

# HMW Statement: How Might We Improve the Wearability of Compression Socks for Elderly People Suffering from Varicose Veins?

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## ABSTRACT

This paper focuses on the factors affecting elderly patients' adherence to wearing compression socks, an appropriate treatment for chronic venous insufficiency. Although compression therapy reduces symptoms, it has poor ergonomic design in wears, making them uncomfortable, clumsy, and less suitable for elderly patients who cannot apply or use the compression socks correctly, thereby undermining compliance and therapy outcomes. The paper process used in the study includes principles derived from user interface design and ethnography to establish users' needs and the design solutions that would adequately meet those needs. Design prototypes were developed for improved fastening methods to improve comfort and durability alongside the best fabric choice and the garment's antimicrobial effectiveness. Patients, medical officials, and clinicians provided feedback incorporated into further cycles of changes that prompted positive feedback regarding the application of functionalities in real-life settings. The study also explored that the quality of compression socks should increase the wearability and accessibility of such garments for older patients and suggests the future development of smart textiles, bio-based fabric, and tailor-made garments. Subsequently, premium importance is to be paid to the affordability and awareness relating to their usage, which is instrumental in the successful implementation undertaken by the broad mass of people.

**KEYWORDS:** Compression Socks, Varicose Veins, Elderly Users, Wearability, Comfort, User-centered Design, Prototyping, Therapeutic

## INTRODUCTION

The article is centered on enhancing the comfort of wearing compression socks to elderly patients with varicose veins. Varicose veins are inflamed, swollen veins that commonly cause a lot of pain, and they can only be managed by wearing stockings that assist in blood circulation, minimizing the formation of clots and promoting movement and health status.

However, the current stock is conventional compression socks that are hard to put on and take off, uncomfortable, or unsuitable for the elderly, thus resulting in low demand rates and decreasing quality of life. The current problems revealed by patients are tightness, difficulty putting on and removing the garment, and limited knowledge of how to prevent it and take care of the garment. In response to these issues, the initiative calls for an ergonomic design featuring comfort, adjustment, and ease of use. Materials under consideration include blends like nylon spandex for optimal compression, bamboo and cotton for comfort, and innovative components like silver-infused yarn for antimicrobial properties. Convenience means having items with zippers, Velcro, or corset-like mechanisms, and also extendibility.

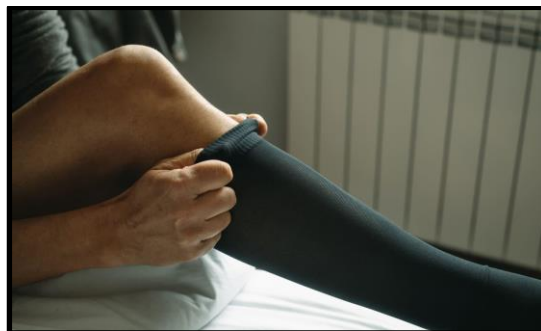
Prototyping activities aspire to improve the compression rates, lifespan, and comfort during later real-life applications and with customer responses. The aim is to develop an affordable product that provides elders with greater independence and improved quality of life consistent with medical requirements. Some scaling strategies include partnerships with healthcare facilities and international expansion to spread the impact. This article explains the background of the work, with a definition and clarification of the identified problem, methods used, results achieved, plans for future work, difficulties faced, and conclusions.

## BACKGROUND

Chronic venous insufficiency (CVI) is a pathological condition from chronic venous valve failure and impaired blood flow in the deep leg veins. It causes symptoms including oedema, skin changes, leg pain, fatigue, and heaviness progressing to complications like chronic leg ulcers or deep vein thrombosis (DVT). Post-thrombotic syndrome is a chronic venous symptom that occurs after DVT and also affects the venous valves adversely. The Clinical-Etiology-Anatomy-Pathophysiology (CEAP) classification categorizes chronic venous disorders based on severity, ranging from C0 to C6. Age, gender, and ethnicity distribution of CVI are not uniform, with age being a major contributing factor to the condition [1].

Action plans include exercise, smoking cessation, weight loss, leg raising, anticoagulants, and wearing medical compression stockings. Compression stockings are of four classes driven by the level of pressure that are often used to relieve symptoms, reduce oedema and enhance microcirculation.

Moreover, class 1 stockings provide light compression for oedema prevention, while higher classes address more severe conditions, including chronic venous insufficiency and lymphoedema. While it has been demonstrated that compression stockings help those under 70 years of age, doubts were noted regarding their efficacy in the older population [2]. Many elderly patients with at least two chronic diseases need help wearing these stockings. Systematic reviews have been published concerning the preventive efficacy of compression stockings for venous insufficiency, and other reviewers have considered some of the earlier reviews as outdated. Issues relating to wearability and correct applicability for elderly users could be of immense importance in enhancing the value and usage of this intervention.



**Figure 1. Compression socks for varicose veins of older people**

The above figure depicts that using compression stockings can help alleviate the common tiredness in the legs and combine with some health complications that are quite prevalent among the elderly, such as varicose veins. These stockings constrain the blood supply pressure level within the legs to improve blood flow. The popular medical graduated pressure stockings have the tightest whatsoever at the ankle and then relax up the leg [3]. This design also minimizes blood accumulation in the veins, which can cause swelling, aching, and fatigue linked to varicose veins.

In the elderly, varicose veins cause pain, swelling, tingling, or cramps; they may also progress to skin changes, leg ulcers, or even blood clots. Compression stockings help these problems because they help to strengthen the veins and valves that have become weak and promote the reduction of swelling and pain. They can also help stop the development of other veins-related issues by promoting blood flow and taking pressure off veins during prolonged periods on your feet or sitting [4].

Over-the-counter nonmedical compression stockings provide less pressure, relieving aching and heaviness in the legs, even for those with no diseases. These are beneficial for older adults needing daytime or general leg fatigue relief. Nonmedical graded stockings, or medical ones, are also safe and helpful: they provide much comfort and improve blood circulation in the elderly's legs.

## PROBLEM STATEMENT

The main concern is related to the difficulties elderly patients face when applying compression socks, a standard treatment for varicose veins. The elderly are always prone to varicose veins, which develop from weakness and immobility, leading to pains, discomfort, blood clots, and other complications. While patients with compression socks can benefit much from compression socks, reduce some of their symptoms, and improve their circulation, the design and functionality of the product cage them. Some of these complications include the user straining the compression socks when pulling them up and off because of poor health and strength. For this reason, it is not sustainable, and the therapeutic value is diminished, and the condition remains or worsens again.

Furthermore, the existing materials and designs for making compression socks usually do not consider the complications of elderly users [5]. Most socks are too tight at the cuffs, which can lead to discomfort. The absence of fabrics with breath or hypoallergenic qualities can cause itchiness for people with sensitive skin.

The socks' durability is another issue since elderly patients require long periods of wearing the socks for treatment. Substandard components that degrade fast or are designed to hold moisture can lead to painful sensations, diminished effectiveness, and skin infections. Also, little pliability in design, like insufficient stretch or no friendly closures like Velcro or zippers, makes these socks disadvantageous for individuals with arthritic issues [6]. In this case, the lack of ease of use, the uncomfortable nature of the device, and the complete lack of personalization are staunch hurdles to adoption and efficacy, which means that elderly persons have no affordable and practical solution for minimizing varicose veins.

However, the challenge comes with wearing and removing the compression socks while also being old. It allows varicose disease sufferers of the elderly age and probably other groups of patients who do not have the necessary muscular strength to get this simple, relatively cheap, and easily accessible cure.

The article intends to consider such difficulties occurring in elderly people with varicose veins and to improve the possibility of compression sock usage. The objective is to design a solution that reduces the amount of physical work needed to wear these socks and remove them to become more comfortable and valuable. It should help enhance compliance with prescribed treatment regimes, especially for the mobility impaired, while at the same time retaining efficacy and practicability.

## PROCEDURES AND METHODS

### *User-Centered Design and Ethnographic Research*

In the development of handle socks, corset socks, and Velcro socks for the elderly with varicose veins, it is essential to apply approaches of the user-centered design (UCD) and ethnographic methods to improve the wearability of the said product. UCD is derived from the question of 'how' to create goods and services to match consumer capabilities and disabilities [7]. It revolves around the capacity to ask elderly users about their experiences, what they look for in a compression sock, and problems they encounter with existing ones. This data involves interviews, questionnaires, and usability tests to advance design solutions that meet user functionalities and enhance satisfaction.

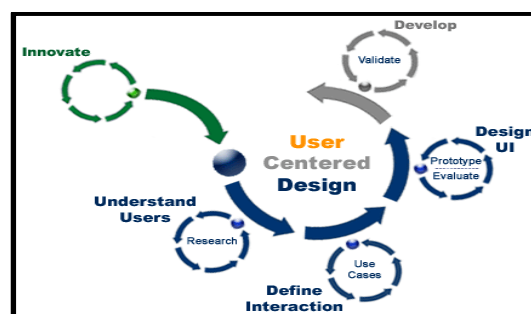


Figure 2. User-centered design approach

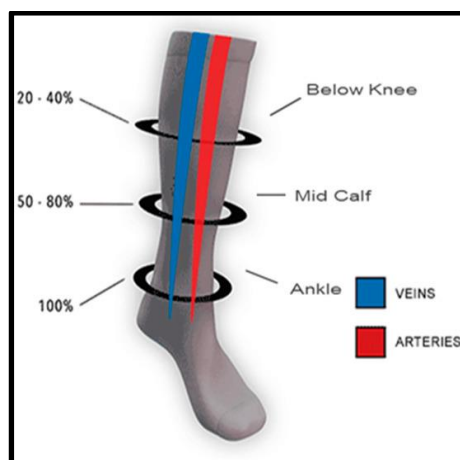
(Taken from [3])

Ethnography supports UCD with valuable information about the everyday activities of elderly people with varicose veins. Through direct observation, researchers have studied end users and their behaviors, cultural settings, and engagement with current compression garments. This approach reveals attitudinal factors and potential obstacles to assimilation that are not canvassed in straightforward questions. By synthesizing those two methodologies, designers can develop compression socks that both have an ultimate function but are user-centered and able to fit senior users' lifestyles. For example, special operations such as the addition of handles, corset mechanisms, or closures, such as Velcro, respond to problems that may arise when dressing or undressing [8]. This approach guarantees that the final product is functional for its intended use besides being appealing to the target population; hence, implementation is typically better therapeutic results.

These methods are essential since they capture all the issues that elderly people with varicose veins undergo, hence making compression socks to meet their needs. To support wearability, functionality, and the overall acceptability of the product, they incorporate user-centered findings and ethnographic findings alongside each other.

### ***Prototyping and Wearability Testing***

In order to create compression socks like handle socks, corset socks, and Velcro socks, especially for elderly patients with Varicose veins, prototyping, and wearability testing are two critical strategies used to increase comfort and usage. Prototyping entails constructing the first samples of the compression socks to test the viable designs and usability. It enables designers to explicate many material options, compression ranges, and fastening methods specific to seniors' end-users. For example, adding zippers and Velcro closures will help increase the donning and doffing experience, which poses common issues among older people [9]. Compression efficacy and intuitive utilization are tested alongside comfort, facilitating modification before graduating to prototypes in the later stages.



**Figure 3. Compression stockings for treating varicose veins**

(Taken from [10])

Wearable testing works alongside prototyping to analyze the comfort, fit, and acceptability of the final developed compression socks. This process entails enlisting the elderly participants to wear the prototypes for a particular duration, after which information concerning the comfort of the prototypes, skin status, ease of putting on the prototypes, and overall satisfaction is obtained. Quantitative parameters, including measures of the pressure provided by the socks together with non-skin checks like observing for skin reactions like blushing or reduced blood flow, are also privileged in this assessment [10]. Conducted from wearability tests by the elderly users, the feedback helps in subsequent changes to the design so that the end product reflects their physical strength and comfort level. By combining both prototyping and wearability testing, designers formulate compression socks that not only meet the medical requisites of dysfunctional varicose veins but also serve the elderly populace for easy wear, thus ensuring immense compliance to compression therapy and, hence, better quality of life.

### Stakeholder Feedback and Evaluation

Improving the function of compression socks for elderly people with varicose veins requires considering the stakeholders' opinions and evaluating the analyses.

**Semi-Structured Interviews:** Semi-structured interviews with elderly users make it possible to obtain detailed information concerning their experiences, preferences, and difficulties arising from using handle socks, corset socks, and Velcro socks. This qualitative approach allows understanding not only the needs of users and their potential needs but also the possible deficiencies of the existing system.

**Functional Resonance Analysis Method (FRAM):** Using the "Functional Resonance Analysis Method" (FRAM), a detailed understanding of the kind of work that compression stocking therapy is in its actual setting can be understood. This process reveals fluctuations in use and where further changes to the design might improve elderly patient use and adherence [11].

**Patient Experience Surveys:** Self-administered, structured questionnaires given to a larger sample of elderly users quantify satisfaction, perceived comfort, and challenges experienced with compression socks. This analysis is helpful to know typical problems as well as popular features among customers.

**Observational Studies:** Observing the elderly putting on and removing the compression socks in their normal activities in real-life situations gives practical experience of the effort they make. This method focuses on identifying ergonomic problems and providing information on improving designs to allow easy use.

**Focus Groups:** Arranging focus group discussions with elder users prompts the participants to share more experiences and develop ideas about improving the designs. This approach reveals various insights and encourages seeing the problem through the end user's viewpoint [12].

Using such methods guarantees that the design of compression socks embraces stake and evaluation results to optimize wearability, specifically among the elderly suffering from varicose veins.

## RESULTS AND IMPLEMENTATION

The objectives of this work were to investigate the problems caused by the usability and comfort of compression socks on elderly people with varicose veins problems. After generating new solutions, the project reached appropriate outcomes in such phases as material choosing, prototyping, and communicating with all interested parties.

The above outcomes are focused on enhancing the convenience of compression socks, promoting the wearing rate of elderly people, and gradually raising the life quality of elderly people.

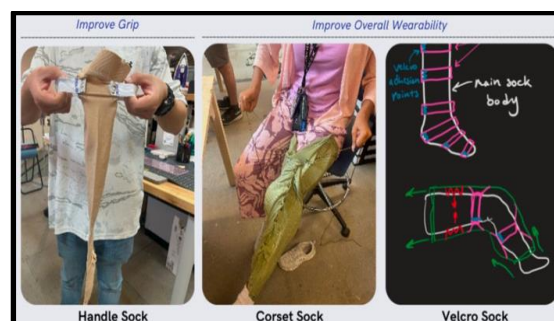


Figure 4. Compression wearable socks for elderly patients having varicose veins

## RESULTS ACHIEVED

### 1. Innovative Design Features:

Two main experimental models were created: one incorporated the BOA-based corseting, and the other – layered zippering [13]. These designs minimize insulation from the ease of putting on and removing them

without causing physical stress to the elderly with weak muscles or joints. Implementing these mechanisms provides the consumer with an easy solution to avoid the issue that we found to be the primary concern of patients and clinicians during stakeholder interviews: the discomfort of compression socks.

## **2. Material Optimization:**

Compression – nylon and spandex fabrics; Comfort – bamboo and cotton; Antimicrobial – using yarns infused with silver was considered and chosen. These choices offer high compression efficacy, comfort, breathability, and durability. The antimicrobial features mean it can be used for a long time and would be very useful for elderly people.

## **3. Stakeholder Engagement:**

Ideas from the patient, caregiver, and nurses are crucial in the developmental processes of such designs. Concerns included fit and comfort, actual or perceived design problems, and the acknowledged requirements for breathability and hypoallergenicity. This feedback was assimilated into the iterative design process to improve user satisfaction and usability.

## **4. Prototyping and Testing:**

The first samples for compression efficiency, durability, and wearability were developed. The initial overall compression ranges were in the ideal range required for handling varicose veins; at the same time, these new designs made the relevant products more straightforward to apply [14]. Stakeholders agreed that the prototypes are likable and convenient and seem effectively deployable in the real world.

## **Implementation**

### **1. Refinement and Validation:**

After the initial testing and receiving user feedback, the prototypes are being fine-tuned to enhance performance. Further tests will also measure adhesion, wear and tear, and comfort over extended periods. The aim is to design products that are as close as possible to the therapeutic aspirations of elderly customers but still functional.

### **2. Collaboration with Healthcare Providers:**

Working together with hospitals, elder care facilities, and healthcare personnel, practical implementation will be made possible. The same will safeguard adherence to specific medical requirements and increase visibility among the target consumers.

### **3. Cost and Accessibility:**

The estimated cost per pair is \$25- \$45 this is based on the customization used and the type of material [15]. This range is a compromise between the basic price and advanced functions and allows expanding the range of customers from the elderly people category.

### **4. Scaling Strategy:**

A phased scaling plan has been outlined:

- **Year 1:** Many of the project goals are to improve prototypes based on user feedback and to carry out clinical trials, which include cooperation with healthcare facilities. To develop a more credible source of information, findings will be published in peer-reviewed journals.
- **Year 2:** Grow locally, diversify into other regions with similar demographics and gain agreements with additional hospitals to produce the designs patented in the region. Larger clinical trials will support the products all the more.
- **Year 3:** Expand nationally and internationally, either through partnerships with world-famous hospitals and healthcare companies for delivery of Hippo home-delivered care for seniors, or through stores' chains or franchises for delivery of Hippo's elder care products [16]. Further attendance at international conferences will bring to market focus on the innovative nature of the product.

### 5. Future Directions:

The next step is to continue experiments to confirm the efficiency of the compression and wearability enhancements, as well as the user's satisfaction. Other features, which include medicated parts and improved support structures, are currently being considered to meet new health-related requirements.

The study's implementation plan guarantees that the proposed compression sock solves some of the main problems of elderly users without undermining their therapeutic value. Thus, achieving the ultimate comfort and adjustability, the product defines a new concept in treating varicose veins among the elderly. Because of this area of focus and a strong scaling model, this initiative can improve the lives of the targeted audience worldwide.

### FUTURE TRENDS AND CHALLENGES

The hope for future developments of compression socks for elderly people with varicose veins is to incorporate technology and device individuality to improve the primary characteristics of these projects. They predicted changes in the product line owing to advanced innovation in smart textiles, including fabric sensors. These sensors can provide real-time data and information such as blood flow rate compression level and extent of user activity that can help to give the requisite therapeutically adjustable data and information such as blood flow rate, compression level, and extent of user activity. Besides, using sustainable and bio-degradable materials integrates good practices on the environment, which is now a priority in healthcare [11].

Other trends include compression socks being developed for specific purposes and requirements, such as need, size, shape, medical problems, and lifestyle. Other forms of manufacturing, such as three-dimensional (3D) knitting and printing, might enhance this personalization even more. Integrating artificial intelligence into the design and testing process throws even more light on creating more user-friendly and effective products.

However, the challenges that need to be addressed are still great. Using such materials and technologies may put forward higher production costs, so the pricing issue may arise as a crucial challenge, especially for elderly persons who cannot afford expensive products [15]. Awareness creation to ensure users employ the right techniques when utilizing these socks is also a major challenge since failure compromises their effectiveness.

Further, managing perception after using the medical compression garments is crucial to implementing the scrubs. The next challenges include providing access to technology in areas where such solutions are scarce and getting approval for innovative applications, respectively.

Implementing solutions to these issues entails continual cooperation between designers, healthcare personnel, and policymakers to guarantee that future compression socks are efficient, affordable, and convenient for everyone.

### CONCLUSION

Ultimately, the study establishes the impetus for developing improved designs, functions, and the ability to apply compression socks to elderly people with varicose veins. Chronic venous disease in which the veins swell and become blue, particularly in the elderly, constitutes a significant medical problem that needs appropriate compression treatment. However, the available compression socks face immense limitations in usability, comfort, and accessibility for the physically challenged or anyone with weak bones.

Typical problems with the development of such applications were resolved using novel methods that combine aspects of user-centered design, ethnography, and iterative prototyping. The study was accomplished to establish numerous experimental designs involving better fastening mechanisms like zippers and corsets and the usage of novel materials that include antimicrobials and effortless breathing. Prototype development and wearability analysis also provided insight into the practicability and acceptability of using these designs; these studies also indicated that the proposed designs had the potential to decrease the inferred physical pressure exerted on the wearer by compression socks. Some of these solutions were further modified through stakeholder engagement to meet user requirements.

The insights suggest that design development should be iterative, production should be increased, and ties with clinicians should be maintained to enhance availability and compliance with clinical care criteria. Considering trends that have not been explored as extensively, including smart textiles and 3D manufacturing, has potential for future developments. Cost issues and increasing awareness are two significant challenges that must be solved to expand the utilization of compression socks in elderly people and enhance corresponding therapeutic outcomes globally.

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## REFERENCES

1. Dahm, K.T., Myrhaug, H.T., Strømme, H., Fure, B. and Brurberg, K.G. (2019). Effects of preventive use of compression stockings for elderly with chronic venous insufficiency and swollen legs: a systematic review and meta-analysis. *BMC Geriatrics*, [online] 19(1), pp.1–8. doi:<https://doi.org/10.1186/s12877-019-1087-1>.
2. Katella, K. (2024). Blood Clots, Varicose Veins, and Sore Legs: Can Compression Socks Help? [online] [www.yalemedicine.org](https://www.yalemedicine.org/news/blood-clots-varicose-veins-sore-legs-compression-socks-help). Available at: <https://www.yalemedicine.org/news/blood-clots-varicose-veins-sore-legs-compression-socks-help> [Accessed 2025].
3. Lubis, M., Sutoyo, E., Azuddin, M. and Handayani, D. (2019). User Experience in Mobile Application Design: Utility Defined Context of Use. *Journal of Physics: Conference Series*, [online] 1361(1), pp.1–7. doi:<https://doi.org/10.1088/1742-6596/1361/1/012043>.
4. Silva, M., Knopp Ribeiro, D., Ribeiro de Jesus, R. and Tavares, R. (2019). Everyday life of elderly with venous insufficiency, who use elastic compression socks. *ESTIMA Brazilian Journal of Enterostomal Therapy*, [online] pp.1–7. doi:[https://doi.org/10.30886/estima.v17.736\\_IN](https://doi.org/10.30886/estima.v17.736_IN).
5. Coelho Rezende, G., O’Flynn, B. and O’Mahony, C. (2022). Smart Compression Therapy Devices for Treatment of Venous Leg Ulcers: A Review. *Advanced Healthcare Materials*, [online] 11(17), p.2200710. doi:<https://doi.org/10.1002/adhm.202200710>.
6. Dahm, K.T., Myrhaug, H.T., Strømme, H., Fure, B. and Brurberg, K.G. (2019). Effects of preventive use of compression stockings for elderly with chronic venous insufficiency and swollen legs: a systematic review and meta-analysis. *BMC Geriatrics*, [online] 19(1), pp.1–8. doi:<https://doi.org/10.1186/s12877-019-1087-1>.
7. Evans, N.S. and Ratchford, E.V. (2021). Vascular Disease Patient Information Page: Compression therapy. *Vascular Medicine*, [online] 26(3), pp.352–355. doi:<https://doi.org/10.1177/1358863x211002263>.
8. Garcia, M.-G., Roman, M.G., Davila, A. and Martin, B.J. (2021). Comparison of Physiological Effects Induced by Two Compression Stockings and Regular Socks During Prolonged Standing Work. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, [online] pp.533–695. doi:<https://doi.org/10.1177/00187208211022126>.
9. Hecht, M. (2020). Compression Therapy for Medical Conditions & Athletic Performance. [online] [www.healthline.com](https://www.healthline.com/health/what-compression-therapy-and-its-benefits-are). Available at: <https://www.healthline.com/health/what-compression-therapy-and-its-benefits-are> [Accessed 2025].
10. Jamshaid, H., Kumar Mishra, R., Ahmad, N., Nadeem, M., Muller, M. and Kolar, V. (2022). Exploration of Effects of Graduated Compression Stocking Structures on Performance Properties Using Principal Component Analysis: A Promising Method for Simultaneous Optimization of Properties. *Polymers*, [online] 14(10), p.2045. doi:<https://doi.org/10.3390/polym14102045>.

11. Kakkos, S.K., Timpilis, M., Patrinos, P., Nikolakopoulos, K.M., Papageorgopoulou, C.P., Kouri , A.K., Ntouvas, I., Papadoulas, S.I., Lampropoulos, G.C. and Tsolakis, I.A. (2018). Acute Effects of Graduated Elastic Compression Stockings in Patients with Symptomatic Varicose Veins: A Randomised Double Blind Placebo Controlled Trial. *European Journal of Vascular and Endovascular Surgery*, [online] 55(1), pp.118–125. doi:<https://doi.org/10.1016/j.ejvs.2017.10.004>.
12. Knight nee Shingler, S.L., Robertson, L. and Stewart, M. (2021). Graduated compression stockings for the initial treatment of varicose veins in people without venous ulceration. *Cochrane Database of Systematic Reviews*, [online] 2021(7), pp.1–71. doi:<https://doi.org/10.1002/14651858.cd008819.pub4>.
13. Saliba Júnior, O.A., Rollo, H.A., Saliba, O. and Sobreira, M.L. (2019). Graduated compression stockings effects on chronic venous disease signs and symptoms during pregnancy. *Phlebology: The Journal of Venous Disease*, [online] 35(1), pp.46–55. doi:<https://doi.org/10.1177/0268355519846740>.
14. SenthamilSelvan, K., Aravind, G., Pavankumar, C., Bhopate, K., Ravshan, M. and Kumar, T. (2023). Varicose Veins Treatment Using Automated Stockings. *E3S web of conferences*, [online] 399(4), p.01017. doi:<https://doi.org/10.1051/e3sconf/202339901017>.
15. Tan, M., Urbanek, T., Rabe, E., Giancesini, S., Parsi, K. and Davies, A.H. (2023). Compression therapy in the management of varicose veins. *Phlebology*, [online] 39(4), pp.276–279. doi:<https://doi.org/10.1177/02683555231222679>.
16. Xi , W., Bao, Y., Qiao, L., Xia , G. and Xiaoming, T. (2025). Parametric modeling the human calves for evaluation and design of medical compression stockings. *Computer Methods and Programs in Biomedicine*, [online] 194, p.105515. doi:<https://doi.org/10.1016/j.cmpb.2020.105515>.