filaments, etc. The conductivity of such yarns usually is very high; however, they are characterised by higher rigidity compared to conventional textile yarns. Electrically conductive yarns can also be produced by coating polymeric fibres with metals like silver, conductive polymers, or metal salts like copper iodide or copper sulphide. Furthermore, electro-conductive carbon nanotube-based nanocomposite fibres can be produced through melt spinning when carbon nanotubes are incorporated into polyester, polyamide or polypropylene filaments [93,123,124]. A variety of metal-based, polymer-based, carbon-based and coated electro-conductive fibres and areas of their application are well summarised in [125].

By knitting electro-conductive yarn in combination with elastomeric yarn and, for example, antibacterial ground yarn it is possible to combine several functional properties, such as thermal therapy, compression therapy and antibacterial activity, in one medical device. The amount and distribution of electro-conductive yarn in the knitted structure are closely related to both the electrical properties of the yarn and target temperature as well as to the capacity of the power source [122]. Moreover, if the electro-conductive yarn is abrasion-sensitive, e.g., silver-coated PA yarn, it must be protected in the inner structure of the knitted pattern by, for example, the plating technique.

6. Conclusion and Future Challenges

Compression textile products may be classified depending on the position of the body and the purpose of the compression therapy. The compression therapy efficiency depends on the quality, structure and construction of a product. One of the main challenges that needs to be solved is the lack of uniform global standards defining compression levels. The mechanism of compression therapy action varies depending on the nature of the medical problem (for example, varicose veins, joint damage, injury prevention or treatment, etc.), and is still not well understood, there are disagreements concerning the ideal level of compression needed to achieve the most significant improvements. The different classifications of compression products and the standards applied by countries (see Table 3) make it difficult to unify these products at the global level. What is more, if the compression level is wrongly assessed and the product of the supposedly necessary class is purchased and manufactured according to a different standard than the one prescribed by the doctor, the patient's condition may not only not improve, but may even worsen. The methods used to measure the compression of compression products are also different. This means that products designed by different manufacturers for a similar purpose may generate different levels of compression, depending on which compression measurement method and evaluation standard was used to describe the product specification. Therefore, a unified standard defining the compression class is a necessity, considering the level of globalisation of world markets and in order to achieve the best results of compression therapy.

Knitted compression fabrics are made by knitting at least two types of yarns together: ground yarn, which ensures stiffness and thickness and elastomeric inlay yarn, which generates compression and helps to achieve better performance of the compression product. The linear density of the elastic yarn does not have an essential influence on compression generation as the compression product is usually used under low elongations (up to 30%), however compression generation increases by increasing the elastomeric inlay yarn insertion density. Knitted orthopaedic compression supports are often designed with additional rigid elements that can be classified into three main groups, depending on the purpose: (a) medical; (b) wearing comfort; and (c) branding. Additional parts inserted into the support may change the elasticity of the entire product even more than 25%. Therefore, the measurement and evaluation of the compression level must be carried out for the final product with all additional, not only functional, but also branding rigid parts. Even more, compression of knitted compression products decreases during the time due to the stress relaxation, and major changes in compression occur during the first 100–200 s. Therefore, evaluation of compression is highly recommended no earlier than after 120 s of stress relaxation.

Electro-conductive knitted heating elements used in orthopaedic compression products offer a wide range of benefits, such as flexibility, comfort, feasibility, etc. However, some challenges still remain to be overcome. It is necessary to apply heating of the orthopaedic compression product without adding external elements with increased rigidity, which will impact changes in the compression therapy. In addition, it is difficult to retain the constant heating functionality under mechanical impact, e.g., abrasion or deformation, and wet treatment, e.g., washing. To keep the heating functionality activated from washing stress, strong interfacial bonding between the electro-conductive coating or embedded particles and polymeric fibre is essential.

Psychological and physiological barriers to wearing compression products, such as thermal conductivity, and air and water vapour permeability, also have a significant impact on the effectiveness of compression therapy. This means that a product that perfectly meets the therapeutic requirements but is uncomfortable, can have a direct impact on the effectiveness of the treatment if the patient does not want to wear the prescribed product. It is always a challenge to find the best balance between the necessary functional properties and comfort. Therefore, the complex evaluation of required functional (not only compression, but also antibacterial, heating, etc.), and comfort properties is highly recommended in the design process of the compression products.

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References

1. Czajka, R. Development of Medical Textile Market. *Fibres Text. East. Eur.* **2005**, *13*, 13–15.
2. Perrey, S. Compression Garments: Evidence for their Physiological Effect. *Eng. Sports* **2008**, *2*, 319–328.
3. Sau-Fun, N.; Chi-Leung, H.; Lai-Fan, W. Development of medical garments and apparel for the elderly and the disabled. *Text. Prog.* **2011**, *43*, 247–252. [CrossRef]
4. Duffield, R.; Portus, M. Comparison of Three Types of Full-body Compression Garments on Throwing and Repeat-sprint Performance in Cricket Players. *Br. J. Sports Med.* **2007**, *41*, 409–414. [CrossRef] [PubMed]
5. Martin, T.J.; Committee on Sports Medicine and Fitness. Technical Report: Knee Brace Use in Young Athlete. *Pediatrics* **2001**, *108*, 503–506. [CrossRef] [PubMed]
6. Senthilkumar, M.; Anbumani, N.; Hayavadana, J. Elastane Fabrics—A Tool for Stretch Application in Sports. *Indian J. Fibre Text. Res.* **2011**, *36*, 300–307.
7. Trenell, M.I.; Rooney, K.B.; Sue, C.M.; Thomspon, C.H. Compression Garments and Recovery from Eccentric Exercise: A P-MRS Study. *J. Sports Sci. Med.* **2006**, *5*, 106–114. [PubMed]
8. Gupta, D. Functional clothing–definition and classification. *Indian J. Fiber Text. Res.* **2011**, *36*, 321–326.
9. Kowalski, K.; Mielicka, E.; Kowalski, T.M. Modelling and Designing Compression Garments with Unit Pressure Assumed for Body Circumferences of a Variable Curvature Radius. *Fibres Text. East. Eur.* **2012**, *20*, 98–102.
10. Saggers, M. Inflatable Garment for Intermittent Compression Therapy. U.S. Patent No. US4722332A, 2 February 1988.
11. Ortopedija. Available online: https://www.orthopedic-pro.com/produkte/supportsorthoses/ (accessed on 18 March 2024).
12. Venosan. Available online: https://www.venosan.com/en/home.html (accessed on 18 March 2024).
13. Sigvaris. Available online: https://www.sigvaris.com/de-ch/expertise/grundlagen/kompressionstherapie (accessed on 20 March 2024).
14. BSN Medical. Available online: http://www.bsnmedical.com/ (accessed on 27 February 2024).
15. Juzo. Available online: https://www.juzo.com/en/products/compression-garments (accessed on 20 March 2024).
16. Marena. Available online: https://marena.com/pages/marena-recovery-postsurgical-compression-garments (accessed on 18 March 2024).
17. Legner, M. Medical Textile with Specific Characteristics Produced on Flat Knitting Machines. In Proceedings of the 2nd International Conference Medical Textiles, Bolton, UK, 24–25 August 1999; pp. 44–51.
18. Özdil, N.; Marmarali, A.; Kretzschmar, S.D. Effect of Yarn Properties on Thermal Comfort of Knitted Fabrics. *Int. J. Therm. Sci.* **2007**, *46*, 1318–1322. [CrossRef]
19. Maklevska, E.; Nawrocki, A.; Ledwon, J.; Kowalski, K. Modelling and Designing of Knitted Products Used in Compressive Therapy. *Fibres Text. East. Eur.* **2006**, *14*, 111–113.
20. Ortopagalba. Available online: https://www.ortopagalba.com/en/products/ (accessed on 18 March 2024).
21. Kraemer, W.J.; Flanagan, S.D.; Comstock, B.A.; Fragala, M.S.; Earp, J.E.; Dunn-Lewis, C.; Ho, J.Y.; Thomas, G.A.; Solomon-Hill, G.; Penwell, Z.R.; et al. Effects of a Whole Body Compression Garment on Markers of Recovery after a Heavy Resistance Workout in Men and Women. *J. Strength Cond. Res.* **2010**, *24*, 804–814. [CrossRef] [PubMed]
22. Marqués-Jiménez, D.; Calleja-Gonzales, J.; Arratibel, I.; Delextrat, A. Are Compression Garments Effective for the Recovery of Exercise-Induced Muscle Damage? A systematic review with meta-analysis. *Physiol. Behav.* **2016**, *153*, 133–148. [CrossRef]
23. Doan, B.; Kwon, Y.H.; Newton, R.; Shim, J.; Popper, E.V.; Rogers, R.; Bolt, L.; Robertson, M.; Kraemer, W. Evaluation of a Lower-body Compression Garment. *J. Sports Sci.* **2003**, *21*, 601–610. [CrossRef] [PubMed]
24. Troynikov, O.; Ashayeri, E.; Burton, M.; Subic, A.; Alam, F.; Marteau, S. Factors Influencing the Effectiveness of Compression Garments Used in Sports. *Procedia Eng.* **2010**, *2*, 2823–2829.
25. Pereira, S.; Anand, S.C.; Rajendran, S.; Wood, C. A study of the Structure and Properties of Novel Fabrics for Knee Braces. *J. Ind. Text.* **2007**, *36*, 279–300. [CrossRef]
26. Lawenda, B.D.; Mondry, T.E.; Johnstone, P.A.S. Lymphedema: A primer on the identifcation and management of a chronic condition in oncologic treatment. *CA Cancer J. Clin.* **2009**, *59*, 8–24. [CrossRef]
27. Liu, R.; Kwok, Y.L.; Li, Y.; Lao, T.T.; Zhang, X. Quantitative Assessment of Relationship between Pressure Performances and Material Mechanical Properties of Medical Graduated Compression Stockings. *J. Appl. Polym. Sci.* **2007**, *104*, 601–610. [CrossRef]
28. Misra, S.; Carroll, B.J. Comprehensive Approach to Management of Lymphedema. *Curr. Treat. Options Cardiovasc. Med.* **2023**, *25*, 245–260. [CrossRef]

29. World Union of Wound Healing Societies (WUWHS). *Principles of Best Practice: Compression in Venous Leg Ulcers. A Consensus Document*; MEP Ltd.: London, UK, 2008.
30. Choucair, M.; Philips, T.J. Compression Therapy. *Dermatol. Surg.* **1998**, *24*, 141–148. [CrossRef]
31. Liu, R.; Kwok, Y.L.; Li, Y.; Lao, T.T. Fabric Mechanical—Surface Properties of Compression Hosiery and their Effects on Skin Pressure Magnitudes When Worn. *Fibres Text. East. Eur.* **2010**, *18*, 91–97.
32. Clark, M.; Krimmel, G. Lymphoedema and the construction and classification of compression. In *Lymphoedema Framework. Template for Practice: Compression Hosiery in Lymphoedema*; MEP Ltd.: London, UK, 2006; pp. 2–4.
33. Lozo, M.; Penava, Ž.; Lovričević, I.; Vrljičak, Z. The Structure and Compression of Medical Compression Stockings. *Materials* **2022**, *15*, 353. [CrossRef] [PubMed]
34. *BS 6612:1985*; Specification for Graduated Compression Hosiery. BSI: London, UK, 2016.
35. *CEN/TR 15831:2009*; Method for Testing Compression in Medical Hosiery. Available online: https://standards.iteh.ai/catalog/standards/cen/fc2f2f09-b1ca-4203-bd20-3104e6d9f4e7/cen-tr-15831-2009 (accessed on 22 May 2024).
36. Morrison, T. American Classification of Compression Stockings. Available online: https://www.tagungsmanagement.org/icc/images/stories/PDF/morrison_american_classification.pdf (accessed on 22 May 2024).
37. ASQAL: Chaussettes, Bas, Collants, et Manchons. Available online: https://www.asqual.com/fiche/chaussettes-bas-collants-et-manchons/ (accessed on 22 May 2024).
38. *RAL-GZ 387/1*; Medical Compression Hosiery, Quality Assurance. RAL Deutsches Institut für Gütesicherung und Kennzeichnung e.V.: Bonn, Germany, 2008.
39. Chiang, J.; Chuang, J. Compression Braces Structure and Material. U.S. Patent No. US6508776B2, 21 January 2003.
40. Rabe, E.; Partsch, H.; Jünger, M.; Abel, M.; Achhammer, I.; Becker, F.; Cornu-Thenard, A.; Flour, M.; Hutchinson, J.; Ißberner, K.; et al. Guidelines for Clinical Studies with Compression Devices in Patients with Venous Disorders of the Lower Limb. *Eur. J. Vasc. Endovasc. Surg.* **2008**, *35*, 494–500. [CrossRef] [PubMed]
41. Alisauskiene, D.; Mikucioniene, D.; Milasiute, L. Influence of Inlay-Yarn Properties and Insertion Density on Compression Properties of Knitted Orthopaedic Supports. *Fibres Text. East. Eur.* **2013**, *21*, 74–78.
42. Calmbach, W.L.; Hutchens, M. Evaluation of patients presenting with knee pain: Part II. Differential diagnosis. *Am. Fam. Physician* **2003**, *68*, 917–922.
43. Briggs, K.K.; Lysholm, J.; Tegner, Y.; Rodkey, W.G.; Kocher, M.S.; Steadman, J.R. The Reliability, Validity, and Responsiveness of the Lysholm Score and Tegner Activity Scale for Anterior Cruciate Ligament Injuries of the Knee: 25 years later. *Am. J. Sports Med.* **2009**, *37*, 890–897. [CrossRef]
44. Klem, N.R.; Wild, C.Y.; Williams, S.A.; Ng, L. Effect of External Ankle Support on Ankle and Knee Biomechanics during the Cutting Maneuvre in Basketball Players. *Am. J. Sports Med.* **2016**, *45*, 685–691. [CrossRef] [PubMed]
45. Orliman. Available online: https://www.orliman.com/categoria-producto/rodilla/ (accessed on 18 March 2024).
46. Medi. Available online: https://www.mediuk.co.uk/products/orthopaedics/ (accessed on 20 March 2024).
47. PhysioRoom. Available online: https://www.physioroom.com/supports-braces (accessed on 20 March 2024).
48. DJO Global. Available online: http://www.djoglobal.eu/en_UK/ (accessed on 20 March 2024).
49. Biofact Pharma. Available online: http://www.biofactpharma.com/ (accessed on 1 March 2024).
50. Cigna Medical Coverage Policy. Subject: Knee Braces. Coverage Policy Number, 2012, *0362*, 0515. Available online: https://www.evicore.com/sites/default/files/clinical-guidelines/2023-08/Cigna_CMM-312_Knee_Surgery_Arthroscopic_and_Open_V102023_eff05312023_pub02162023.pdf (accessed on 22 May 2024).
51. Chew, K.T.; Lew, H.L.; Date, E.; Fredericson, M. Current evidence and clinical applications of therapeutic knee braces. *Am. J. Phys. Med. Rehabil.* **2007**, *86*, 678–686. [CrossRef]
52. Aagaard, P.; Simonsen, E.B.; Andersen, J.L.; Magnusson, S.P.; Bojsen-Møller, F.; Dyhre-Poulsen, P. Antagonist Muscle Coactivation during Isokinetic Knee Extension. *Scand. J. Med. Sci. Sports* **2000**, *10*, 58–67. [CrossRef]
53. Beynnon, B.D.; Pope, M.H.; Wertheimer, C.M.; Johnson, R.J.; Fleming, B.C.; Nichols, C.E.; Howe, J.G. The Effect Functional Knee-Braces on Strain on the Anterior Cruciate Ligament in Vivo. *J. Bone Jt. Surg.* **1992**, *74*, 1298–1312. [CrossRef]
54. Kruger, T.H.; Coetsee, M.F.; Davies, S. The effect of prophylactic knee bracing on proprioception performance in first division rugby union players. *Sports Med.* **2004**, *16*, 33–36.
55. Paluska, S.A.; McKeag, D.B. Knee Braces: Current Evidence and Clinical Recommendation for Their Use. *Am. Fam. Physician* **2000**, *61*, 411–416. [PubMed]
56. Prosthetic Stump Shrinkers for Arm–Above Elbow, Compression, Healthcare, Amputee Arm Sleeve. Available online: https://www.amazon.com/JianiMed-Prosthetic-Compression-HealthCare-Excellence/dp/B0CDKNMZLK (accessed on 16 April 2024).
57. Juzo Stump Shrinkers. For Individual Oedema Treatment on Arms and Legs. Available online: https://www.juzo.com/en/products/compression-garments/oedema-therapy/flat-knit-compression-for-maintenance-therapy/juzo-stump-shrinkers (accessed on 16 April 2024).
58. Stump Shrinkers. Medi BK Stump Shrinker with Clima Comfort and Clima Fresh, Silicone Top Band. Available online: https://amputeestore.com/collections/stump-shrinkers/products/ossur-medi-bk-stump-shrinker (accessed on 16 April 2024).
59. Compression Hosiery Testing. Available online: http://www.smtl.co.uk/testing-services/34-medical-device-testing/52-compression-hosiery-testing.html (accessed on 22 May 2024).

60. Hohenstain. Examination of the Compressive Behaviour of Medical Compression Hosiery and Similar Products Using the Compression Measurement System Hohenstein (HOSY). Available online: https://www.hohenstein.com/en/expertise/health/medical-compression-textiles-according-to-ral-gz-387-and-din-58133 (accessed on 18 March 2024).
61. Liu, R.; Kwok, Y.L.; Li, Y.; Lao, T.T.H.; Zhang, X.; Dai, X.Q. Objective evaluation of skin pressure distribution of graduated elastic compression stockings. *Dermatol. Surg.* **2005**, *31*, 615–624. [CrossRef] [PubMed]
62. Rotsch, C.; Oschatz, H.; Schwabe, D.; Weiser, M.; Möhring, U. Medical bandages and stockings with enhanced patient acceptance. In *Handbook of Medical Textiles*; Bartels, V., Ed.; Bartels Scientific Consulting GmbH: Bad Kreuznach, Germany, 2011; pp. 481–504.
63. Liu, R.; Lao, T.T.; Li, Y.; Kwok, Y.L.; Ying, M.T. Physiological Response and Comfort Sensory Perception towards Physical–Mechanical Performance of Compression Hosiery Textiles. *J. Fiber Bioeng. Inform.* **2008**, *1*, 55–64.
64. Wang, Y.; Cui, Y.; Zhang, P.; Feng, X.; Shen, J.; Xiong, Q. A smart mannequin system for the pressure performance evaluation of compression garments. *Text. Res. J.* **2011**, *81*, 1113–1123. [CrossRef]
65. Hegarty-Cravera, M.; Kwonb, C.; Oxenhamb, W.; Granta, E.; Reid, L., Jr. Towards characterizing the pressure profiles of medical compression hosiery: An investigation of current measurement devices and techniques. *J. Text. Inst.* **2015**, *106*, 757–767. [CrossRef]
66. Mikucioniene, D.; Muraliene, L. Influence of orthopaedic support structure and construction on compression and behavior during stress relaxation. *J. Ind. Text.* **2022**, *51*, 5026S–5041S. [CrossRef]
67. Lyashenko, I.; Gonca, V.; Oks, B. Designing Medical Knitwear in View of Geometrical and Biomechanical Characteristics of Rounded Surfaces. In Proceedings of the 1st International Textile Clothing & Design Conference, Zagreb, Croatia, 6–9 October 2002; pp. 517–521.
68. Oks, B.; Lyashenko, I. Methods of Calculation of Local Pressure of Elastomer Products. In *Medical Textiles*; Cambridge Woodhead Publishing Limited: Bolton, UK, 1999; pp. 82–91.
69. Petrova, A.; Ashdown, S.P. Three-Dimensional Body Scan Data Analysis: Body Size and Shape Dependence of Ease Values for Pants' Fit. *Cloth. Text. Res. J.* **2008**, *26*, 227–252. [CrossRef]
70. Troynikov, O.; Ashayeri, E. 3D body scanning method for close-fitting garments in sport and medical applications. In *HFESA 47th Annual Conference*; Ergonomics Australia—Special Edition; Crows: Crows Nest, Australia, 2011; pp. 1–6.
71. Wong, A.S.W.; Li, Y.; Zhang, X. Influence of Fabric Mechanical Property on Clothing Dynamic Pressure Distribution and Pressure Comfort on Tight-Fit Sportswear. *Fiber* **2004**, *60*, 293–299. [CrossRef]
72. Alisauskiene, D.; Mikucioniene, D. Investigation on Alteration of Compression of Knitted Orthopaedic Supports during Exploitation. *Mater. Sci. (Medžiagotyra)* **2012**, *18*, 362–366. [CrossRef]
73. Bodenschatz, S.; Herzberg, T.; Doheny, F. Anatomically Shaped Medical Bandages. U.S. Patent No. US626 7743B1, 31 July 2001.
74. Wang, L.; Felder, M.; Cai, J.Y. Study of Properties of Medical Compression Garment Fabrics. *J. Fiber Bioeng. Inform.* **2011**, *4*, 15–22. [CrossRef]
75. Halavska, L.; Batrak, O. The properties of weft knitted fabric medical and preventive treatment action using eco-raw materials. In *IOP Conference Series: Materials Science and Engineering*; IOP Publishing: Bristol, UK, 2016; Volume 141, p. 012013.
76. Kumar, B. Innovation in Compression Therapy for Chronic Venous Insufficiency—Smart Textile. *Ann. Vasc. Med. Res.* **2016**, *3*, 1037.
77. Akaydin, M.; Cana, Y. Research of Strength Properties of Socks Knitted from New Cellulose-Based Fibers. *Electron. J. Text. Technol.* **2012**, *6*, 28–36.
78. Abdessalem, S.B.; Abdelkader, Y.B.; Mokhtar, S.; Elmarzougui, S. Influence of Elastane Consumption on Plated Plain Knitted Fabric Characteristics. *J. Eng. Fibers Fabr.* **2009**, *4*, 30–35. [CrossRef]
79. Meulemeester, S.; Van Langenhove, L.; Kikens, P. Study of the Weavability of Elastane Based Stretch Yarns on Air–Jet Looms. *AUTEX Res. J.* **2009**, *9*, 55–60. [CrossRef]
80. Tezel, S.; Kavusturan, Y. Experimental Investigation of Effects of Spandex Brand and Tightness Factor on Dimensional and Physical Properties of Cotton/Spandex Single Jersey Fabrics. *Text. Res. J.* **2008**, *78*, 966–967. [CrossRef]
81. Kumar, V.; Sampath, V.R. Investigation on the Physical and Dimensional Properties of Single Jersey Fabrics Made from Cotton Sheath-Elastomeric Core Spun. *Fibres Text. East. Eur.* **2013**, *21*, 73–75.
82. Marmarali, B.A. Dimensional and Physical Properties of Cotton/Spandex Single Jersey Fabric. *Text. Res. J.* **2003**, *73*, 11–14. [CrossRef]
83. Melnyk, L.; Kyzymchuk, O. Novel Elastic Warp Knitted Fabric With Perforatio. *Vlak. Text.* **2000**, *30*, 120–125.
84. Pavko-Cuden, A. Parameters of compact single weft knitted structure (part 2): Loop modules and munden constants—Compact and super-compact structure. *Tekstilec* **2010**, *53*, 259–272.
85. Abramaviciute, J.; Mikucioniene, D.; Ciukas, R. Structure Properties of Knits from Natural Yarns and their Combination with Elastane and Polyamide Threads. *Mater. Sci. (Medžiagotyra)* **2011**, *17*, 43–46.
86. Mikucioniene, D.; Alisauskiene, D. Prediction of Compression of Knitted Orthopaedic Supports by Inlay-Yarn Properties. *Mater. Sci. (Medžiagotyra)* **2014**, *20*, 311–314.
87. Ozbayrak, N.; Kavusturan, Y. The Effects of Inlay Yarn Amount and Yarn Count of Extensibility and Bursting Strength of Compression Stockings. *Tekst. Konfeksiyon* **2009**, *2*, 102–107.
88. Domanski, E.; Lamping, C.; Bruce, L.; Hinds, S.; Bodenschatz, S. Orthopaedic Supports. U.S. Patent No. US20020115950A1, 22 August 2002.

89. Milosavljevic, S.; Škundric, P. Contribution of Textile Technology to the Development of Modern Compression Bandages. *Chem. Ind. Chem. Eng. Q./CI CEQ* **2007**, *13*, 88–102. [CrossRef]
90. Senthilkumar, M.; Sounderraj, S.; Anbumani, N. Effect of Spandex Input Tension, Spandex Linear Density and Cotton Yarn Loop Length on Dynamic Elastic Behavior of Cotton/Spandex Knitted Fabrics. *J. Text. Appar. Technol. Manag.* **2012**, *7*, 1–16.
91. Fatkić, E.; Geršak, J.; Ujević, D. Influence of Knitting Parameters on the Mechanical Properties of Plain Jersey Weft Knitted Fabrics. *Fibres Text. East. Eur.* **2011**, *19*, 87–91.
92. Choi, W.; Powel, N.C. Three Dimensional Seamless Garment Knitting on V-bed Flat Knitting Machines. *J. Text. Appar. Technol. Manag.* **2005**, *4*, 1–33.
93. Alagirusamy, R.; Eichhoff, J.; Gries, T.; Jockenhoevel, S. Coating of conductive yarns for electro-textile application. *J. Text. Inst.* **2013**, *104*, 270–277. [CrossRef]
94. Gupta, D.; Chattopadhyay, R.; Bera, M. Comfort properties of pressure garments in extended state. *Indian J. Fibre Text. Res.* **2011**, *36*, 415–421.
95. Treigyte, V.; Chaillou, T.; Eimantas, N.; Venckunas, T.; Brazaitis, M. Passive heating-induced changes in muscle contractile function are not further augmented by prolonged exposure in young males experiencing moderate thermal stress. *Front. Physiol.* **2024**, *15*, 1356488. [CrossRef] [PubMed]
96. Araújo, M.; Fangueiro, R.; Hong, H. Modelling and Simulation of the Mechanical Behaviour of Weft-Knitted Fabrics for Technical Applications, Part II. *AUTEX Res. J.* **2003**, *3*, 117–123.
97. Araújo, M.; Fangueiro, R.; Hong, H. Modelling and Simulation of the Mechanical Behaviour of Weft-knitted Fabrics for Technical Application. Part III. *AUTEX Res. J.* **2004**, *4*, 25–32. [CrossRef]
98. Senthilkumar, M.; Anbunami, N. Dynamics of Elastic Knitted Fabrics for Sports Wear. *J. Ind. Text.* **2011**, *41*, 13–24. [CrossRef]
99. Kononova, O.; Krasnikovs, A.; Dzelzitis, K.; Kharkova, G.; Vagel, A.; Eiduks, M. Modelling and experimental verification of mechanical properties of cotton knitted fabric composites. *Est. J. Eng.* **2011**, *17*, 39–50. [CrossRef]
100. Watkins, P. Designing with stretch fabrics. *Indian J. Fibre Text. Res.* **2011**, *36*, 366–379.
101. Yamada, T.; Matmuo, M. The Study of Effect of a Polyurethane Filament on Mechanical Properties of Plain Stitch Fabrics. *Text. Res. J.* **2009**, *79*, 310–317. [CrossRef]
102. Das, A.; Kumar, B.; Mittal, T.; Singh, M.; Prajapati, S. Pressure Profiling of Compression Bandages by a Computerized Instrument. *Indian J. Sci. Technol.* **2012**, *37*, 114–119.
103. Chen, D.; Liu, H.; Zhang, Q.; Wang, H. Effects of Mechanical Properties of Fabrics on Clothing Pressure. *Prz. Elektrotechniczny* **2013**, *89*, 232–235.
104. Harpa, R.; Piroi, C.; Radu, C.D. A New Approach for Testing Medical Stockings. *Text. Res. J.* **2010**, *80*, 683–695. [CrossRef]
105. Radu, C.D.; Popescu, V.; Manea, L.R.; Harpa, R.; Piroi, C. Behavior of Medical stockings used in chronic venous failure of leg. In *Book of Abstracts of 8th Autex Conference*; Citta Studi: Biela, Italy, 2008; Volume 29.
106. Abramaviciute, J.; Mikucioniene, D.; Ciukas, R. Static Water Absorption of Knits from Natural and Textured Yarns. *Fibres Text. East. Eur.* **2011**, *19*, 60–63.
107. Mikucioniene, D.; Milasiute, L. Influence of Knitted Orthopaedic Support Construction on Compression Generated by the Support. *J. Ind. Text.* **2016**, *47*, 551–566. [CrossRef]
108. Salopek Cubric, I.; Skenderi, Z.; Mihelic-Bogdanic, A.; Andrassy, M. Experimental Study of Thermal Resistance of Knitted Fabrics. *Exp. Therm. Fluid Sci.* **2012**, *38*, 223–228. [CrossRef]
109. Raju, S.; Hollis, K.; Neglen, P. Use of Compression Stockings in Chronic Venous Disease: Patient Compliance and Efficacy. *Ann. Vasc. Surg.* **2007**, *21*, 790–795. [CrossRef] [PubMed]
110. Montoya, M.I.; Avila, M.L.; Vincelli, J.; Williams, S.; Brandao, L.R. Understanding the Barriers in Compliance to Elastic Compression Garments in the Treatment of Pediatric Post-thrombotic Syndrome: A qualitative study. *Thromb. Res.* **2016**, *144*, 113–115. [CrossRef] [PubMed]
111. Majumdar, A.; Mukhopadhyay, S.; Yadav, R. Thermal Properties of Knitted Fabrics Made from Cotton and Regenerated Bamboo Cellulosic Fibres. *Int. J. Therm. Sci.* **2010**, *49*, 2042–2048. [CrossRef]
112. Bartkowiak, G.; Frydrych, I.; Greszta, A. Fabric Selection for the Reference Clothing Destined for Ergonomics Test of Protective Clothing: Physiological Comfort Point of View. *AUTEX Res. J.* **2016**, *16*, 256–261. [CrossRef]
113. Afzal, A.; Ahmad, S.; Rasheed, A.; Ahmad, F.; Iftikhar, F.; Nawab, Y. Influence of Fabric Parameters on Thermal Comfort Performance of Double Layer Knitted Interlock Fabrics. *AUTEX Res. J.* **2017**, *17*, 20–26. [CrossRef]
114. Vlasenko, V.; Kovtun, S.; Bereznenko, N.; Suprun, N.; Murarova, A. Water and Heat Transfer through multilayer Textile Composites. *Vlak. Text.* **2006**, *13*, 29–32.
115. Bivainyte, A.; Mikucioniene, D.; Milasiene, D. Influence of the Knitting Structure of Double-Layered Fabrics on the Heat Transfer Process. *Fibres Text. East. Eur.* **2012**, *20*, 40–43.
116. Kilinc-Balci, F.S. Testing, analyzing and predicting the comfort properties of textiles. In *Improving Comfort in Clothing*; Song, G., Ed.; Woodhead Publishing: Sawston, UK, 2011; pp. 138–162.
117. Das, A.; Alagirusamy, R. Improving tactile comfort in fabrics and clothing. In *Improving Comfort in Clothing*; Song, G., Ed.; Woodhead Publishing: Sawston, UK, 2011; pp. 216–244.
118. Arabuli, S.; Suprun, N.; Ocheretna, L.; Arabuli, A. Investigation of sensory comfort of textile materials for hospital line. Bulletin of the Kyiv National University of Technologies and Design. *Tech. Sci. Ser.* **2020**, *1*, 38–49.

119. Goetzendorf-Grabowska, B.; Karaszewska, A.; Vlasenko, V.I.; Arabuli, A.T. Bending stiffness of knitted fabrics—Comparison of test methods. *Fibres Text. East. Eur.* **2014**, *103*, 43–50.
120. Paulauskas, H.; Baranauskiene, N.; Wang, J.; Mikucioniene, D.; Eimantas, N.; Brazaitis, M. Local knee heating increases spinal and supraspinal excitability and enhances plantar flexion and dorsiflexion torque production of the ankle in older adults. *Eur. J. Appl. Physiol.* **2020**, *120*, 2259–2271. [CrossRef] [PubMed]
121. Sekins, K.M.; Lehmann, J.F.; Esselman, P.; Dundore, D.; Emery, A.F.; de Lateur, B.J.; Nelp, W.B. Local muscle blood flow and temperature responses to 915MHz diathermy as simultaneously measured and numerically predicted. *Arch. Phys. Med. Rehabil.* **1984**, *65*, 1–7. [PubMed]
122. Repon, M.R.; Mikucioniene, D.; Baltina, I.; Blums, J.; Laureckiene, G. Ag/PA Based Electro-Conductive Knitted Fabrics for Heat Generation in Compression Supports. *AUTEX Res. J.* **2022**, *22*, 55–63. [CrossRef]
123. Mirjalili, M.; Karimi, L. Preparation of melt spun electroconductive fine fibres containing carbon nanotubes. *AUTEX Res. J.* **2015**, *15*, 87–92. [CrossRef]
124. Devaux, E.; Koncar, V.; Kim, B.; Campagne, C.; Roux, C.; Rochery, M.; Saihi, D. Processing and characterisation of conductive yarns by coating or bulk treatment for smart textile applications. *Trans. Inst. Meas. Control* **2007**, *29*, 355–376. [CrossRef]
125. Repon, M.R.; Mikučionienė, D. Progress in flexible electronic textile for heating application: A critical review. *Materials* **2021**, *14*, 6540. [CrossRef]