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Sole Solutions: Redefining Comfort and Safety for Elderly Women with Cutting-Edge Ergonomic Footwear

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Abstract

This research aims to design ergonomic footwear catering to the comfort, safety, and well-being of elderly women by considering their different anatomical characteristics. We collected anthropometric foot measurements from 25 elderly women in Sharjah, UAE, the results showed consistent dimensions, particularly within the 95th percentile. By comparing the data with existing studies, the proposed interior shoe dimensions were validated, and ethnic differences were highlighted. Several adjustable features were recommended, including stretchable materials, removable insoles, and closure mechanisms. We propose a shoe design that integrates key components such as a low heel height, a sloped heel, a wide rigid sole, stretchable materials, and an adjustable closure. Among the most important considerations in elderly footwear design were proper fit, cushioning, breathability, slip resistance, arch support, and durability. Developing ergonomic footwear tailored to elderly women's needs based on this research paves the way for developing safe, comfortable, and well- being-promoting footwear.

Keywords
Ergonomic footwear, Elderly women, slip-resistance, Anthropometric measurement, Footwear Design.

1. Introduction
Ergonomic footwear plays a crucial role in enhancing the comfort and safety of individuals, particularly the elderly population. As we age, our feet undergo various structural changes, affecting our overall well-being and quality of life. There is a pressing need to address these issues and create footwear that caters specifically to the needs of elderly women. Elderly women represent a significant portion of the global population, and they often face numerous challenges related to mobility, balance, and musculoskeletal health. The feet are critical components of mobility and body support, and they are susceptible to age-related changes, including reduced elasticity, muscle strength, and joint flexibility. Furthermore, older women may experience foot conditions such as osteoarthritis, bunions, hammertoes, and other issues that can be escalated by improper footwear. Ergonomics presents an unmet challenge in developing specialized footwear that enhances elderly women's safety and comfort. As individuals age, they experience a range of anatomical and physiological changes, and the feet, being the foundation of mobility, are significantly affected. Elderly women face heightened vulnerability to discomfort, instability, and an increased risk of falls, injuries, and pain due to the unsuitability or poor design of their footwear. These issues have a significant impact on their overall quality of life and well-being. This research project aims to address this issue by focusing on the creation of ergonomically optimized footwear. The primary objective is to design footwear that not only accounts for the unique anatomical characteristics of elderly women's feet but also prioritizes their safety and comfort. The methodology involves the collection of anthropometric data from

25 elderly women, allowing for a precise assessment of the dimensions and characteristics of their feet to contribute to the advancement of ergonomically safe and comfortable footwear, highlighting a significant concern affecting the well-being of an aging demographic and enhancing the lives of elderly women through evidence-based ergonomic design solutions.

1.1 Objectives

The choice of footwear is a pivotal aspect of reducing these age-related problems. Ergonomically designed footwear can help reduce the risk of falls, relieve discomfort, and enhance overall foot health, ultimately minimizing the risk of these disorders. Therefore, addressing the ergonomic needs of elderly women through optimized footwear design is a compelling research area. Therefore, the main objective of this research is:

- To gather anthropometric data from 25 elderly women to understand the unique characteristics of their feet.
- To compare our collected data with existing research findings and measurements, providing a comprehensive analysis of the specific needs of elderly women.
- To design and propose ergonomic footwear tailored to the requirements identified in our study.
- To provide recommendations for well-designed footwear that promotes comfort, safety, and overall well-being.

2. Literature Review

Ergonomic footwear has gained significant attention recently due to its potential to enhance foot health, comfort, and overall well-being. It considers the natural shape and movement of the foot, providing appropriate arch support, cushioning, and stability. Studies have shown that ergonomic footwear can improve gait patterns, increase shock absorption, and reduce excessive pressure on specific areas of the foot (Ochsmann, et al., 2016).

Comfort is a key consideration in ergonomic footwear design, as it significantly affects user experience and satisfaction (Menz and Bonanno, 2021). Research has examined different comfort-related aspects of ergonomic footwear, such as cushioning, breathability, and slip resistance characteristics. As they can reduce foot discomfort, fatigue, and the risk of developing issues such as blisters, calluses, or other foot diseases. Comfort was tested in a study by Hurst, et al. (2017) through various aspects including heel cushioning, forefoot cushioning, side-to-side support, as well as the dimensions of the shoe.

The field of ergonomic footwear is constantly evolving, with ongoing innovations and advancements. Recent developments include the integration of technologies such as 3D foot scanning, slip resistance machines, and pressure mapping to customize footwear based on individual foot profiles (Menz, et al., 2014; Sarghie, et al., 2016). Additionally, there is a growing interest in using sustainable and eco-friendly materials in the manufacturing of ergonomic footwear (Fernandes, 2019). An area that has not been researched thoroughly is the neutral positions of the feet, despite its impact on around a quarter of bones in the human body and hence its significance to ergonomic footwear (Witana, 2008). Future research in this field can further explore the long-term effects of ergonomic footwear, optimize design parameters, and investigate the influence of ergonomic footwear on specific activities or populations.

3. Methodology

To ascertain the optimal footwear for elderly women, a comprehensive methodology was implemented. The study involved the assembly of a sample group consisting of elderly women, and precise foot measurements were obtained, encompassing parameters such as foot length, heel length, ball length, foot width, heel width, ball width, ball girth, instep girth, and instep height. Utilizing accurate measurement tools, the collected data was then compared to established findings in a relevant research paper, enhancing the reliability and validity of our dataset. Subsequently, Using the knowledge gained from both the measurements we took from our sample and information we found in existing research papers., we proceeded to design ergonomically friendly footwear made specifically for elderly women. This thorough approach aimed to ensure the universality of the footwear, accommodating a broad spectrum of foot dimensions within the elderly female population.

4. Data Collection

Our research method to study the ergonomic shoe requirements of elderly women in Sharjah, United Arab Emirates includes a quantitative data collection method to thoroughly study the ergonomic shoe requirements of elderly women. Our sample includes 25 elderly women whose age is 50 years or older. The data collected consists of anthropometric data including various foot measurements as shown in Table 1, that were collected through precise measurements. These measurements are analyzed to determine the best shoe designs and patterns related to shoe comfort and safety for old women. It is important to recognize that this study has limitations, including possible reporting bias, variation in the sample population, and a sample size limited to 25 participants.

4.1 Anthropometric Data

The foot anthropometric data of a sample of 25 elderly women in Sharjah, UAE was collected and is summarized in Table 1. The data includes the foot dimensions shown in Figure 1 that are relevant to shoe design.

Figure 1 below displays the measurements of the feet that were collected for this study.

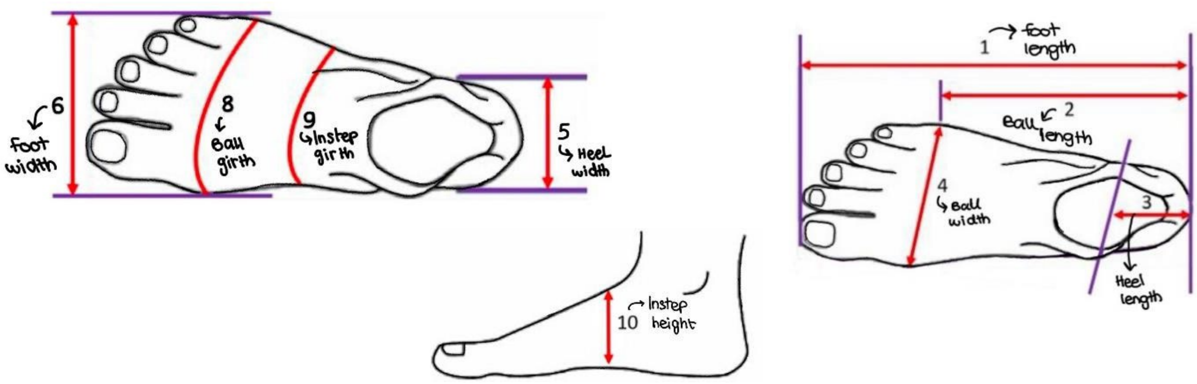


Figure 1. Dimensions of a Foot

(Pictures adapted from the work of Li et al. (2023))

Table 1. Our Measurements of 25 elderly women's feet.

	A	B	C	D	E	F	G	H	I
1	Foot length	Heel length	Ball length	Foot width	Ball width	Heel width	Ball girth	Instep girth	Instep height
2	219.8	54.5	161.3	90.9	91.7	61.9	150.7	200.7	59.6
3	220.5	56.7	163.2	89.6	92.5	62.7	151.9	201.9	58.9
4	219.6	53.9	159.7	87.3	89.9	64.4	149.9	199.6	57.8
5	220.1	51.3	163.5	90.9	90.6	63.2	150.7	198.7	60.1
6	220.3	56.2	162.6	92.1	90.9	62.9	151.6	198.5	56.9
7	220	57.1	164.5	90.2	89.6	63.7	150.3	196.7	55.5
8	219.9	52.1	163.4	89.4	90.7	60.9	149.7	194.6	59.1
9	220.4	52.5	164.2	91.6	93.4	61.7	150.6	197.3	57.3
10	220.2	53.8	163.9	89.1	94.2	64.1	151.6	201.9	56
11	221.5	54.7	165.6	87.5	92.5	63.7	152.7	195.6	59.7
12	219.7	51.9	167.3	88.5	93.1	62.9	152.1	197.6	58.2
13	220.5	55.6	166.9	87.5	94	63.1	153.1	202.6	60.4
14	220.8	52.6	163.5	90	91.9	64	150.5	196.5	56.8
15	219.3	53.8	165.3	90.9	88.9	61.9	149.8	198.6	55.7
16	218.9	51.3	167.8	91.5	92.7	59.8	146.8	199.5	54.9
17	221.1	53.7	168.1	89.1	93.2	60.9	153.1	198.5	62.3
18	220.4	54.5	166.6	89.4	94.1	61.7	151.3	195.9	60.7
19	220.6	56.1	167.4	90.6	91.4	63.2	153.1	197.4	59.7
20	218.8	50.9	161.9	91.5	89.9	59.6	147.9	196.9	56.4
21	219.9	54.8	164.3	90.3	89.7	61.5	149.6	199.1	55.3
22	220.1	56.3	165.3	91.2	90.6	61.9	152.1	203.1	59.1
23	220.3	55.9	163.9	90.8	93.9	63.2	150.9	197.4	58.5
24	219.8	51.6	165.8	87.5	92.8	63.7	150.4	195.3	57.9
25	220.1	52.5	168.4	88.5	94.1	62.5	152.3	200.6	59.6
26	219.7	50.9	162.8	88.7	90.8	61.2	150.9	200.1	56.9
27	AVG:								
28	220.092	53.808	164.688	89.784	91.884	62.412	150.944	198.584	58.132
29	5th percentile:								
30	218.98	50.98	161.42	87.5	89.62	60.02	148.24	195.36	55.34
31	50th percentile:								
32	220.1	53.8	164.3	90	91.9	62.7	150.9	198.5	58.2
33	95th percentile:								
34	221.055	56.285	168.055	91.585	94.1	64.085	153.1	202.495	60.655

Table 2 shows the foot anthropometric data of a sample of 41 young women and 41 old women, obtained from the study conducted by Li, et al. (2023). This data will be compared to the data collected for this study to establish its validity as well as gain better insight into any patterns of women's foot anthropometry.

Table 2. Anthropometric measurements of old women based on research paper. (Li et al., 2023)

	Young women ($n = 41$)	Old women ($n = 41$)	Young women (value normalized to foot length)	Old women (value normalized to foot length)
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Foot length (FL) (mm)	224.88 (11.44)	229.19 (10.80)	N/A	N/A
Heel length (HL) (mm)	46.09 (6.17)	59.69 (4.74)*	0.20 (0.02)	0.26 (0.02)*
Ball length (BL) (mm)	165.78 (8.89)	169.96 (7.93)*	0.74 (0.02)	0.74 (0.01)
Foot width (FW) (mm)	89.06 (4.67)	92.15 (5.26)*	0.40 (0.02)	0.40 (0.02)
Ball width (BW) (mm)	90.92 (4.36)	94.42 (4.96)*	0.40 (0.02)	0.41 (0.02)
Heel width (HW) (mm)	55.76 (4.71)	64.49 (5.77)*	0.25 (0.02)	0.28 (0.02)*
Ball girth (BG) (mm)	143.89 (7.82)	152.74 (10.92)*	0.64 (0.04)	0.67 (0.04)*
Instep girth (IG) (mm)	191.16 (10.73)	201.89 (13.67)*	0.85 (0.05)	0.88 (0.06)*
Instep height (IH) (mm)	57.36 (4.13)	60.20 (5.01)*	0.26 (0.02)	0.26 (0.02)
Degree of hallux valgus deformity (HVD) (°)	8.22 (5.82)	13.26 (8.96)*	N/A	N/A
Valgus index (VI) (%)	−5.94 (6.23)	−1.42 (7.39)*	N/A	N/A

SD: standard error; N/A: not applicable.
*Significant difference at $p < 0.05$ (two-tailed).

5. Results and Discussion

An examination of the older women's foot measurements that we took showed a well-organized dataset with proportionate dimensions. The range of foot lengths is rather limited, ranging from 218.8 to 221.5, with an average of 220.1 and a standard deviation of approximately 0.61. This constancy helps in the creation of shoes that fit older women comfortably by catering to a precise range of foot sizes. There is some variance in the heel lengths; they range from 50.9 to 57.1. This variety makes it possible to accommodate various heel sizes, which is essential for guaranteeing older people's comfort and stability in their footwear. Ball lengths range from 159.7 to 168.4, offering a flexible range that can accommodate different types of shoes. Because of this diversity, shoes that cater to various tastes and foot shapes can be made.

The specifications for both foot and ball width are consistent, which adds to the feet's overall stability. This uniformity helps to improve the fit and comfort of shoes. Additionally, heel width has a consistent range, suggesting considerations for support and stability. Maintaining a constant heel width is crucial for balanced and appropriate weight distribution. Moderate variances in ball girth, instep girth, and instep height provide shoe designers options when creating shoes for a range of girths and instep heights. Because of this variation, shoes may be designed to accommodate a wide range of foot shapes and preferences. These measurements show a balanced and consistent dataset, giving designers the freedom to make shoes that satisfy the various requirements and tastes of senior citizens.

To have an idea of the validity of our results, we searched for anthropometric foot measurement data and compared our results to theirs. The data we found was obtained through a study conducted by Li, et al. (2023) in Hong Kong. Based on a comparison of our data and the research paper data, we can say that there is consistency in the patterns and trends observed in both data sets which reinforces the validity of the measurements collected in this study. Therefore, we can ensure that the dimensions used for the shoe design are reliable as the measurements they were created from are valid. Noticeably, our measurements were consistently smaller than those obtained in their study, which is likely due to the relationship between ethnic differences in anthropometric measurements (Monye, et al., 2023). This is supported by the study conducted by Hajaghazadeh et al. (2018), where the anthropometric data of Middle Eastern individuals were compared to that of Asian individuals. The study found that many foot anthropometry measurements such as foot width, foot length, and ball grith of Hong Kong Chinese females were larger than those of Middle Eastern females. This sheds light on the target user of our shoe design, which is going to be targeted mainly at old women living in the Middle East. This is the geographical area represented by the anthropometric data we collected.

Percentiles

After calculating the 5^{th},$50^{th,}$ and 95^{th} percentiles It is advisable to take the 95th percentile (or 95th percentile value) into consideration when designing footwear, particularly for elderly adults. The 95th percentile is the value that 95% of the population falls below. By designing this percentile, the footwear is guaranteed to be comfortable and well-fitting for most people in the target demographic. This is especially significant looking at the fact that many individuals of the elderly population suffer from foot issues such as bunions, corns, edema, and calluses where it is preferred to have a slightly enlarged shoe size to provide some extra space that is needed to accommodate the feet in these cases.

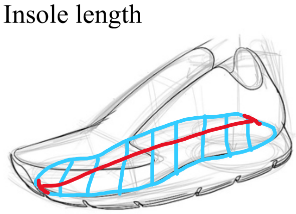
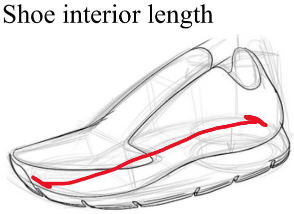
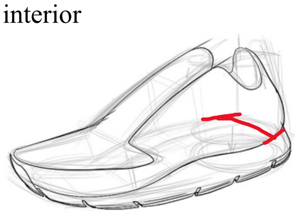
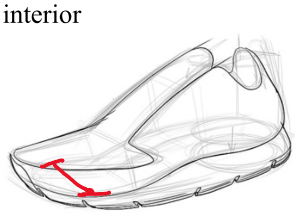
It's important to consider a range of sizes and offer options that appeal to a broad spectrum of foot dimensions, especially for older women who may suffer changes in foot size and shape owing to factors like aging, arthritis, or other health concerns. In addition, considering elements like cushioning, ease of donning and taking off the footwear, and arch support becomes crucial when catering to the unique requirements of senior citizens. However, it’s crucial to remember that everyone is unique, and that people have different tastes in footwear. Thus, getting input from the intended audience and carrying out extensive testing can improve the design process even further and guarantee that the footwear satisfies the varied needs of senior citizens. Working with podiatrists or other specialists in the field of senior foot care can yield important insights for creating shoes that support stability, comfort, and general foot health in this population.

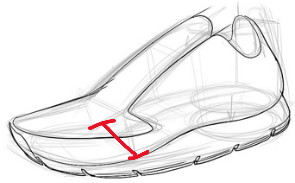
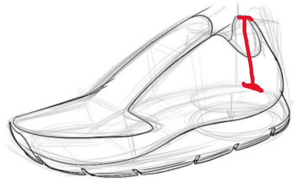
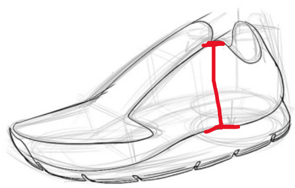
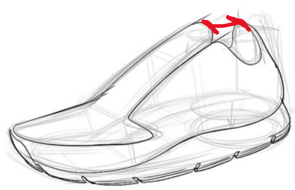
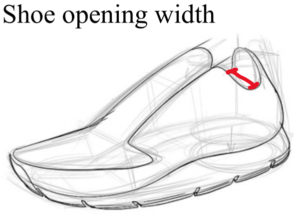
Dimensions of Shoe Design

In this section, the dimensions of the shoe design interior are created using the measurements obtained in the data collection phase as shown in Table 3. We focus on shoe interior rather than exterior dimensions because they depend on the anthropometric measurements collected. While exterior dimensions are a slight increase of the interior ones depending on the desired thickness of the shoe design and the chosen materials. As mentioned in the previous section, the 95th percentile of the measurements is used to ensure the design fits as many elderly women as possible. In addition to accommodating the foot sizes of the elderly population who usually suffer from foot conditions and deformities that necessitate more space inside the shoe. The relevant foot anthropometry measurement was used to create the dimension of each part of the shoe, as shown in Table 3. The first column of the table displays the part of the shoe that is being considered. The second column shows how the dimension of this part of the design was created, including the specific foot anthropometry data that was used. All data on foot anthropometry used in Table 3 was obtained from the data collected for our study, shown in Table 1. The data used for the creation of the shoe design dimensions are that of the 95th percentile, due to its ability to encompass the largest possible number of individuals in the studied population. The calculation done to create the dimension of the corresponding part of the shoe design is also shown in the second column of the table. The third column explains the reason behind creating the dimension the way it has been done.

Table 3 displays the chosen dimensions of the shoe design based on the anthropometric data collected (shown in Table 1) and justifies the reasoning behind the chosen dimensions.

Table 3. Analysis of Anthropometric Data.

	Shoe part	**Dimension**	**Justification**
1.	Insole length 	Feet length + 10 mm + 15 mm 221.055 + 10 + 15 = **246.055 mm**	Length of the insole should be at least one centimeter longer than the foot length so that the feet is not stuck to the shoe interior for comfortable wear. Moreover, there should be some empty room at the toe box between the longest toe and shoe forefront interior.
2.	Shoe interior length 	Same as insole length **246.055 mm**	If the shoe was longer in its interior than the insole, the insole will keep moving inside the shoe, which will be uncomfortable to wear. If it was shorter, the insole will not be well-laid on the shoe floor, it will move upwards at the beginning and end of the shoe, which will restrict the space available for the toes and heels.
3.	Width of rear part of shoe interior 	Heel width + 5 mm 64.085 + 5 = **69.085 mm**	Width of the rear side of the shoe interior should be slightly wider than the heel width to allow for a comfortable, snug fit in terms of width.
4.	Width of front part of shoe interior 	Foot width + 10 mm 91.585 + 10 = **101.585 mm**	Slightly wider than feet width to for a comfortable fit. Some extra room is provided for the toes in order to avoid a tight toe box which causes pain and may result in calluses or soreness.
5.	Width of middle part of shoe interior	Ball width + 10 mm 94.10 + 10 = **104.10 mm**	Slightly wider than the ball girth to allow for a comfortable fit, with the same amount of extra space as that in the toe box.

			
6.	Collar height 	Instep height + 5mm 60.655 + 5 = **65.655 mm**	Should be roughly the same height as the instep. 5mm increase is provided as a higher collar enhances balance.
7.	Height of instep area of the shoe interior 	Instep height **60.655 mm**	Equal to instep height to fit snuggly and avoid having the foot move up and down inside the shoe while walking.
8.	Shoe opening length 	(Heel length x 2) + 10mm (56.285x2) + 10 = **122.57 mm**	This length should be roughly equal to the ankle length. Since this measurement was not taken, it is approximated as double the heel length. 10 mm increase is added to aid in putting the shoe on and taking it off rather than struggling due to an exact fit.
9.	Shoe opening width 	Heel width + 10 mm 64.085 + 10 = **74.085 mm**	Roughly equal to heel width. 10mm increase is added to provide more space to ease putting the shoe on and taking it off.

The original image used in the above table was created by Nugent, Spencer.

Adjustability of shoes

In shoe sizing systems, different shoe sizes are generally created according to the length of the feet. Other dimensions should be considered as well such as the foot width in shoe sizing. Such dimensions are not always prioritized in shoe manufacturing as it would result in very precise shoe sizes. While this is more user-friendly, it would be difficult for shops to order quantities of each specific shoe size. Hence, shoe designers resort to other means of ensuring the shoe size is properly fitting for everyone. This is done by incorporating adjustable features so the shoe can accommodate everyone. To better understand the adjustable features incorporated in different shoe designs, we visited several shoe shops and had a look at the designs available. We noticed the below adjustable features in the shoes available in the market:

Stretchable material: shoe manufacturers use stretchable material for the shoe, which can help comfortably accommodate wider feet. Edema (swelling) and toe deformities are common among the elderly. Shoes made of materials such as Lycra or Spandex can stretch to fit comfortably (Roy, et al., 2023). This is especially useful in case the user has such foot conditions. Hence, the elderly population usually prefers shoes made of stretchable material.

Removeable inner sole: some shoe designs offer a removable inner sole so that the shoe buyer can replace them with their preferred insole such as one that provides better cushioning or increased support for the arch. This feature enables the user to customize their shoes to improve the fit. Having better control over the shoe design this way makes users more likely to accept and purchase the design. This is because they are reassured that they can do something to improve their fitness in case their needs change in the future due to any foot conditions they may get. It is also very practical for shoe manufacturers to create this design feature as many shoes in the market designed for the elderly incorporate this feature.

Shoe-closing mechanism: the shoes we examined had various types of closing mechanisms such as velcro straps, standard laces, elastic laces, and zippers. Other options are also available such as shoe-tightening mechanisms and even magnetic closures. All that helps improve the design fit for the individual wearing the shoe. For example, in case an individual's feet are narrow, the shoe will be a bit loose, so the closing mechanisms mentioned can be used to tighten the fit. Shoe-tightening mechanisms act as a lock for shoelaces to ensure they do not loosen up. This is important to prevent tripping and accidents (Bansal, et al., 2019). Elastic laces can stretch and can consequently better accommodate wider feet. Using magnetic shoe closures is also useful as they securely snap according to the fit required by the shoe user. Shoe-closing mechanisms should be easy to use and effective (Jellema, et al., 2019). Each user's specific needs will determine what type of closing mechanism they find effective. Therefore, shoe manufacturers should consider the specific type of elderly user whose shoe design is targeted to choose the most suitable closing mechanism. From the manufacturing viewpoint, laces, zippers, and velcro straps are the most practical, simple, and cost-effective. Through mass production, shoe-tightening mechanisms can be cost-effective and is a feasible option for manufacturers as they do not require labor of high skill level (Bansal, et al., 2019). Other mechanisms like magnetic closures and automatic closing mechanisms are less widely adopted in the market.

Creating serval widths of a shoe design: in case the above-mentioned adjustable features are not sufficient or effective, shoe designers then create several widths of each shoe length. Here, other features can also be incorporated to enhance this design like using inner soles that adjust the inner part of the shoe. A shoe inner sole that restricts or expands the inner part of the shoe should also be used according to the individual's feet width state to enhance fit. While this design feature could receive wide user acceptance by providing more sizes that allow for better and more comfortable fit, it is impractical to manufacture several shoe widths of the same length. This is because it is more costly and more difficult to forecast the number of units required for each shoe width. An alternative is to produce a different size in terms of shoe width upon request from the customers. This is ideal in terms of shoe production, but such customization will be more expensive for the customer (Nácher, et al., 2006).

5.1 Suggested Design:

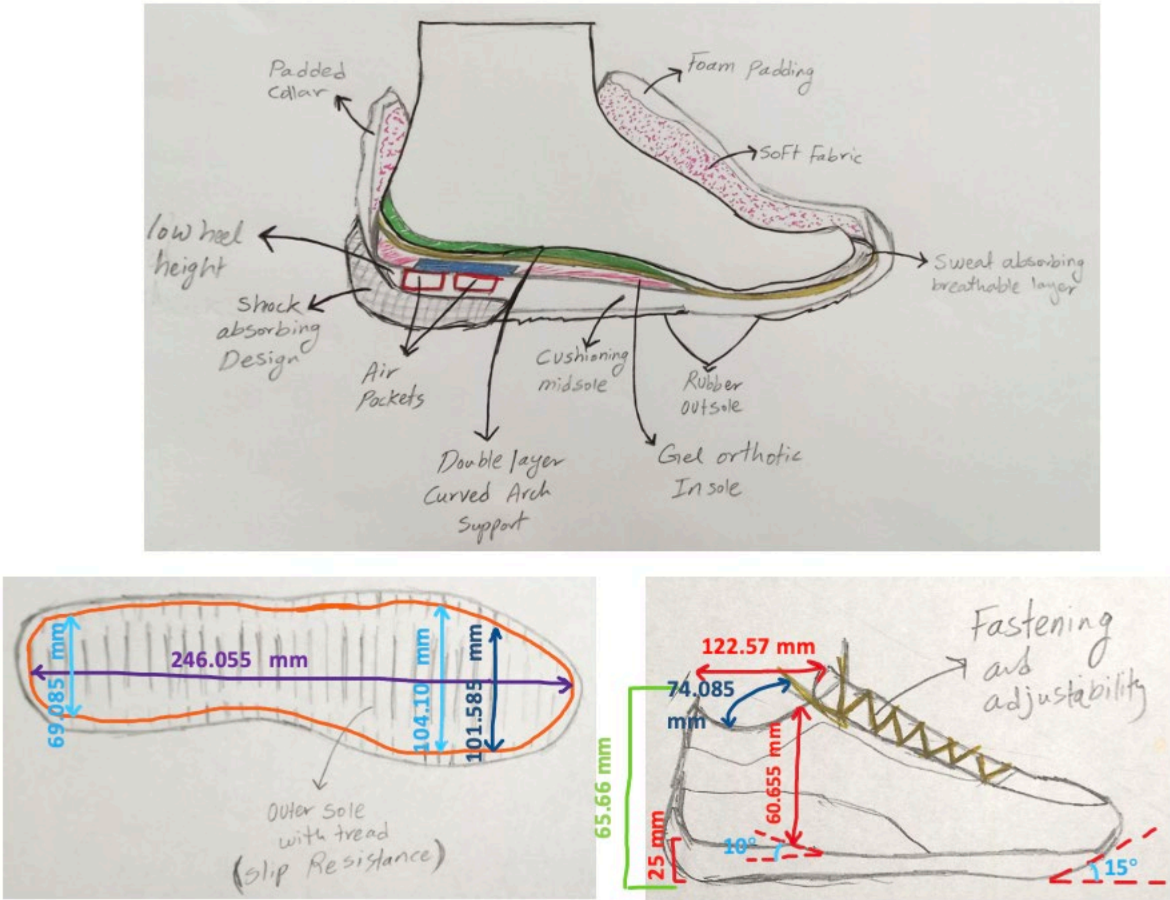


Figure 2. Suggested Footwear Design

The shoe design created in this study is displayed in Figure 2. It includes annotations for the elements of the shoe design as well as the important dimensions of the shoe design.

Table 4 discusses the characteristics or features considered in the shoe design created in the above section.

Table 4. Characteristics of the Suggested Footwear Design

Cushioning and Shock Absorption	Integrates ample cushioning in the insole to provide a soft and supportive feel. Includes shock-absorbing features to reduce the impact on joints and minimize discomfort.
Breathability	Chooses materials that allow for proper ventilation to keep feet cool and reduce the risk of moisture-related issues.
Adjustability	Considers designs with adjustable closures, such as Velcro straps or laces to accommodate variations in foot swelling and ensure a secure fit.
Lightweight Construction	considers lightweight materials to reduce the overall weight of the shoe, making it easier for elderly women to walk and maintain mobility.

Non-Slip Soles	Incorporates non-slip or anti-skid soles to enhance traction and prevent slips, especially on different surfaces.
Arch Support	Incorporates proper arch support to alleviate strain on the arches and provides additional comfort during prolonged periods of standing or walking.
Durability	Uses durable materials to ensure the longevity of the shoes, offering good value for the investment.

A well-designed shoe is characterized by certain rules of thumb. Firstly, the heel should not be too high as this increases the pressure on the plantar forefoot and causes heel pain. It also increases the compression forces on the knee and increases the rotation of the hips which creates instability that increases the risk of falling. When wearing shoes with short heels, the walking pace is much better than shoes with long heels. Hence, the heel height should not exceed 2.5cm. The width of the heel is also an important factor, where the heel height-to-width ratio should be considered as it indicates the critical tipping angle as a measure of lateral stability. (Jellema, et al., 2019).

The shoe heel should be positioned at a certain slope to create a 'bevel' as it aids in creating grip which decreases the chance of slippage. The guideline is the use of a sloping heel of 10 degrees. The front of the shoes should also be made at an angle to aid during the walking where the bent foot is brought back to the ground, as it improves toe clearance. The shoe front should be at a 'rocker angle' of 10-15°. (Jellema, et al., 2019).

As for the shoe sole, it is preferred to have a wide enough sole as it improves support and lateral stability which reduces the risk of falling. The sole rigidity is also an important factor. Despite the belief that soft soles are more comfortable, they provide less balance. Hard soles are the better option as they provide better postural stability. The density of the soles is optimum at a medium level. The material used to create the sole should be a less resilient one that holds compressed thickness which is the most optimal choice in terms of comfort and balance. Inner soles are important as they help align the foot joints which help maintain balance, as well as distribute the plantar pressure more evenly. Balance is enhanced with flat inner soles that have a certain texture. It is suggested to use inner soles of approximately 10mm thickness created using such a material as plastozote which can improve postural stability. Inner soles made of materials like silicon are good for walking long distances. It is preferred to have a border or ridge on the inner sole outline as it aids lateral stability through movements. (Jellema, et al., 2019). The heel collar should be high as it provides better balance while standing and walking than a low heel collar. A high-heel collar also enhances leaning range, body displacement while standing still, as well as coordinated balance. (Jellema, et al., 2019).

The length of the ball is a significant input to shoe design measurements as it identifies the flex angle of the ball of the foot. To facilitate maximum foot flexion, this angle should be close to the shoe's flex angle. In some studies, it was shown that older women have a longer ball length. This should be reflected in the shoe design, where the width of the shoe design should increase for the ball head at a farther location than that in younger women's shoe designs. (Mickle, et al., 2010).

It is also important to consider the fact that most senior people face footwear comfort issues due to conditions they suffer from such as foot deformities. These conditions alter the footwear design they should opt for. For instance, hallux valgus is a prevalent foot deformity among the elderly. Therefore, shoe design could be considered to provide sufficient space for the excess grith of the forefeet by matching the shoe's flex angle to the feet's flex angle. Another deformity that exists widely among senior people is the deformity of the lower toes. Individuals suffering from it show longer first and fifth toes, ball length and shorter ball height, navicular height and instep height. To accommodate the longer toes, more depth should be allocated in the toe box design. This will help curb callus formation which is caused by tightening of the toes in the toe box and consequently their rubbing against the top of the shoe. The condition flatfoot is also more common among the older population. Some characteristics of the suffering of this condition are the shorter ball height, instep height, navicular height, and a wider heel bone. People with this condition should get shoes with rigid heel counters for more support. Feet swelling is also common among the elderly. People with this condition usually resort to several options like wearing unstructured shoes to accommodate the increased foot size or squeezing their feet into a small shoe size. Those are not ideal options as the first may be unsafe for the elderly and the latter may result in tripping. In this case, it is recommended to buy shoes with specific materials capable of stretching when the feet exhibit swelling. (Mickle, et al., 2010). Hence, there are many considerations when designing a perfect shoe. The ideal shoe fits well, is comfortable to wear, and is safe to walk in. Some elements of a well-designed shoe include proper fit of the toe-box, a sloping heel with a low heel height, a wide enough heel, a rigid inner sole, a rigid middle sole, a tread-like structure of the outer sole, rigid, close-fitting heel counter, an easy-to-use closing for the shoe such as shoelaces (Jellema, et al., 2019).

Slip Resistance Characteristics

Slipping accidents can be prevented by ensuring that footwear has soles and heels with high slip-resistance characteristics. The use of suitable combinations of footwear and underfoot surfaces can provide adequate friction to prevent slipping accidents. It's also important to consider surface textures, as they play a significant role in the friction mechanism between shoes and floor surfaces. Regular maintenance and replacement of footwear to ensure optimal slip resistance performance is also recommended (Kim et al., 2001). Kim et al.'s findings reveal that variations in the geometry of shoe heels significantly impact the wear of the shoe heel surface, with the topography of the counterface emerging as the primary factor influencing wear in various shoe-floor combinations. Each shoe surface exhibited distinct wear patterns, and the sliding interfaces displayed prevalent plastic asperity contacts across the entire contact area. The study identified that progressive wear is more severe than anticipated, manifesting in the early stages of sliding. Furthermore, the research developed hypotheses concerning wear progression and surface alterations, specifically focusing on analyzing the slip resistance characteristics of shoe heels. The relationship between surface alteration processes and surface roughness parameters was explored experimentally, involving three different shoes in the investigation. The criteria that should be met for a shoe to be well-designed are summarized in Table 5.

Table 5. Characteristics of a Well-Designed Shoe

Heel Design	• Keep heel height below 2.5cm for comfort and prevent forefoot pressure. • Use a 10-degree sloped heel for improved grip and stability.
Slip Resistance Characteristics	• Ensure footwear features high slip-resistant soles and heels. • Use suitable footwear-surface combinations for adequate friction, preventing slips. • Consider textures influencing the friction mechanism between shoes and floor surfaces. • Emphasize regular upkeep and timely replacement for optimal slip resistance.
Front and Sole Design	• Design the front with a 10-15 degrees rocker angle for toe clearance. • Consider a wide, rigid sole to enhance support and stability. • Include 10mm thick inner soles made of materials like plastozote for joint alignment and even pressure distribution.
Heel Collar and Ball Length	• Design a high-heel collar for improved balance. • Adjust shoe width for variations in ball length, especially in the elderly.
Special Considerations	• Accommodate common foot deformities like hallux valgus with sufficient space. • For flat feet, include rigid heel counters for support.
Foot Swelling and Overall Design	• Address foot swelling with stretchable materials. • Ensure a proper toe box fit, easy-to-use closures like shoelaces, and elements for stability.

6. Conclusion

In conclusion, this research project addresses the crucial need for ergonomically optimized footwear for elderly women, aiming to enhance comfort, safety, and overall well-being. The study collected anthropometric data from elderly women in Sharjah, UAE, emphasizing the 95th percentile in designing footwear for optimal comfort. The study's results demonstrated consistency and validity, confirming the importance of this study. Throughout the study, we prioritized ethical considerations for the elderly participants. A strong focus on protecting privacy was placed on obtaining explicit permission and informed consent before collecting anthropometric data. We created an environment that respects participants' well-being during measurements by prioritizing their comfort. After analyzing the anthropometric measurements obtained, a footwear design was proposed. It highlights key design considerations, including heel height, slope, and width, as well as the importance of a wide and rigid sole. Adjustability features such as stretchable materials and various closing mechanisms were explored to fit individual preferences and foot conditions. Footwear's slip-resistance characteristics were emphasized as well, highlighting the importance of high slip-resistant soles and regular maintenance to avoid slipping accidents. The findings of this study offer valuable insights and practical recommendations for developing ergonomic footwear for elderly women. By combining anthropometric data, design considerations, and adjustability features, the suggested footwear aims to enhance the daily lives of elderly women. These findings can be further developed to improve ergonomic footwear for diverse populations and specific conditions in the future. To be more specific, it would be useful for future studies to test whether users of the chosen demographic would want to buy such a shoe as the one designed in this study. In addition, the shoe design developed in this study incorporated design features that would make the shoe fit comfortably for elderly women with different foot conditions. Future studies could build upon the findings of this study perhaps by researching the dimensions and design features preferred by groups of elderly women who are facing different foot conditions. For example, a shoe design targeted specifically for elderly women with swollen feet, and another design for elderly women with arthritis could be created. This will ensure meeting the needs of the individuals facing a specific foot condition better. Future studies could also research the dimensions and features most suitable for the elderly male population. Lastly, it would be useful if shoe manufacturers could take into consideration the design features established by this study and any future studies in developing their future shoe products to better meet the needs of the elderly population.

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Fatma Al Shamsi is an undergraduate student currently studying Industrial Engineering and Engineering Management at the University of Sharjah. She earned the Full International Baccalaureate Diploma upon graduating from the prestigious IB curriculum. Fatma is committed to a well-rounded education, constantly striving to grow personally and professionally, improve her skills, and engage in extracurricular activities and community service. This has been the driving force behind her participation in several programs that were truly transformational experiences, including Model United Nations, Estedad National Ambassadors Program, and the Emirati Future Leadership Program. With a strong foundation in academics and a diverse skill set, Fatma aspires to complete her higher education and create a lasting impact in her field.

Mariam Elghobashi is a junior undergraduate student at the University of Sharjah, studying Industrial Engineering and Engineering Management. She graduated from a distinguished British curriculum international school, and so sat both Cambridge and Oxford exams and achieved outstanding results. Beyond the academic corridors, Mariam is known for her active engagement in various volunteering initiatives. Eager to evolve her social skills, she passionately contributes her time and efforts across diverse areas, including social causes, educational endeavors, and entertainment initiatives. Mariam's commitment to both academic excellence and community service exemplifies her holistic approach to personal and professional development, making her a dynamic presence within the university community.