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RESEARCH ARTICLE

Evaluation of Basic Shirt and Pant Fit Using Analytic Hierarchy Process-AHP and 3D CLO for 20-25 Years Bangladeshi Men

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Abstract

Background: The proportion of a garment to its body is known as garment fit. To ensure comfort between the human body and clothing, fit is very important. At present, 3D simulation of garment fit has great potential for business purposes. However, in previous analyses, there were expert opinions on manual fit analysis, which is very popular in the industry. **Objectives:** The main objectives of this research are to ensure manual clothing fits with a live model with 3D CLO software evaluation. **Method:** In this study, up to 50 textile experts from industries have chosen to analyze the analytical hierarchy process (AHP) to evaluate clothing fit. Findings: In this study, small, medium, and large-sized basic shirts and pants (20–25 years old) have been developed for live model fit evaluation. According to the analytical hierarchy process (AHP), among small, medium, and large-sized basic shirts and pants, one or two sizes of garments have been tested for garment fit evaluations. The results of these fit evaluations are satisfactory, according to 50 textile experts, and are the main output of the 3D CLO software. **Novelty:** The analytic Hierarchy Process (AHP) is fully adopted by the Bangladeshi newly developed size chart, which is enhanced by the 3D CLO software.

Keywords: Analytic Hierarchy Process (AHP); 3D CLO; Shirts; Pant; Garments; Bangladesh

1 Introduction

Fit is a vital issue to ensure comfort between the human body and the garments. Close-fitting garments mean without stretching or deforming and no gaps between the human body and the garments will confirm the easy movement of the body. The garments

should be parallel to the floor during wearing on the body like 90 degrees against the body to ensure better balance of the garments[1]. The adaption of garments with the human body in three dimensions is referred to as fit. Fit is the main option for customers to be satisfied. In the market it's very convenient to find the desired color, price, and style and then fit garments. If any garments don't fit well with the human body the main objectives of the garments are destroyed[2,3]. Careless design or construction can be an obstacle to ensuring garments fit. Different ages people have different types of body structures. The scanning system can scan and procedure the total measurements of the body very easily[4]. After converting this data into a computer-assisted unique pattern, men's garments created using this method can be cut and sewn within seven minutes of receiving the measurement data[5]. The resulting clothing fits very perfectly because the computer scanner detects the smallest deviations in body shape that conventional measuring methods. These systems are currently being tested but would be expensive and take a while to become widely available. Different people have different ideas about what constitutes a good fit. Age, gender, body type, lifestyle, and cultural influences all play a role in determining an individual's fit preferences. The desired fit is also influenced by the intended use of the garment. Due to changes in the human population, the relationship between size charts and body measurements is not constant to ensure fit. No more than 25% of the population relate to the clothing sizing system according to a recent survey of the UK, US, China, Germany, and other countries[6,7]. A good fit and satisfied customers depend on the right size of their garments. The parameters on which the assessment of adjustment is typically based are referred to as the five classic elements of adjustment. Grain, Set, Line, Ease and Comfort[8]. There are seven (07) different human body shapes that can be found globally. But according to the 37 model, 38% of the population in Bangladesh is an inverted triangle[9]. Twenty percent of Bangladesh's population does not have access to a size chart. Therefore, before implementing it at the industrial level, it is crucial to implement this new size chart to ensure the fit[10].

In this study, the researchers have tried to analyze the fit and balance issue of the newly developed size chart for Bangladeshi (20-25 years) aged men by two approved methods. The Analytic Hierarchy Process (AHP) and 3D CLO software have been adopted in Bangladesh during the analysis of the final product.

2 Methodology

Materials and Methods

2.1 Material

Size Chart (20-25 years), 3D CLO Software, Investigator, Human Body.

2.2 Method

Live model selection: Healthy, and according to the newly developed size chart, the live model has been chosen for the garment trial and the AHP system (in Table 1). The CLO 3D model has been created according to the body measurements of the newly developed size chart.

Analytic Hierarchy Process (AHP): Thomas L. Saaty created it in the 1970s, and since then, it has been improved. It consists of three parts: the primary objective or issue it's attempting to resolve, all potential answers or alternatives, and the standards by which you'll evaluate the options. By putting the decision's criteria and potential outcomes into numerical form and connecting them to the main objective, AHP offers a logical framework for making necessary decisions[11,12]. There are three levels for the AHP structure, consisting of level 0 (goal or objective), level 1 (criteria), and level 2 (alternative).

3D CLO : CLO is 3D CAD software that CLO Virtual Fashion Inc. offers to the apparel industry. CLO 3D software is capable of simulating garments based on both 2D and 3D models. Without making real samples, users can examine dress silhouettes and their thoughts about the outfit. Additionally, it can export data from 3D clothing models and utilize that data with 3DCG characters (It's a type of three-dimensional character like animation, cartoon, etc.)[13–15].

Preparation of sample: In this study, all the fabrics have been collected according to the mechanical properties listed in Table 2 for better fit and balance purposes. This type of fabric shows better fit and balance when worn on a live model. To demonstrate the ease and fit of the garments, the sample is ironed after preparation.

Table 1. Live model garments fit analysis by adopting Analytic Hierarchy Process (AHP)

Fitting standard	Advantages	Disadvantages
Actual model	Actual body type Actual motion	Subjective and qualitative psychological sabotage

Preparation of human body models (For casual shirts and pants): Preparation of human body models (For casual shirts and pants) is prepared by selecting the casual shirts and pants with the explanations of the evaluation areas. Then the research team collects the data according to the guidelines for estimating the clothing fit[16].

Table 2. Fabric constructions used in this fit test

Type of weave	Fabric composition, %	Yarn density, yarns/cm		Yarn linear density, tex		Surface mass, g/m^2
		Warp	Weft	Warp	Weft	
Plain Weave	100% Cotton	30	34	3.6	15	141

The investigation used both parametric simulations of fundamental environments and physical models of real situations. Fit was studied using the shirt and pants of a man whose body measurements were typical of his 20–25 years. Figure 1 shows the study model of interest.

2.3 Materials and outline of the garments

In Table 2, all the sizes of basic casual shirts and pants fabric properties are shown to analyze the garments fit. Made of gray fabric suitable for wearing basic shirts and pants. Simple shirt and pants designs were created using similar fabrics and designs. The shirts and pants were sewn using actual garment production techniques, and the patterns were created manually. The real-life model was a middle-aged male population between the ages of 20 and 25.

Table 3. Mechanical properties of the fabrics

Extension at a load of 40 Nm-1, %		Bending rigidity, μNm		Shear rigidity, Nm^{-1}	Surface thickness, mm
Warp	Weft	Warp	Weft		
1.5	1.9	8.64	3.75	13.85	0.658

Table 3 expresses the mechanical properties of common 100% woven fabrics. The properties of these fabrics show the minimum standard required to make basic shirts and pants manually. If we want to simulate in CLO 3D software, this value range is also valid.

2.4 Explanation of evaluation areas

For casual shirts: Three distinct sections (A, B, and C, D) were established to evaluate the validity of shirt designs (see Figure 1) and to assess how well genuine casual shirts fit onto an actual human body. Selection of the evaluation areas resulting from the shirt pattern development guidelines was done. The crucial body measures required for creating the pattern and specifying the tolerance for the perfection of a shirt are the shoulder line, neck opening, armhole opening, chest line, sleeve length, and shirt length. The dimensions of the evaluation areas were chosen based on prior research on what users needed to assess how a garment looked on a real body. The assessors considered the following instructions for front and back views to estimate the garment's fit in predefined areas: in the shoulder slope, neck round with neck drop, armhole opening, sleeve length from TPS (Tip points of the shoulder) from the cuff and the garment's length and yoke for perfect fitting of the shirt.

For casual pants: Three distinct sections (A, B, C, and D) were established to evaluate the validity of all pant types (see in Figure 1) and to evaluate the fit of casual trousers to the living human body. To select the evaluation areas, we used the guidelines for creating pants patterns as a guide. The basic body dimensions required for creating the design and specifying the tolerance for comfort in a pair of trousers are those of the waist, hips, length line, and thigh line. The requirements of the user for the subjective assessment of the appearance of trousers on the human body have been considered in previous research to define the width of the assessment zones. Therefore, regardless of the design of the pants, customers consistently rated the waist, hips, stomach, and length as being attractive. To assess the fit of the garment in predefined areas, the assessors considered the following directions for front and back views: they looked for transverse or longitudinal creases in the waist area, creases in the hip and stomach areas, and the length area, and a straight line of pant length.

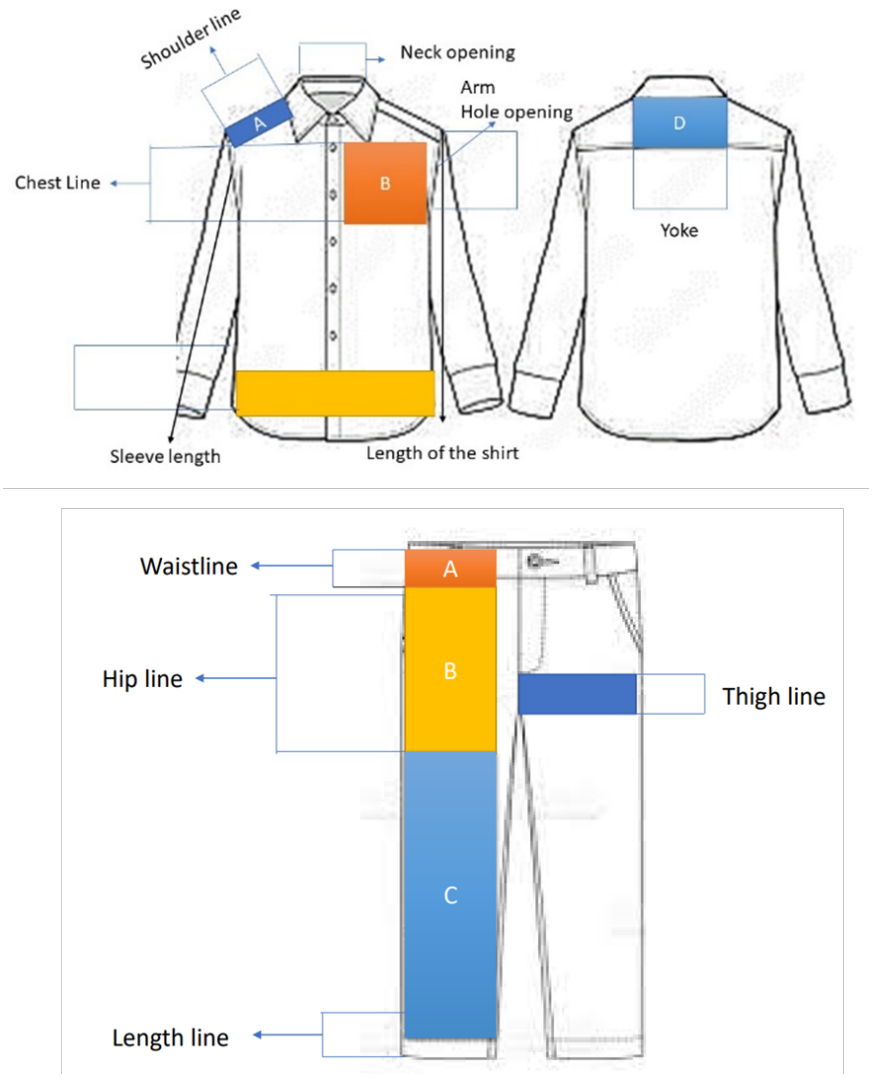

Fig 1. Evaluation areas and Designs of shirts and pants in matching materials (N.B: The design will be the same for all the sizes) (Common design for all sizes of basic shirts and pants)

2.5 Process of Garment fit analysis

The Analytical Hierarchy Method (AHP) is a decision-making method for dealing with complex issues with multiple attributes. Pairwise comparison matrices are constructed either by directly calculating pairwise dominance ratios using actual data or by providing ratings to estimate dominance using absolute values from the AHP 1-9 baseline scale. The AHP sets priorities based on paired comparison assessments of the decision-making criteria's parent elements. Satya's developed scale range of 1 to 9 will be applied as the evaluation scale [17–19]. The key criteria had been "selecting the satisfactory model to verify a shirt and pants in shape for the human body," and the outcomes had been assessed by that standard. 50 estimators, who are specialists in textiles and work in a range of cloth fields, evaluated the shape of the shirt and pants. In the past, picture pixels were projected onto human bodies to demonstrate the informal clothing on human bodies after explaining the evaluation method to the evaluators. The Analytical Hierarchy Process (AHP), on the other hand, is a multi-criteria decision-making process that can be used to make complex decisions. Derive ratio scales from pairwise comparisons. The internal decision-making process and function of the AHP approach run independently of human intervention, making it a truly objective method. Therefore, this approach to using the AHP system to assess clothing fit can be classified as a subjective/objective hybrid approach.

For ironing purposes, some garments look like they are not fitted according to the selected fit area. But for the reasons of fabric properties, the iron is not permanent after wearing the garments. Every size of the garment has been developed. But for

Fig 2. Fitting results for shirt styles (a, b, c, d, e, f)

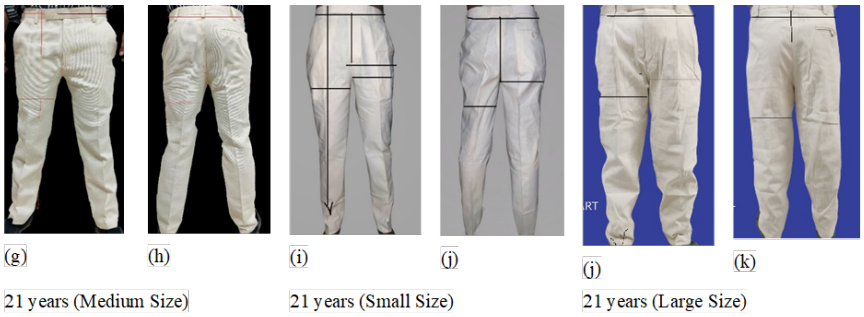

Fig 3. Fitting results for pant styles (g, h, I, j, k)

example, the research team has shown only 21-year-old garments (see in Figures 2 and 3).

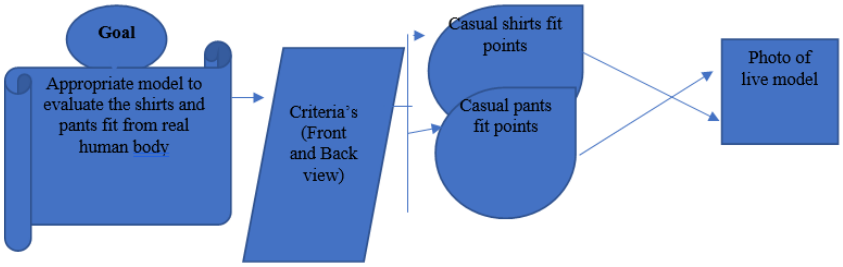

Fig 4. Actual model from the decisions of the textile expert

In Figure 4, the flow process of the decision-making process of the selected textile expert from different factories in Bangladesh. The section's criteria for the textile expert depend on the working experience minimum of 10-20 years.

3 Results And Discussion

PART I: EVALUATION OF CRITERIA: 1 = Equal, 3 = Slightly more important, 5 = More important,7 = Too much important, 9 = Extremely more important.

1. Which "MAIN CRITERIA" is more significant than the other when comparing the stores based on their success?
2. Which of the following factors should be prioritized when "FRONT" is considered? (For woven casual shirts)
3. Which of the following factors should be prioritized when "BACK" is considered? (For woven casual shirts)
4. Which of the following factors should be prioritized when "FRONT" is considered? (For everyday pants)

In this study, the researchers took (50 fifty) textile experts from different factories in Bangladesh who have a minimum of 10–20 years of experience in this sector. The researcher went through a complete questionnaire to gather their comments about the basic shirt and pant fit analysis. Figure 5 shows that, in total, 51 textile experts have given their opinion. Most of the experts

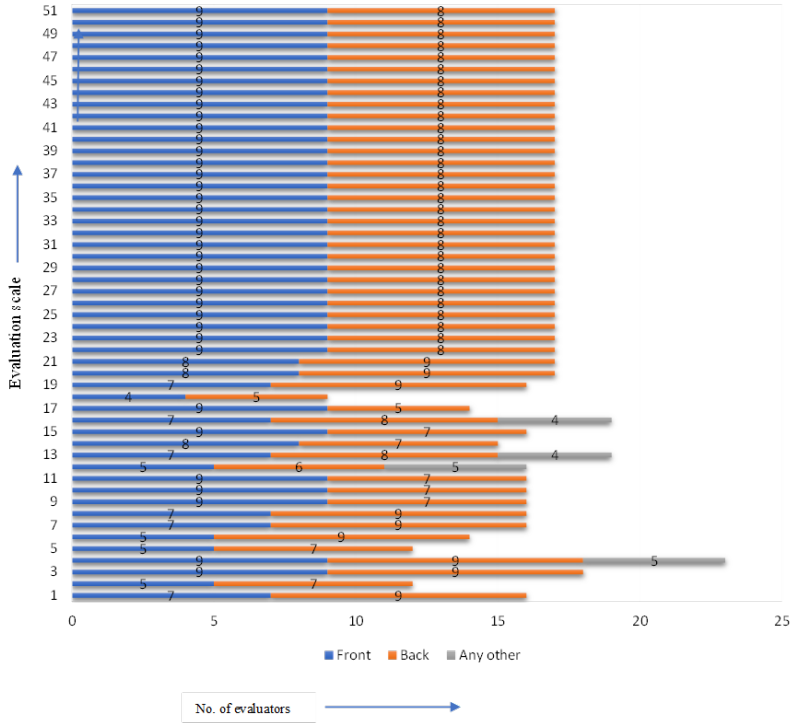

Fig 5. Summary of the comments from textile experts about the main criteria

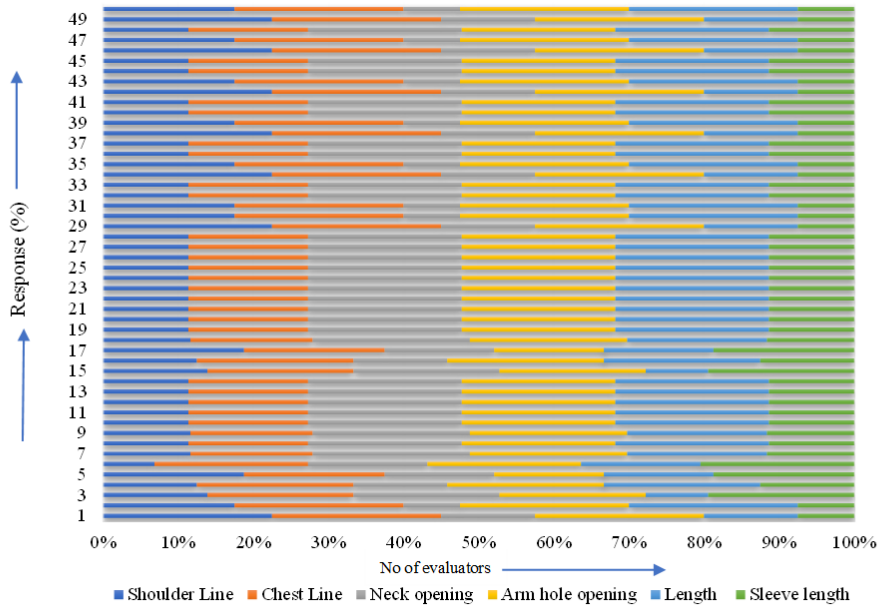

Fig 6. Summary of the comments from textile experts about basic woven shirts main fit criteria (Front side)

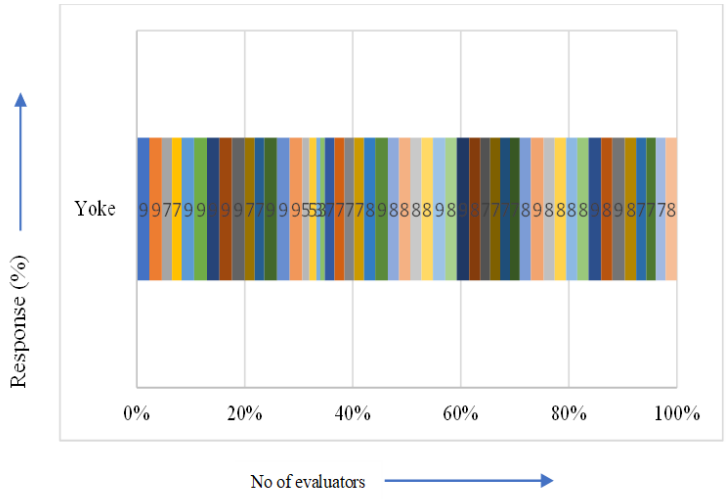

Fig 7. Summary of the comments from textile experts about the basic shirt's main fit criteria (Back side)

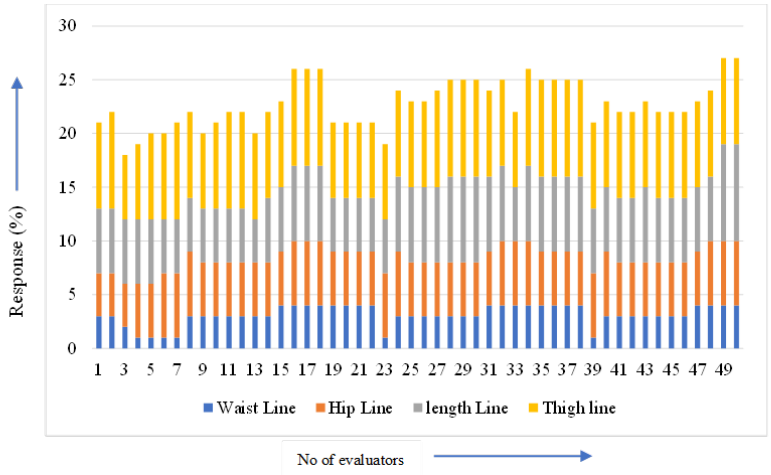

Fig 8. Summary of the comments from textile experts about basic pant main fit criteria (Front side)

have given their highest rating (7,9) about the main criteria of any type of product, like a casual woven shirt and pants, from the point of view of the front and back. Few experts have given their opinion differently, which is shown in Figure 6.

In Figure 7, the researcher specified some fit-critical issues for a casual basic woven shirt. Then he took comments from textile experts. It was noted that the textile experts agreed with the researcher regarding the specified fit points for basic shirts during the process of asking their opinions. The textile experts have given their comments on the importance of fit points. Most of the experts have given 100% concentration on sleeve length (see in Figure 7). The concentration (60–80%) depends on armhole length. Up to 60% concentrate on the chest line. So, after making the summary of this sectional survey, six major fit points are important for the human body to evaluate the fit of the garments, but one must concentrate on sleeve length, armhole opening, garment length, and chest points very seriously.

In Figure 7, most of the textile experts have given their 100% concentration on the back yoke.

In Figure 8, we can see that most of the textile experts have given their highest (100%) rating to fly pieces, ending points, and crotch points (see in Figure 3). 70–80% of textile experts concentrate on garment length. 40–60% of textile experts have given their opinion on hip lines and waistlines.

In this survey (From Figure 8), 49 textile experts have given their valuable opinions. They have already agreed with the researcher to specify fit points for basic woven pants and shirt fit criteria for the front-side view. Maximum textile expert shows their voting for fit evaluations depends on human age, then other criteria.

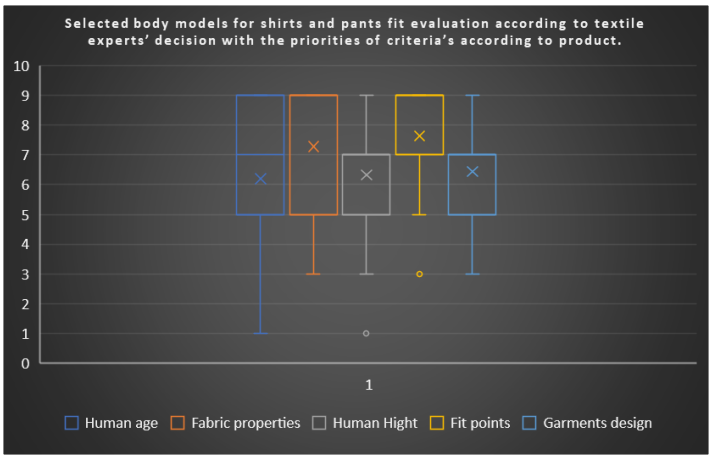

Fig 9. Selected body models for shirts and pants match assessment by textile experts' selection with the priorities of criteria per the product

Avatar model garments (Casual shirt) Fit analysis by 3D CLO software

In Figure 11, we can see the total measurement sheet according to the size chart of Bangladeshi 20–25-year-old men. In this Figure, the avatar is designed according to the top and bottom measurements of the actual human body shape. In this measurement chart, some allowance or tolerance has been given (0.5–1). A few of the measurements have been made according to the respective measurements in the Bangladesh size chart. This avatar reflects the measurements of a 22-year-old medium-size human body. This measurement reflects other ages' human body shapes.

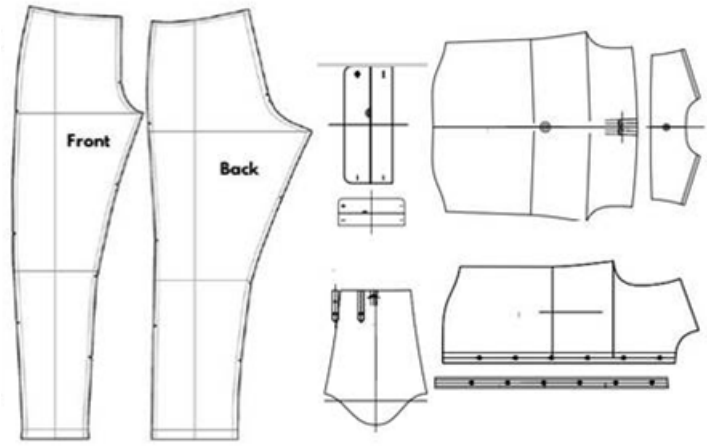

Fig 10. Casual shirts and pant patterns created by 3D CLO

First, for basic casual shirts: In this fit analysis, 3D CLO software has been used. Woven fabric (100% cotton) is considered for fabric design. Simple, casual, basic shirts have been developed for this test. This size is related to 20–25-year-old Bangladeshi

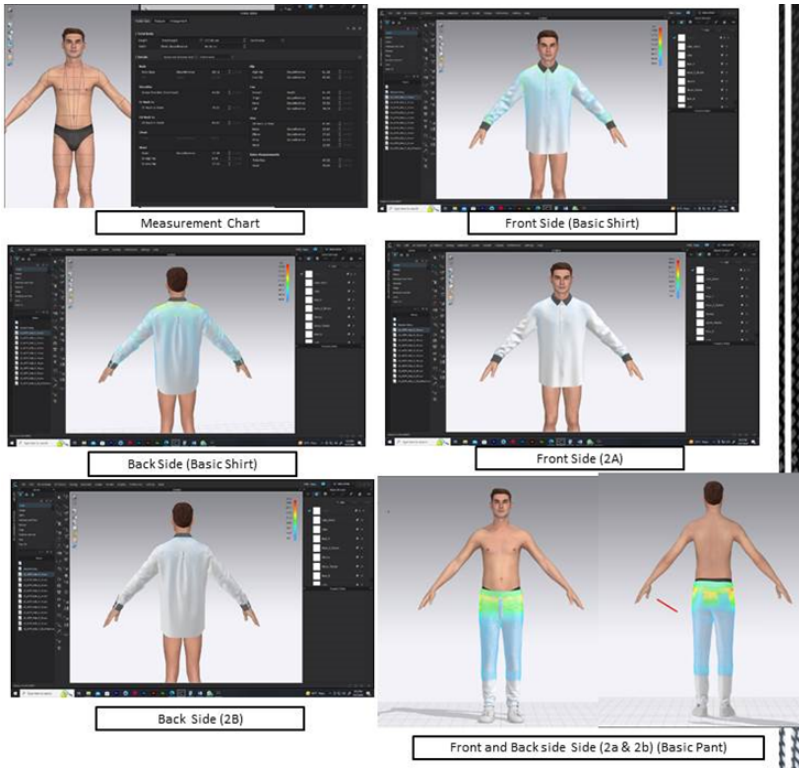

Fig 11. Basic shirt and pant fit analysis by 3D CLO software

men's 22-year-old medium size. In this software, four types of figures are shown in Figure 11. The front and back sides have been considered very seriously, according to the opinions of 50 textile experts using the AHP method.

In this section, three types of color have been represented in the garments. RED, YELLOW, AND GREEN. In this section, RED means a severe issue, YELLOW is also a major issue, and GREEN is in the moderate category. The color bar represents the minimum and maximum level of stress on the product when it is worn as a dummy or dress form. In terms of stress, it refers to the amount of pressure that is generated on the body because of garments and vice versa because of garments adorning a body[17,18,20]. Stress is measured in percentages. The front view of the shirt is marked in red for shoulder, armhole, chest, front body width, sleeve length, and sleeve opening. In the back, the major stressed areas are the neck, yoke, and shoulder.

Secondly, for basic casual pants, the rearview illustrates the stress generated by the hip circumference, waist circumference, thigh circumference, back rise, cuffs, and crotch point. While the front illustrates the major stressed areas, they are the waist, front rise, outer seam, inside leg measurement, and crochet point. Regarding Strain Mapping, similar areas are stretched when being worn, which also causes damage to the body, and the fabric may be distorted from its original shape; sometimes it may also show seam puckering. Due to stress and strain, pressure points are generated on the garments. Generally, pressure points should be created in the functional area where body proportion allows for seam line construction, as stated above.

According to this study, men have a wide range of fit issues when selecting and wearing men's clothing, especially shirts and pants. Most significantly, men experience fit issues with the dimensions of their garments, which are fixed by the current sizing system: neck circumference, sleeve length, waist circumference, pants leg length, chest circumference, rise measurement, and body width.

4 Conclusions

To ensure the fit and balance of the clothes, all Bangladeshi factories conduct research and development using a virtual fitting system. The study team has therefore adhered to the AHP and CLO 3D systems to guarantee that clothing fits the recently created Bangladesh garment size chart. The key takeaway from this study's findings is that AHP and CLO 3D software can be used to evaluate and predict basic shirt and pant fit. In terms of the product's evaluation of efficacy and flexibility of execution of tiny adjustments for the intended application, the result of digital clothing pressure values measured in various body zones shows

adequate improvements. Making a preliminary assessment of the materials draped on the body is also possible, since the virtual representation demonstrates the production of surface texture, volume, and deformation following the cut of the pattern and the physical properties of the simulated fabric, making the body feasible as well [21]. Sometimes the program's findings have error points that are visible in production. The authors in this instance used the AHP approach to avoid production errors. Finally, the study's concluding findings point to a favorable development for Bangladesh's ready-to-wear market's final production. The new size chart has been adopted by the AHP method and evaluated by the 3D CLO software. So, in the future, garment production in Bangladesh can use the AHP method absence of any 3D software or 3D Scanner. In the future, more body models in various postures will improve the research model, as this is the first attempt at the section of the most appropriate human body models for evaluating garment fit. Furthermore, greater focus will be placed on defining the assessment areas to enhance correspondence among apparel manufacturers, retailers, and consumers.

Authors Contributions

All authors have equal contributions to project design, data analysis, original draft preparation, writing, review, and approval of final submission.

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