Development and fitting evaluation of a new method for preparing women's pants patterns by using direct body measurements

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ABSTRACT – REZUMAT

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Clothing is an integral part of human life. Clothing fit is one of the important, critical, complex, and dynamic factors considered by users to evaluate the garment quality and to make purchasing decisions. Therefore, one of the most important stages in garment manufacturing is the accurate preparation of the garment pattern. This study aims to examine a system proposed as an alternative to the most commonly used pattern-making methods globally, introduce it to industry, and contribute to its development. The patterns are prepared based on individual body measurements. In this study, women's basic pants were examined in practice. The fit of the clothing patterns made in this study was analysed using CLO 3D software. First, virtual avatars were created to simulate the wearers of the pants; then, these avatars were made to perform not only static poses but also 5 different dynamic movements (walking, running, sitting, climbing stairs, and kneeling) in order to evaluate the patterns. The results of the study indicate that this pattern system is brief, practical, and easily comprehensible by everyone, and also yields successful outcomes in terms of clothing fit.

Keywords: *clothing fitting, pattern design, women's pants, virtual try-on, dynamic fit*

Elaborarea și evaluarea adecvării unei noi metode de realizare a tiparelor pentru pantaloni de damă pe baza măsurătorilor directe ale corpului

Îmbrăcămintea reprezintă o parte integrantă a vieții umane. Corespondența îmbrăcămintei este unul dintre factorii importanți, critici, complecși și dinamici luați în considerare de utilizatori pentru a evalua calitatea articolului vestimentar și pentru a lua decizii de cumpărare. Prin urmare, una dintre cele mai importante etape în procesul de fabricație a articolelor vestimentare este proiectarea precisă a tiparului. Prezentul studiu își propune să examineze un sistem propus ca alternativă la metodele de realizare a tiparelor cele mai utilizate la nivel global, cu scopul de a le introduce în industrie și de a contribui la dezvoltarea acesteia. Tiparele sunt proiectate pe baza măsurătorilor corporale individuale. În cadrul acestui studiu, au fost analizați în practică pantalonii clasici pentru femei. Corespondența tiparelor realizate în cadrul acestui studiu a fost analizată cu ajutorul software-ului CLO 3D. Mai întâi, au fost create avatare virtuale pentru a simula purtătorii pantalonilor; apoi, aceste avatare au fost programate să execute nu doar poziții statice, ci și 5 mișcări dinamice diferite (mers, alergare, așezare, urcarea scărilor și îngenunchere) pentru a evalua tiparele. Rezultatele studiului indică faptul că acest sistem de tipare este concis, practic și ușor de înțeles de către oricine, oferind totodată rezultate în ceea ce privește corespondența articolelor vestimentare.

Cuvinte-cheie: *corespondența articolelor vestimentare, proiectarea tiparelor, pantaloni de damă, probare virtuală, ajustare dinamică*

INTRODUCTION

Importance of clothing fit

Clothing is an integral part of human life. Clothing comfort is when a person is anatomically, physically and/or mechanically, and psychologically in harmony with the material [1–3].

There is a mutual interaction amongst the human body, microclimate, and garment. While people cannot modify the characteristics of their environment and bodily features, garments are the only factor they can modify [4].

The garment's ability to adapt to body movements, to allow for free motion, to avoid restricting mobility, to be lightweight, to be fashionable, to appeal to the wearer's five senses for a feeling of comfort, and to enhance self-confidence through social approval refer to the characteristics of clothing fit.

Research on this topic is significant in terms of improving the living standards of humans.

Clothing fit is one of the important, critical, complex, and dynamic factors considered by users to evaluate the garment quality and to make purchasing decisions [5–16].

In order to meet consumers' demand for clothing fit, manufacturers and researchers are working with different garment patterns, different body types, and different size tables.

Importance of pattern design

In the light of the literature, it is understood that the concept of clothing fit is not only critical to clothing

comfort but also multidimensional and complex. One of these dimensions is the pattern-making stage.

People expect to move freely within a garment. Even though all comfort parameters related to the garment are fulfilled, if the size of the garment is not fit for purpose, either freedom of movement will be restricted, or seam ruptures will occur due to the person's body movements. In other words, these forces that emerge with movements and impact the garment can become intense enough to tear it, depending on the type of motion and the cut of the garment. These issues, which are usually observed in pants, frequently occur in shirts, blouses, jackets, skirts, and dresses as well [17].

Achieving ergonomic compatibility and freedom of movement in the garment is possible by thoroughly understanding the human body, considering the garment's intended use, and being aware of the properties of the materials used [18].

In order to make patterns based on body size, body measurements are needed. Each pattern-making system has its own measurement techniques. The success of a system depends on how well the measurement technique is comprehended and practised. The German Müller & Sohn, the British Metric, the German Contec, and the American Basic Blocks Pattern-Making systems, which are empirical methods consisting of a set of drawing rules, are the most widely used systems for making basic garment patterns from scratch. Many measurements in these pattern-making systems are obtained through either various calculation methods and formulas or empirical constants directly. In some cases, since what these constants represent is not exactly known, the pattern-making process is acted out by rote. And sometimes, people preparing the patterns may fail to apply the formulas correctly [19].

Tama and Öndoğan, in their study utilising 4 different pattern-making systems to prepare basic skirt patterns with identical body measurements for different body types and conducting fitting evaluation, suggested that existing pattern-making systems were not sufficient for all body types [20]. Unal and Utkun examined how women's body types impact the pattern-making process, and studied different basic body patterns tailored to different female bodies [21].

Chrimes et al. identified a gap in the literature regarding subjective fit, and suggested that comprehensive surveys were needed to better understand consumers' thoughts on fit. In addition, they emphasised that women's body type had a significant impact on clothing fit, and suggested that body types needed to be taken into consideration when designing commercial collections [22].

In the literature, there are several studies that propose different pattern-making methods considering the issues in the existing pattern-making systems.

Cho et al. modified the conventional draping system and developed a personalised pattern-making system that could be used with 3D modelling techniques. When they compared the skirts, the patterns of which were prepared by their system to those prepared by conventional methods, they saw that approximately 80% of the users preferred the skirts made by the newly developed system [23].

Mete developed a new form-fitting basic pattern-making technique for women's upper body based directly on body measurements, and tested these patterns in terms of clothing fit. It was observed that the newly developed system (EFES) was able to provide full compatibility with the whole body, and applied to any body type or size during the pattern-making process [19].

Song and Ashdown split women into 3 different categories based on their lower body shapes by using a method they developed. Then, they examined the shortcomings of the Basic Blocks Pattern-Making system and modified the standard basic pants patterns prepared with this system (standard customisation method) by considering different body shapes and postures (body-shape-driven customisation method). It was observed that the pants patterns prepared based on body shapes yielded better clothing fit outcomes compared to standard patterns [24].

Similarly, in their study, Kılıç et al. developed a new pattern method (AnMePa) for women by using the measurements obtained through an anthropometric measurement system. They evaluated the fitting of the basic pants patterns through a 3D clothing system and fuzzy logic method. It was observed that the patterns made with this newly developed system yielded better clothing fit outcomes than those made with other pattern-making methods [25].

Jin and Gu aimed to achieve the automatic generation of individualised prototype patterns by combining 3D body clouds and 2D measurement techniques. This method aims to overcome the formulas used in other pattern-making methods and to consider different body types during the pattern-making process. The authors stated that in subsequent studies, they intended to simplify and streamline this method [26].

However, when these studies are reviewed, it is observed that these newly developed methods are not yet practical and therefore have not been widely popular within the industry. Furthermore, it is noted that a single garment category is exemplified in these studies, and studies on other garment categories are still ongoing.

3D clothing fitting evaluation

Conventionally, the evaluation of a garment's clothing fit is conducted through wear trials. These wear trials may involve feedback from subjects wearing the garment as well as expert opinions. However, this evaluation method is costly, time-consuming, inflexible, and also unsuitable for online (remote) shopping. In recent years, 3D garment computer-aided design (CAD) systems have been used to simulate the clothing experience. Software such as CLO 3D, OptiTex, and Browzwear are the virtual fitting solutions that are in use within the industry [27]. These solutions also facilitate communication among designers, patternmakers, and technical designers [28].

In the literature, there are studies on the applicability and success of 3D virtual systems for evaluating clothing fitting.

Song and Ashdown examined the validity of 3D virtual fitting systems for pants by both conducting wear trials and using 3D virtual try-on systems. The results of the study indicate that the overall accuracy of virtual fitting technology is moderately good for use, especially for pants with good fit, but not to the extent that apparel professionals could fully use it as a visual fit analysis tool [28].

Wu and Liu used the CLO 3D modelling system in their study aiming to improve clothing fit, and their findings yielded successful outcomes regarding the CLO 3D system when compared to subjective evaluations [29].

Mohamed et al. analysed the clothing fit of jacket patterns designed for obese women by using both real and 3D virtual methods (CLO 3D), and suggested that there was no difference between the two methods [30].

Teyeme et al. analysed a form-fitting T-shirt designed for cyclists by using the CLO 3D system. They evaluated a series of local fit levels and pressure at certain critical contact areas of the body with a tight-fitting shirt. At the end of the study, they stated that the variety of elastic fabrics available in the CLO 3D system's library was limited, that physical manufacturing was still necessary for deciding on a final prototype garment, and that CLO 3D significantly accelerated the progress in the early stages of the garment development process [31].

Kim and Baytar investigated the accuracy and applicability of virtual systems under dynamic human body conditions by using the CLO 3D software. In their study, 6 female participants performed 4 different athletic movements, and the participants' bodies were scanned in 3D. The data were evaluated in both real and virtual environments. As a result, the study revealed the advantages and disadvantages of 3D virtual fit technology, pointing out that the system remained limited in dynamic environments and identifying the areas that required improvement [32].

In this study, one different pattern-making systems developed by Saime Sezal were examined [33]. A pattern-making system based on body measurements was described. In this study, women's basic pants were examined in practice. While the proposed pattern system can be applied to non-stretch woven fabrics, it can also be applied to stretch fabrics. However, in such cases, it is required to reduce the width or length measurements of the pattern in line with the direction and degree of fabric stretch.

MATERIAL AND METHOD

Material

In the pattern-making system based directly on body measurements, only the waist and hip circumferences taken from the body are sufficient; other measurements vary depending on the design features of the pants. The waist circumference should be measured at the narrowest part of the waist by using a measuring tape, while the hip circumference should be measured at the widest part of the hips.

Within the scope of the study, first, a basic pants pattern of size 38 was prepared and graded across the sizes 36 and 40. Thereafter, to demonstrate how the proposed system performs in the model, a new modelling was conducted on the basic pants pattern of size 38, which was also graded across the sizes 36 and 40. The size table for both the basic size and modelled pants is given in table 1, while their technical drawings are given in figures 1 and 2.

The fabric used in the CLO 3D system for the study is a 100% cotton woven non-stretch fabric with a weight of 192 g/m^2, and a thickness of 0.38 mm.

Table 1

SIZE TABLE FOR WOMEN'S PANTS

Measurement values (cm)	Size 36	Size 38	Size 40
Waist circumference	74	78	82
Hip circumference	93	97	101
Knee circumference of pants (measured 38 cm below the inseam)*	41	42	43
Hem circumference of pants*	37	38	39
Side length of pants*	103.5	104	104.5
Fly length*	13	14	14
Fly width*	3.5	3.5	3.5
Waistband height*	4	4	4
Side height of the front panel*	3	3	3
Front centre height of the front panel*	6	6	6
Side height of the back panel*	3	3	3
Front centre height of the back panel*	7	7	7

Note: *The measurements provided for the pants vary depending on the model.

Methodology

When compared to the well-known pattern systems, the pattern-making system developed within the scope of the study displays some distinctive properties as follows.

1. The descriptive language of the process steps is concise, in order, and clear.
2. The process steps are sequenced and associative.
3. The process steps are straightforward.
4. It is easy to keep the process steps in mind.
5. They require scarcely any mathematical formulas and calculations.
6. It is possible to perform measurement verification and validation.
7. Both length and width measurements can be drawn together during the pattern-making process.

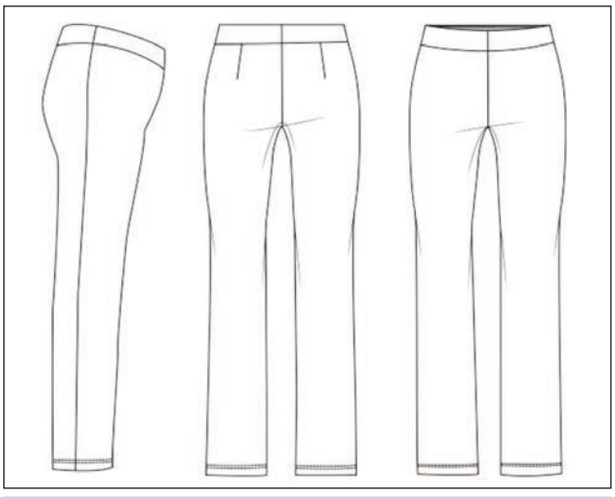

Fig. 1. Technical drawing of the basic size pants

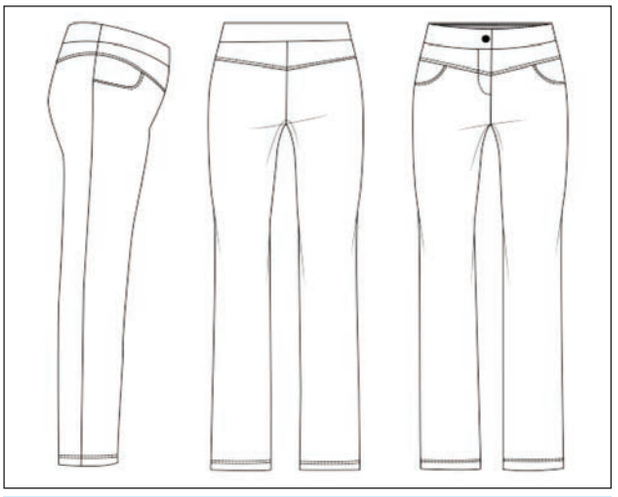

Fig. 2. Technical drawing of the modelled pants

8. The system, designed with the ergonomics of the body in mind, enables easy adjustment of modifications (e.g. dart lengths, etc.) by preventing unwanted looseness in the garment.
9. For lower body garments (skirts and trousers), the difference between the waist and hip measurements is not used for dart distribution, but instead, dart allowances are directly incorporated into the waist measurement.
10. A drawing method has been suggested within the system to prevent deformation (whiskering) that may occur while drafting the front crotch of the pants (figure 3). According to this method, the part between points F and L is divided into four equal parts and marked. Point E is connected to the first part of (F-L)/4, then the midpoint of this line is found and connected to the second part of (F-L)/4. The process continues in this way by preparing the front crotch curve of the pants from point E towards point L. This technique eliminates the need for bisector measurements while drafting the crotch, and prevents deformation.

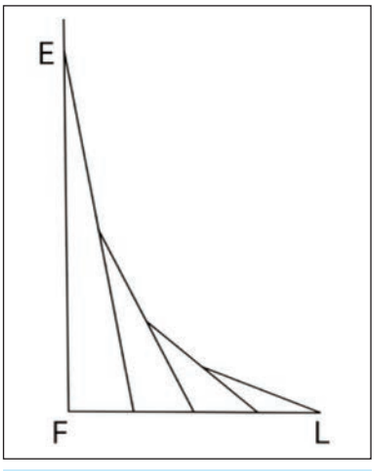

Fig. 3. The method developed for drawing a smooth crotch curve

Process steps

All process steps of front and back pants on pants patterns are given in table 2 and 3.

Table 2

FRONT PANTS DRAWING PROCESS STEPS	
Step no.	**Step description**
1	Draw a straight vertical line.
2	Mark from point A to B equal to the pants' side length.
3	Mark from point A to C equal to the crotch depth (hip circumference/4).
	Note: In this system, for high-rise pants, the crotch depth can be up to (hip circumference/4 + 1, 2, or 3 cm). For low-rise pants, the crotch depth can be up to (hip circumference/4 – 1, 2, or 3 cm). For pants with a lower rise, low-rise modelling should be conducted after preparing the basic pants pattern.
4	From point C, go up 8 cm (constant value) and find point D.
5	Draw horizontal lines from the marked points A, B, C, and D.
6	On the horizontal line from point D, mark (hip circumference/4 – 1) cm. Find point E; the line between D and E is the hip line.
7	Draw a perpendicular line from point E that intersects the horizontal lines coming from points A and C. Find points F and H.
8	From point H, mark 1 cm to the left. Find point I.

Table 2 (continuation)

Step no.	Step description
9	From point I toward point A, mark (waist circumference/4). If a dart is included in the pattern, add the dart width to (waist circumference/4). Find point J.
10	From point J, move 1 cm upwards and find point K.
11	Connect points I and K with a curved line (curving downward).
12	Connect points K and D with a front side curve.
13	From point F, mark (hip circumference/20) cm to the right and find point L.
14	The part between points I, E, and L forms the front crotch.
15	Mark the midpoint between points D and B, and find point M. Draw a horizontal line from M to construct the knee line.
16	Mark the midpoint between points C and L, and find point N.
17	From point N, draw vertical lines upward and downward to find point O on the knee line and point P on the hemline.
18	On the right and left sides of point O, mark (knee circumference/4 – 1 cm). Find points R and S. (42 cm / 4 = 10.5 cm; 10.5 cm – 1 = 9.5 cm)
19	On the right and left sides of point P, mark (hem circumference/4 – 1 cm). Find points T and U. (38 cm / 4 = 9.5 cm; 9.5 cm – 1 = 8.5 cm)
20	Connect R to T and S to U with straight lines.
21	Connect points C to R and L to S with straight auxiliary lines, and find the midpoints of these lines. From the midpoints, move inward by 0.5 cm to shape the calf area with a curve, and draw two lines opposite each other.

Table 3

BACK PANTS DRAWING PROCESS STEPS	
Step no.	**Step description**
1	The back pants pattern is drawn directly over the front pants pattern.
2	The horizontal lines D-E, C-L, R-S, and T-U, as well as the vertical line N-P, which are used for the front pattern, are also applicable to the back pattern.
3	For the difference between the front and back pants, add 2.5 cm (constant value) outward from points C and L, and find points C1 and L1.
4	For the difference between the front and back pants, add 2 cm (constant value) outward from points R and S, and find points R1 and S1.
5	For the difference between the front and back pants, add 2 cm (constant value) outward from points T and U, and find points T1 and U1.
6	Connect points R1 to T1 and S1 to U1 with straight lines.
7	Connect points C1 to R1 and L1 to S1 with straight auxiliary lines, and find the midpoints of these lines. From the midpoints, move inward by 0.5 cm to shape the calf area with a curve, and draw parallel lines.
8	From point L1, move downward by 0.5 cm (room for flexibility), and find point L2.
9	From point E, mark 1cm to the left. Find point V.
10	From point V, mark (hip circumference/4 + 1) cm to the left. Find point Y.
11	Connect points Y and C1 with a straight line.
12	Move inward by 4cm from point I, and find point Z.
13	Connect points V and Z with a straight line, while moving upward by 4cm from point Z along the same line without shifting the ruler. Find point W.
14	Connect points V and L2 with a curved line.
15	From point K, draw a horizontal auxiliary line to the left.
16	Starting at point W, estimate the length on the auxiliary line (waist circumference/4 + dart width), and find point Q.
17	Connect points Q and Y with a straight line.
	Note: The length between points D and K, which defines the sideline of the front pants, is measured. This length is compared to the length between points Q and Y on the back pants. If a discrepancy is observed due to curvature differences, the deficiency is compensated by moving point Q upward accordingly.
18	Find the midpoint of the distance between points V and Y, and from this point, draw a vertical line upward toward the waistline. On this line, draw the back dart by using a dart length (12 cm) downward from the waist, and a dart width (3 cm) sideways.

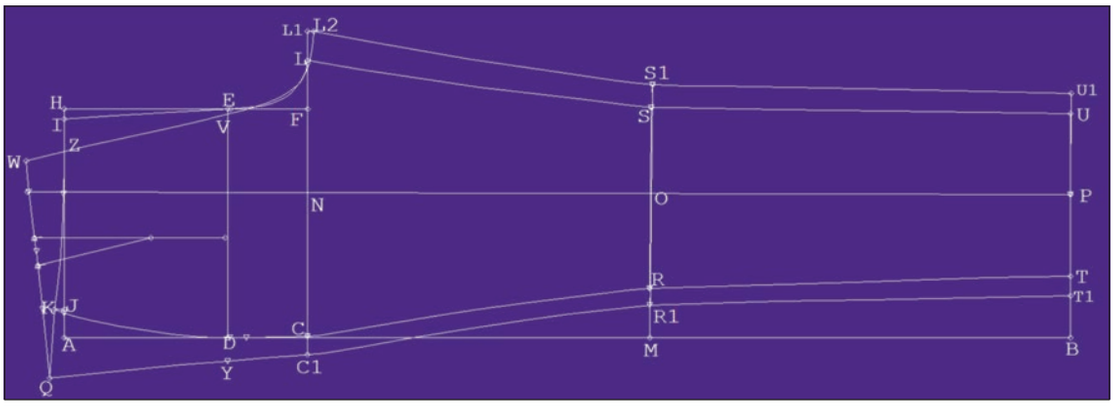

Fig. 4. Front and back women's basic pants patterns

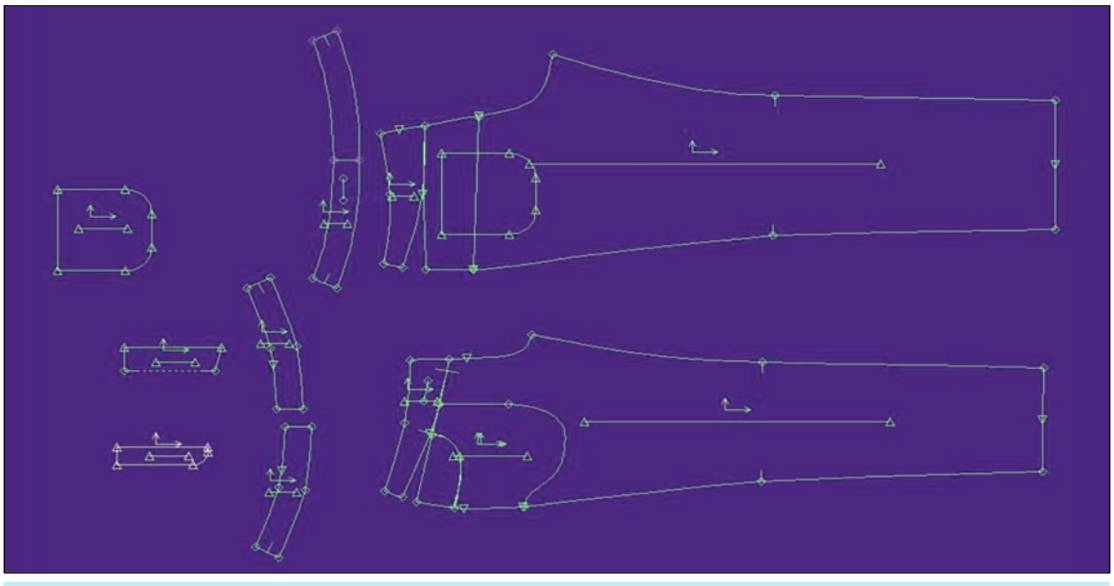

Fig. 5. Pattern pieces of the modelled pants

All points used for the process steps of front and back pants drawing are illustrated on pants patterns in figure 4. The pattern pieces of the modelled pants are given in figure 5.

3D fitting evaluation

The software CLO 3D is applied to measure digital clothing pressures. This software permits the creation of virtual, close-to-life garment visualisation with cutting-edge simulation technologies [34]. The clothing fitting of the patterns made within this study was analysed by using CLO 3D software, version 2024.2.284. First, virtual avatars were created to simulate the wearers of the pants; then, these avatars were made to perform not only static poses but also 5 different dynamic movements (walking, running, sitting, climbing stairs, and kneeling) in order to evaluate the patterns.

RESULTS AND DISCUSSION

Pressure and stress maps of the pants were obtained using the CLO 3D software. The pressure map helps to visually analyse the comfort levels in areas where the fabric comes into contact with the body. It typically illustrates the areas with minimal pressure (i.e. loose-fitting parts) and highlights the room for movement. A stress map, on the other hand, illustrates the amount of tension and pressure exerted by the fabric on the body using a colour-coded map. Areas with higher stress (tension) generally appear in brighter or red-toned hues. Using both maps in conjunction serves as a helpful method for optimising both the technical fit and user experience in garment design. The scales used for evaluating the stress and pressure maps are shown in figure 6. In table 4, what the colours in the scales represent based on the evaluation range is explained.

Table 4

COLOURS ACCORDING TO ASSESSMENT RANGE [19]	
Assessment range	**Colours**
Very tight	Red
Tight	Red - Orange
Well	Yellow - Green
Large	Light blue - Yellow
Very large	White

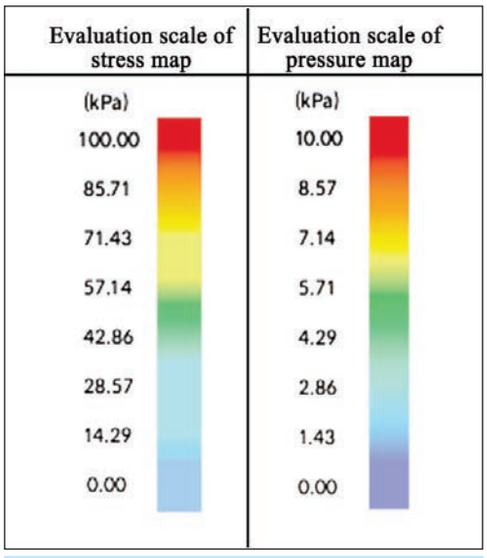

Fig. 6. Evaluation scales of stress and pressure maps

For both the basic and modelled pants of sizes 36, 38, and 40, the stress and pressure maps were prepared separately for standing, walking, sitting, stair climbing, and kneeling positions. The numerical values obtained from the stress and pressure maps are separately given in tables 5, 6, 7, and 8.

Upon analysing the maps of the pants, it is observed that each position yields unique values, which internally vary. It is observed that the values mostly fall within the yellow, green, blue, and white colour intervals, and remain within technically acceptable tolerance ranges. Moreover, it has been determined that the data given in the respective tables exhibit internal consistency and stability. This confirms both the accuracy of the patterns and the reliability of the grading process.

Due to space limitations, the images of stress maps and pressure maps, as well as the overall visuals of the positions used for the sample basic pants pattern of size 38, are given in figures 7, 8, 9, 10, 11, and 12.

Table 5

DIGITAL CLOTHING STRESS VALUES OF BASIC PANTS (kPa)

Position	Standing			Walking			Running			Sitting			Stair-climbing			Kneeling		
Size	36	38	40	36	38	40	36	38	40	36	38	40	36	38	40	36	38	40
Waist	30.56	32.85	39.4	22.46	28.12	36.09	47.05	49.55	53.41	72.25	85.08	95.33	22.05	41.89	50.69	22.52	40.55	49.93
Hip	10.62	12.85	17.55	15.82	20.64	20.72	23.52	20.93	19.91	25.86	28.91	30.99	39.25	42.62	43.5	15.68	19.4	20.14
Thigh	18.06	19.88	20.68	26.21	29.48	30.37	32.24	39.36	41.33	31.22	38.05	39.39	20.41	19.67	18.92	10.64	13.04	14.47
Knee	1.2	1.58	1.92	9.24	10.37	10.59	14.26	19.95	21.9	39.47	43.69	49.17	21.87	19.17	16.82	61.82	63.86	64.64
Calf	1.96	2.25	3.66	4.85	5.87	6.19	5.1	5.88	6.2	20.5	10.96	9.01	0.67	0.69	0.7	0.76	1.15	1.43
Ankle	0.03	0.46	0.5	0.85	0.51	0.14	0.23	0.41	0.66	0.49	0.59	0.76	0.07	0.14	0.17	4.17	4.77	4.96

Table 6

DIGITAL CLOTHING PRESSURE VALUES OF BASIC PANTS (kPa)

Position	Standing			Walking			Running			Sitting			Stair-climbing			Kneeling		
Size	36	38	40	36	38	40	36	38	40	36	38	40	36	38	40	36	38	40
Waist	0.13	0.15	0.16	0.06	0.08	0.16	0.2	0.18	0.13	0.3	0.37	0.4	0.12	0.28	0.2	0.02	0.9	0.1
Hip	0.02	0.04	0.06	0.02	0.07	0.09	0.57	0.52	0.41	0.51	0.49	0.46	0.44	0.53	0.59	0	0	0.03
Thigh	0.24	0.26	0.29	0.22	0.29	0.39	1.19	1.8	2.19	1.21	1.35	2.52	0.5	1.01	1.04	0.02	0.02	0.02
Knee	0	0	0	0.15	0.1	0.08	0.4	0.41	0.43	1.02	0.97	0.93	0.55	0.49	0.47	1.25	1.26	1.29
Calf	0.04	0.05	0.6	0.05	0.04	0.02	0.05	0.11	0.18	0.1	0.16	0.18	0.05	0.07	0.09	0.01	0	0
Ankle	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 7

DIGITAL CLOTHING STRESS VALUES OF MODEL-APPLIED PANTS (kPa)

Position	Standing			Walking			Running			Sitting			Stair-climbing			Kneeling		
Size	36	38	40	36	38	40	36	38	40	36	38	40	36	38	40	36	38	40
Waist	29.19	31.87	32.01	52.19	54.26	55.31	49.43	50.59	52.41	44.21	38.54	44.89	66.59	58.69	59.65	9.01	15.29	30.7
Hip	10.68	15.21	19.36	4.68	10.86	18.01	50.68	54.35	55.46	3.88	4.06	5.11	2.94	2.89	2.93	3.45	11.08	16.2
Thigh	24.37	25.38	31.65	8.19	15.37	20.42	107.65	123.84	122.07	12.75	17.43	29.65	73.84	94.14	98.36	11.54	21.36	24.23
Knee	0.2	0.53	0.32	4.3	5.74	5.87	32.95	32.27	18.56	11.38	12.54	13.75	50.32	46.46	42.98	5.28	30.07	50.65
Calf	3.56	3.57	4.65	0.36	1.14	1.23	10.29	9.93	9.72	1.8	1.79	2.5	13.8	10.09	8.54	2.03	2.23	1.58
Ankle	4.5	3.53	2.84	0.25	0.23	0.24	0.31	0.34	0.52	0.05	0.09	0.11	0.67	0.22	0.18	3.55	4.3	6.54

Table 8

DIGITAL CLOTHING PRESSURE VALUES OF MODEL-APPLIED PANTS (kPa)

Position	Standing			Walking			Running			Sitting			Stair-climbing			Kneeling		
Size	36	38	40	36	38	40	36	38	40	36	38	40	36	38	40	36	38	40
Waist	0.2	0.17	0.11	0.18	0.19	0.23	0.6	0.66	0.35	0.2	0.23	0.21	0.01	0.25	0.3	0.29	0.22	0.21
Hip	0.06	0.06	0.07	0.1	0.12	0.17	0.82	0.81	0.77	0.13	0.13	0.11	0.28	0.17	0.16	0.15	0.33	0.34
Thigh	0.21	0.34	0.35	0.17	0.2	0.5	2.5	2.3	1.52	0.62	0.54	0.37	1.15	1.8	2.26	0.58	0.3	0.37
Knee	0	0	0	0.1	0.09	0.12	0.79	0.75	0.73	0.31	0.31	0.3	1.35	0.53	0.4	0.38	1.3	2.61
Calf	0.5	0.04	0.03	0	0	0	0.07	0.05	0.04	0.01	0.01	0.01	0.16	0.24	0.3	0.34	0.06	0.08
Ankle	0	0	0	0	0	0	0	0	0	0	0	0	0.02	0	0	0.05	0.1	0.16

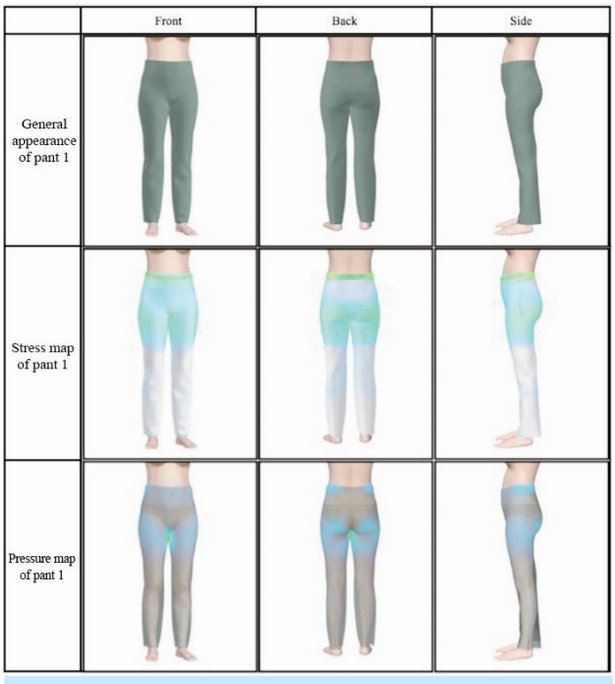

Fig. 7. Fit evaluation in standing position

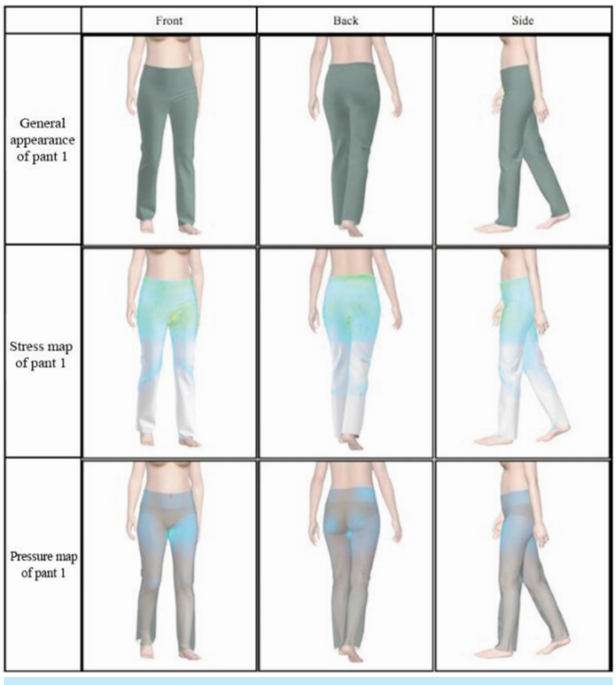

Fig. 8. Fit evaluation in walking position

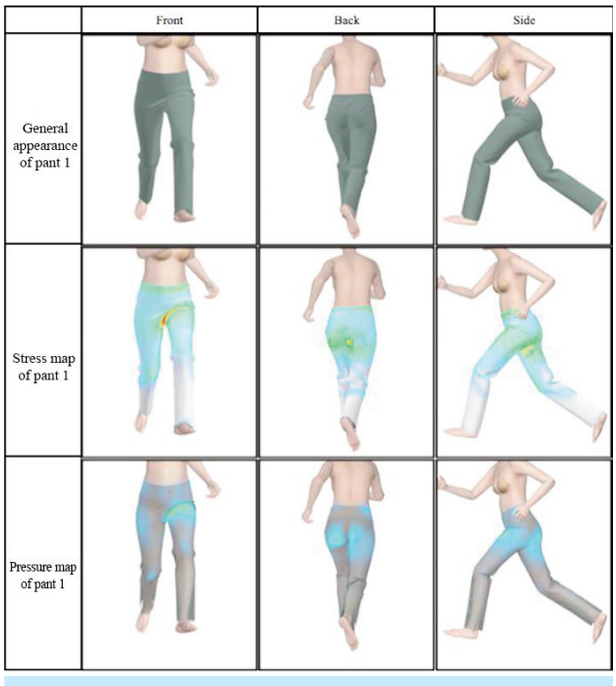

Fig. 9. Fit evaluation in running position

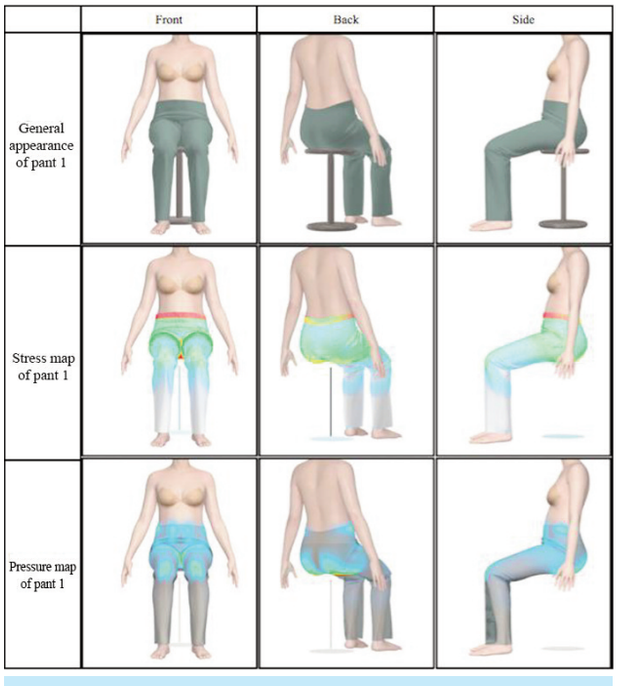

Fig. 10. Fit evaluation in sitting position

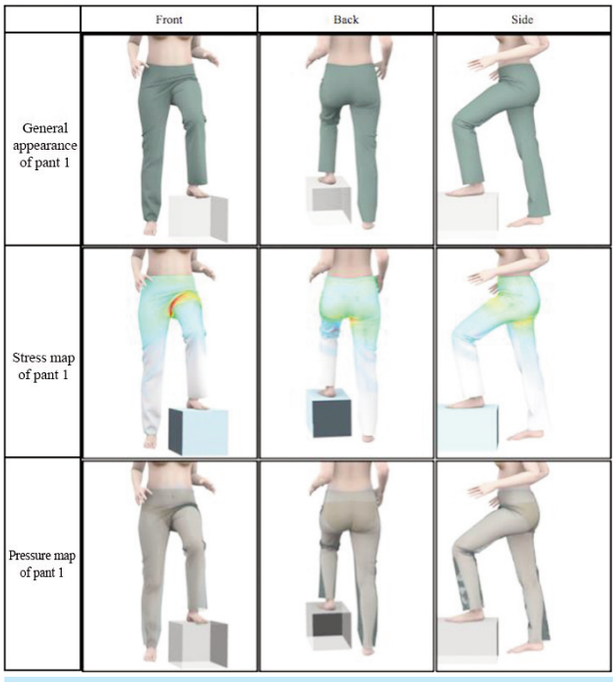

Fig. 11. Fit evaluation in stair-climbing position

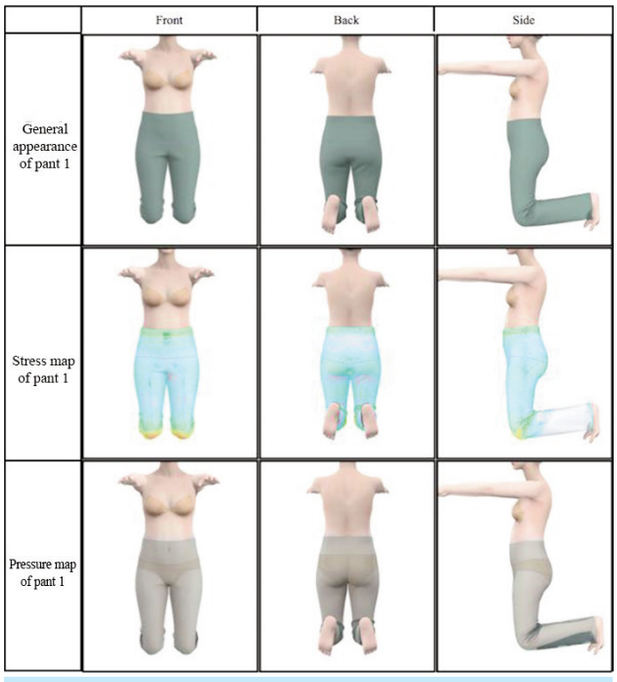

Fig. 12. Fit evaluation in kneeling position

CONCLUSION

As described in the literature review, one of the most important manufacturing stages in the clothing industry is the accurate preparation of the garment pattern. Each faulty pattern prolongs the sample manufacturing cycle and therefore results in losses in time, labour, and cost. It is essential to minimise this sample manufacturing cycle. Both 2D and 3D pattern-making systems are used to reduce this time frame. However, the skills, experience, and familiarity of the users with the pattern-making systems are also crucial. This study aims to contribute to the industry by proposing a simplified and practical system.

When the pressure and stress maps of the pants made with the pattern-making system proposed within the study are examined, it is clearly observed that the pants adapt well to the body and allow for body movement comfort. The system described is also practical and easy to learn, as it does not require complex formulas or calculations during the pattern-making phase; from this perspective, it is evident that the system meets the objectives of the study.

In addition, the following future research topics are proposed.

- While the clothing fit evaluation of the patterns made within this study was conducted by using the CLO 3D system, future studies may include wear trials with human subjects.
- The developed system may also be adapted for other garment categories.

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