TEKSTİL VE KONFEKSİYON

VOL: 34, NO. 2
DOI: 10.32710/tekstilvekonfeksiyon.1110944

Fit Analysis for Racket Sports Apparel by Virtual Simulation Technique

Sai Krishnan A N[1] 0000-0003-2873-2986
Kanakaraj P[2] 0000-0003-2678-159X
Ramachandran R[3] 0000-0001-5954-0747

[1] PSG Polytechnic College,Department of Apparel Technology / Coimbatore, India
[2] PSG College of Technology,Department of Fashion Technology/Coimbatore, India
[3] National Institute of Fashion Technology/Kannur,India

Corresponding Author: Sai Krishnan A N, vijayysai@gmail.com

ABSTRACT

This study determines the fit of racket sportswear for women's interlock knitted top in different body zones of sports personnel by altering the pattern shapes and fabric yield by using a virtual CAD platform.The fabrics with areal densities of 120,160,and 200 Grams / Sq.m were chosen, and twenty-seven virtual patterns were developed by altering the patterns in armhole shapes and dart positions based on the measurements taken by female sports personnel. A parametric avatar was created, and all the patterns were simulated to check the fit of the avatar by virtual simulation techniques using Lectra - Modaris software. Ease and strain were determined in critical fit zones and optimized using design expert statistical software to get the perfect fit on the customized avatar. Sportswear has been constructed using optimized parameters, and subjective evaluation is done to compare the virtual and real fit.

ARTICLE HISTORY
Received: 30.04.2022
Accepted: 20.12.2022

KEYWORDS

Avatar, CAD, garment fit, pattern alteration, sportswear, 3D virtual simulation

1. INTRODUCTION

Currently, consumers are purchasing apparel products by choosing the apparel fit as an important element for making a buying decision and how it looks in appearance [1]. Garment fit is an important factor that brings confidence and comfort to the wearer, as well as individual psychological comfort and social well-being [2]. Positive and negative feelings toward one's body are stated as "body cathexis." It may also influence the wearer's satisfaction with the fit. [3]. Dissatisfaction with the fit is also due to a consumer purchasing the apparel product by selecting the size without visualising the garment on their physical body [4]. In the purchase decision, the consumer is also evaluating the fit in terms of multi-dimensional characteristics such as physical, aesthetic, functional, and social comfort. Physical fit often relates to the tightness and length, while aesthetic fit is the overall appearance related to the proportions of the individual body, which influence the wearer's perceptions of attractiveness. The functional fit defines the wearer's experience of comfort in walking, sitting, standing, and exercising without any restriction of garments; social comfort on clothing is often expressed by others in verbal terms such as tightness or the aesthetic appearance of the garment [5]. The fit also plays an important role in functional clothing as apparel is subjected to dynamic movement [6]. The critical factors to be taken into consideration are garment size, material parameters, style details, and body size [7].

In a study by Kurt Solomon, it was stated that although women may have similar girth measurements, they differ in body shape, proportion, and posture [8]. Zumrut Bahadr Unal reported that growth and shrinkage of body parts of athletes are also affecting their fit, which needs special attention to solve the problems of developing correct

To cite this article: Sai Krishnan A N, Kanakaraj P, Ramachandran R. 2024. Fit Analysis for Racket Sports Apparel by Virtual Simulation Technique. *Tekstil ve Konfeksiyon,* 34(2), 99-109.

patterns for their higher muscular bodies[9]. Jiaqi Yan and Victor E Kuzmichev studied that body morphology is an important factor in pattern design and the evaluation of apparel fit. [10]. The fit is evaluated for close- fitting dress in the virtual platform by inputting the low stress mechanical properties of woven fabrics. The local deformation in the virtual simulation dress found that the mechanical properties of the fabric influence the garment fit and appearance quality [11]. The drape and flexural rigidity of knitted fabrics are also important for designing sports clothing due to the formability of clothing according to human body movement, as the fabric draping behavior influences the fabric geometry, shearing, tensile, and bending properties [12]. Ancutienė and Sinkevičiūtė investigated and found that material aspects of fabric mechanical properties such as tensile, bending, shear,and fabric structural properties affect the stress and strain of the wearer [13]. It is also stated that knitted fabric has inherent characteristics of stretch and elasticity, which have advantages for designing a comfortable fit to the body [14]. It has been reported that the comfort and fit of a garment are measured by its visual and tactical quality; the visual aspects include how the garment looks on the wearer's body. The tactile quality of touching and pressure sensation, where the pressure sensation is created as a kinesthetic response on clothing fit.

Generally, sports garments should have key properties such as body fit, moisture management, and durability [15–16]. The wear comfort of sportswear influences the performance of the sports activity, especially ergonomic wear comfort, which depends directly on the fabric properties and pattern design of the garment component. Sportswear performance also depends on the sport and the amount of physical activity. Sports like tennis, badminton, soccer, and volleyball are played with lower duration and maximum physical activity. The player's comfort level affects sports performance [17–18]. Since the stretch and elastic recovery of fabric provide sufficient fit and freedom of movement, sports garments with body compression characteristics will also enhance athletic performance and reduce muscle fatigue [19–20]. Assessing the fit is an important aspect for both the manufacturer and the client to fulfil the customer's preference while wearing.

Nowadays, the scope of using 3D CAD technology eventually brings faster product assessment and development, since the time consumption in product development constitutes 70% of the total and actual manufacturing is only about 30% [21]. The 3D virtual fit technology is emerging as a new solution and reducing the lead time of sample garment development and assessment. At present, the apparel sourcing agents are swiftly adopting the technology, and domestic suppliers understand its importance. It also acts as an effective communication tool between buyers and apparel manufacturers in the apparel supply chain [22]. It is also found that the designer has an idea to validate the fit in different fabric types and apparel styles by simulating the 2D pattern pieces in the parametric avatar model [23]. The effective use of 3D virtual simulation technology was reported by Lee and Park [24]. Moreover, an investigation was carried out by developing woven and knitted blouse styles and comparing the differences between the virtual and real garments. It was reported that the ratability of the system depends on the effective use of fabric properties and virtual sewing. CAD systems have an interlink between fabric material parameters and pattern design since mechanical properties have a significant influence on the garment fit [25]. Considering the importance of 3D simulation technology, this study aims to investigate the fit of interlock knitted sportswear for women subjected to badminton sports action using 3D simulation software. The fit is determined by integrating low stress mechanical properties and changing the pattern variables for the objective evaluation, which is validated with the subject using a wear study.

2. MATERIAL AND METHOD

2.1 Material

The polyester interlock knitted fabric with three different areal densities namely P1, P2,and P3, was sourced for the study. The reason for choosing interlock fabric was due to its better dimensional stability when compared to single jersey fabric. These fabrics were tested for physical properties and are tabulated in Table 1.

Table 1. Physical properties of fabrics

Properties	Standards	P1	P2	P3
Structure	ISO 23606:2009	Interlock	Interlock	Interlock
Yarn Linear density,Tex	ASTMD1907	14.7	17.4	19.6
Fabric Areal, g/m^2 Density(GSM)	BS EN12127	120	160	200
Thickness, cm	ISO 5086:1996	0.051	0.054	0.065

cc BY NC ND

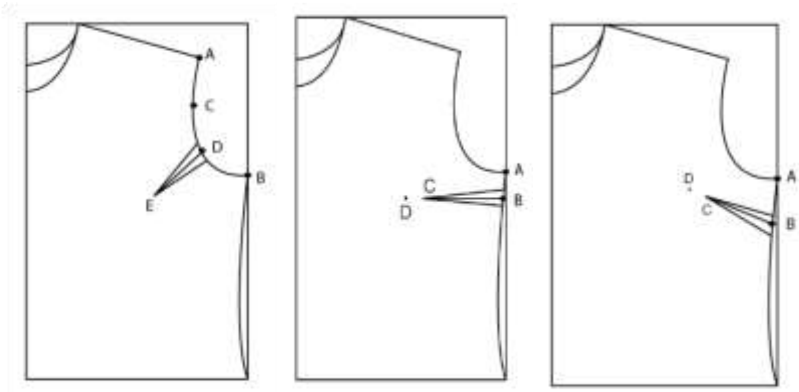
2.2 Method

2.2.1 Virtual pattern development

The sportswear T-shirt patterns were developed from Lectra Modaris V8/R1 3D fit software based on the subject's measurements. The subject chosen for the study was a badminton player with a good track record at the state level in India. The body measurements of the subject were taken manually, and a 3D avatar was developed using Modaris V8R1 3D simulation software. The subject body measurements are shown in Table 2. The mid armhole contour shape and dart position were varied as practised in the industry to assess the influence of these variables on the fit of the garment. The dart position is varied by positioning the flat patterns in the armhole region, bust line, and underbust line regions, represented as D1, D2, and D3 respectively, in Figure 1. The armhole dart D1 is developed by the way that the dart fold line moves toward the bust point from the armscye at an angle of -30˚ to the bust point. The bust line dart D2 is positioned such that the dart fold line is moving towards the bust point straight from the side seam at an angle of 0˚ to the bust point. The under bust dart D3 is positioned such that the dart fold line is moving towards the bust point from the side seam at an angle of 15˚ to the bust point. The dart points for all darts ended at 0.5" away from the bust point, with a dart intake of 2 cm. The armhole curve is a major aspect of fittings at the armhole, which leads to the movement of the hand. For racket sports, hand movement is very important, so this is considered one of the major factors. By analysing various shapes of armhole patterns, three variations in armhole curve shape were chosen for this study. As shown in Figure 2, the shape of the armhole curve is drafted by joining A a' B from the shoulder point A. The a to a' mid armhole is measured as 2, 3, and 4 cm towards the centre front for A1, A2, and A3.

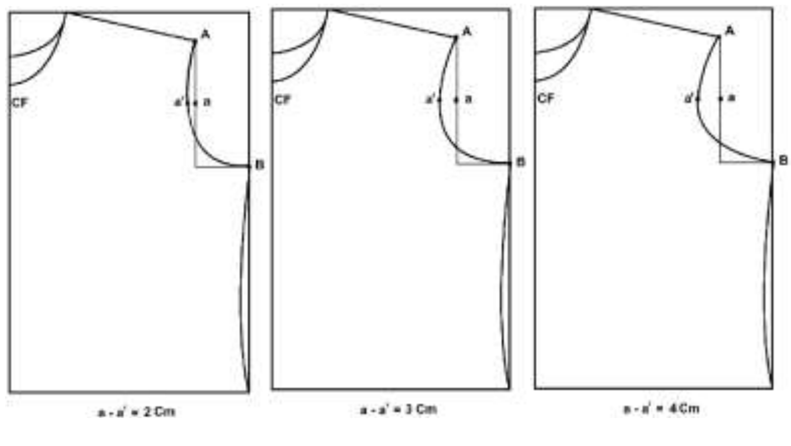
Table 2 Subject body measurements

S.No	Description	Measurement, cm
1	Neck circumference	31
2	Across front	31.5
3	Bust circumference	88.5
4	Under bust circumference	77
5	Across back	32
6	Waist circumference	83
7	Mid hip circumference	86
8	Shoulder length	12
9	Wrist Circumference	15
10	Arm Circumference	33
11	Arm length	56
12	Neck to Bust point	28



D1 D2 D3

Figure 1. Dart variations



A1 A2 A3

Figure 2 Armhole variations

CC BY NC ND

The experimental design is prepared using the design expert software, and the coded level for developing a virtual pattern is mentioned in Table 3. Totally 27 combination virtual patterns were developed by changing the fabric areal density,dart position angle, and mid arm hole curve using the modaris V8R1 software. The virtual development patterns were given with virtual stitches to convert them into 3D form.

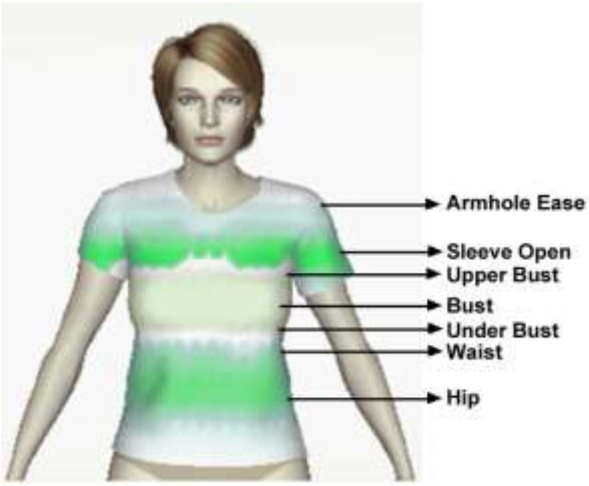


Figure3. Critical FIT Zones Indentified

2.2.2 Fit Assessment Method

The critical zones that affect the fit of the garment were identified as ease and strain values in these zones, which represent the fit, and were analyzed in the simulated garment on the created avatar. To obtain the digital fit in the critical zone, the low stress mechanical properties of the fabric, which are tabulated in Table 4, were fed as input in the 3D simulation software. The critical zones in which the fit of the garment is measured are shown in Figure 3. The optimal combination of the factors is determined using the best line of fit. Garments are created from optimised results in order to determine the subject's fit while wearing the garment and performing badminton sporting activities. A Likert-scale (1-poor to 5-excellent) format questionnaire was used to assess the subjective evaluation. Wearer opinions of the fit of the garment in the arm region, like the freedom of movement, and how the garments fit well in zones like the bust, upper bust, and under bust region were taken into consideration. The comfort and feel of the garment are also subjectively assessed by the wearer.

3. RESULTS AND DISCUSSION

The results in Table 5 show the strain and ease obtained from the virtual simulation for the various critical fit zones of the avatar. The effect of the independent variables on garment fit at various fit zones is discussed.

3.1 Effect of fabric GSM, mid armhole contour and dart angle on fit at armhole and sleeve open region

The effect of fabric GSM, armhole contour and dart angle on fit at the armhole and sleeve open regions are shown in Figures 4 and 5, respectively. Table 6 shows the models are significant for analyzing the fit at the armhole region (p-value<0.05) and sleeve open (p-value 0.0277<0.05). The armhole region and sleeve opening exhibit ease due to varying pattern variables and fabric GSM. It is also observed from the statistical analysis that there is a significant influence on fit at the armhole region and sleeve open, when the fabric GSM, mid-armhole contour shape, and dart position are varied. The dart angle of 0° to 15° at an armhole contour of 3 cm shows sufficient ease with lower fabric GSM; when the angle of the dart changes to -30°, it provides looseness for all the fabric GSM. Mc Cartney J and Hinds B K is also reported that customized garments can be effectively designed by considering some amount of fullness in terms of darts on the 3D surface, which also balances the significant effect of fabric thickness [26]. In terms of armhole shaping, a mid armhole contour distance of 3 cm provides sufficient ease for lower fabric GSM; the finding also shows that any dart angle of lower fabric GSM provides sufficient ease. The required fit is achieved by the dart angle of -7.5 to -8.5 and the A3 curve position of the armhole, which is more concave and provides sufficient ease in the armhole fit and reveals good wearer comfort.

In the sleeve open region, the armhole dart (D1), which has been positioned at -30° in the armhole region, provides a significant difference in ease in the sleeve region; the ease is higher for fabrics with a lower GSM. This may also be due to the low stress mechanical properties of interlock knitted fabric, i.e., the tensile strain (EMT) and tensile resilience (RT) are higher for P1 fabric, which will have good wearing comfort. The bending rigidity and bending hysteresis are less for P1 fabric, which will bend easily and have a higher ability to recover. .

Table 3. Coded level for developing patterns

Variables	Coded levels		
	-1	0	1
Fabric areal density (P), g/m^2	P1, 120	P2, 160	P3, 200
Mid armhole contour (A), cm	A1(2)	A2(3)	A3 (4)
Dart angle (D), ˚	D1 (-30˚)	D2 (0˚)	D3 (15˚)

Table 4. Low stress mechanical properties of Interlock fabric

Fabric	Tensile				Bending		Shear		Friction
Interlock	LT	WT (gf.cm /cm^2)	RT (%)	EMT (%)	B (gf. cm ^{2}/cm)	2HB (gf.cm/cm)	G (gf/cm.deg)	2HG (gf/cm)	MIU
P1	0.79	5.22	39.86	12.69	0.008	0.010	0.76	2.72	0.24
P2	0.85	3.64	39.46	8.52	0.010	0.011	0.94	3.67	0.30
P3	0.80	3.48	39.13	8.27	0.020	0.018	1.09	4.32	0.28

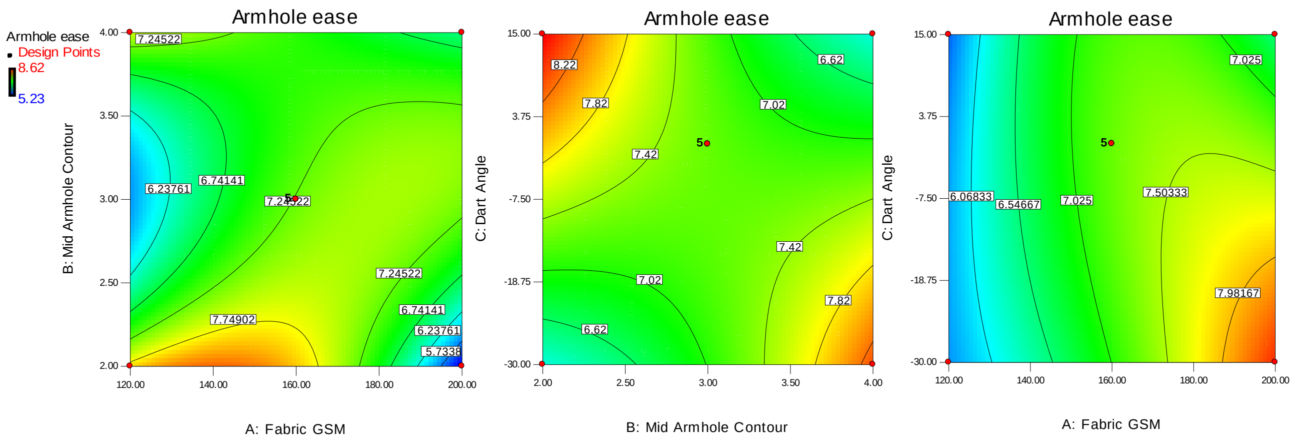


Figure 4. Effect of GSM, Mid arm hole contour and dart angle on fit at armhole

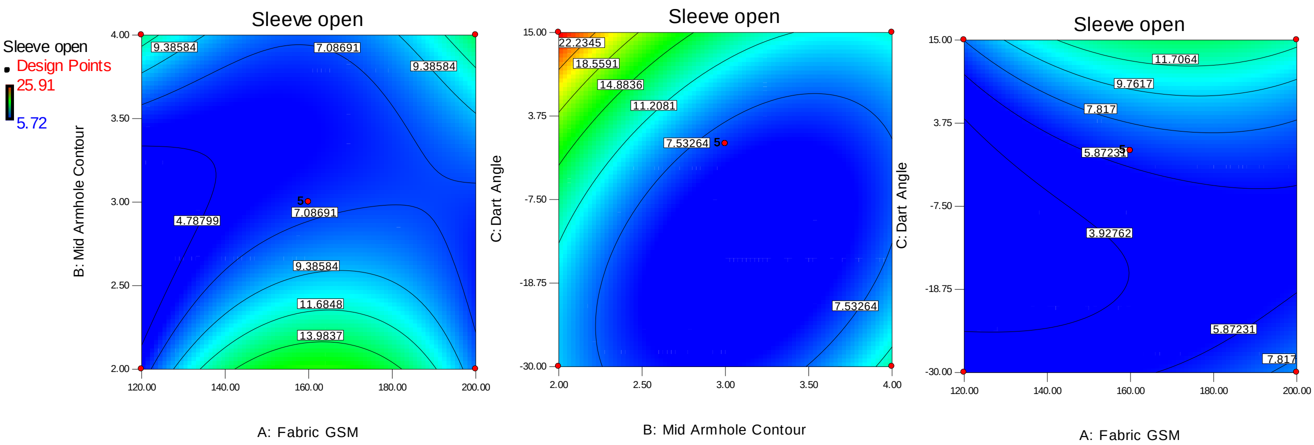


Figure 5. Effect of GSM, Mid armhole contour and dart angle on fit at sleeve open

3.2 Effect of fabric GSM, mid armhole contour ,and dart angle on fit at upper bust and bust regions

Figures 6 and 7 show the effects of fabric GSM, armhole contour, and dart angle on garment strain or ease in the upper bust and bust regions, respectively. Table 6 shows the models are significant for analyzing the fit at the upper bust (p-value<0.05) and bust region (p-value 0.0221<0.05). In the upper bust region at a dart angle of -30°, a minimal amount of ease has been noticed in the fabric GSM 120 to 140, and beyond that, very little strain has been noticed. The strain increases as the fabric GSM increases in the dart angle range of 0° to 15°. The shaping of the upper armhole also shows a distinct effect in the fit zone of the upper bust, which exhibits more strain in the upper bust region. Regardless of dart position, strain is much higher in the bust region, and varying dart angle has no significant influence on fit in the upper bust and bust regions. But the fabric GSM influences the bust fit zone more than the armhole contour. It is found that the mid-armhole contour A2 provides a sufficient amount of tightness, and it is also noticed that the fabric is subjected to minor compression by virtually fitting the garment in the avatar model.

BY NC ND

Table 5 Fit zone ease and strain

Sample code			Armhole	Sleeve Open	Upper Bust	Bust	Under Bust	Waist	Hip
P1	A1	D1	8.59	7.28	-2.29	-7.16	-2.54	4.74	2.28
P1	A1	D2	7.85	6.02	-5.4	-7.19	-2.49	4.6	2.52
P1	A1	D3	8.26	4.99	-1.32	-6.81	-4.74	4.31	2.26
P1	A2	D1	5.74	5.72	2.99	-3.67	2.82	12.25	3.78
P1	A2	D2	10.64	6.34	-0.49	-4.1	-2.44	10.46	3.49
P1	A2	D3	5.59	7.86	-1.37	-6.9	-3.94	4.83	2.32
P1	A3	D1	5.68	9.16	-3.62	-6.84	-2.26	4.35	2.15
P1	A3	D2	7.55	12.75	-2.96	-7.18	-4.14	4.65	2.67
P1	A3	D3	6.62	10.58	0.3	-6.97	-5.29	4.93	2.41
P2	A1	D1	6.22	9.6	-1.19	-7.17	-4.07	4.64	3.71
P2	A1	D2	3.28	11.42	-4.22	-7.26	-2.75	4.6	3.67
P2	A1	D3	8.62	25.91	-5.06	-6.97	-3	4.68	2.74
P2	A2	D1	7.7	8.84	-3.04	-6.8	-2.7	4.81	1.85
P2	A2	D2	7.26	6.52	-3.45	-6.83	-0.49	4.27	2.2
P2	A2	D3	6.6	9.83	-4.69	-7.05	-3.27	4.3	2.32
P2	A3	D1	8.33	12.32	-3.04	-6.86	0.59	4.61	1.9
P2	A3	D2	7.63	11.4	-3.68	-7.16	-3.53	4.29	2.71
P2	A3	D3	6.23	11.34	-3.88	-6.96	-3.73	4.2	2.2
P3	A1	D1	3.63	8.74	-4.52	-7.22	-3.92	4.55	3.11
P3	A1	D2	5.23	8.11	-5.99	-7.22	-5.41	4.11	3.37
P3	A1	D3	7.64	17.23	-5.54	-7.2	-4.51	4.37	2.88
P3	A2	D1	8.46	8.44	-3.19	-6.89	-3	4.25	2.25
P3	A2	D2	6.68	4.88	-3.43	-6.74	-3.78	4.59	1.95
P3	A2	D3	6.58	12.18	-3.96	-7.06	-3.72	4.44	2.51
P3	A3	D1	7.98	6.47	-5.64	-6.78	-5.25	4.08	1.92
P3	A3	D2	6.55	13.72	-3.05	-7.06	-5	4.2	2.54
P3	A3	D3	6.1	14.5	-3.27	-7.02	-4.84	4.06	2.12

Table 6 ANOVA test results for the responses-Armhole, Sleeve open and Upper bust and Bust region

	Armhole		Sleeve open		Upper bust		Bust	
	F	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Model	1.846E+05	<0.0001*	3.20	0.0277*	3.92	0.0122*	3.40	0.0221*
P	1.235E+05	<0.0001*	7.37	0.0133*	12.60	0.0020*	6.91	0.0161*
A	9.211E+05	<0.0001*	2.42	0.1149*	1.09	0.3546**	3.76	0.0411*
D	7052.16	<0.0001*	1.70	0.2080**	2.16	0.1413**	0.5778	0.5702**
P*A	3311.50	<0.0001	-	-	-	-	-	-
A*D	2.155E+05	<0.0001	-	-	-	-	-	-
P*D	12388.27	<0.0001	-	-	-	-	-	-

*=Significant terms at 95% level **= Not significant terms at 95% level

Table 7 ANOVA test results for the responses-Under bust, Waist and Hip region

	Under Bust		Waist		Hip	
	F	*P*	*F*	*P*	*F*	*P*
Model	4.44	0.0070*	2.81	0.0445*	2.60	0.0574**
P	8.00	0.0104*	6.07	0.0230*	0.3399	0.5664**
A	3.68	0.0437*	2.60	0.0990**	5.24s	0.1483**
D	2.51	0.1066**	0.9355	0.4089**	2.00	0.1615**
P*A	-	-	-	-	-	-
A*D	-	-	-	-	-	-
P*D	-	-	-	-	-	-

*=Significant terms at 95% level **= Not significant terms at 95% level

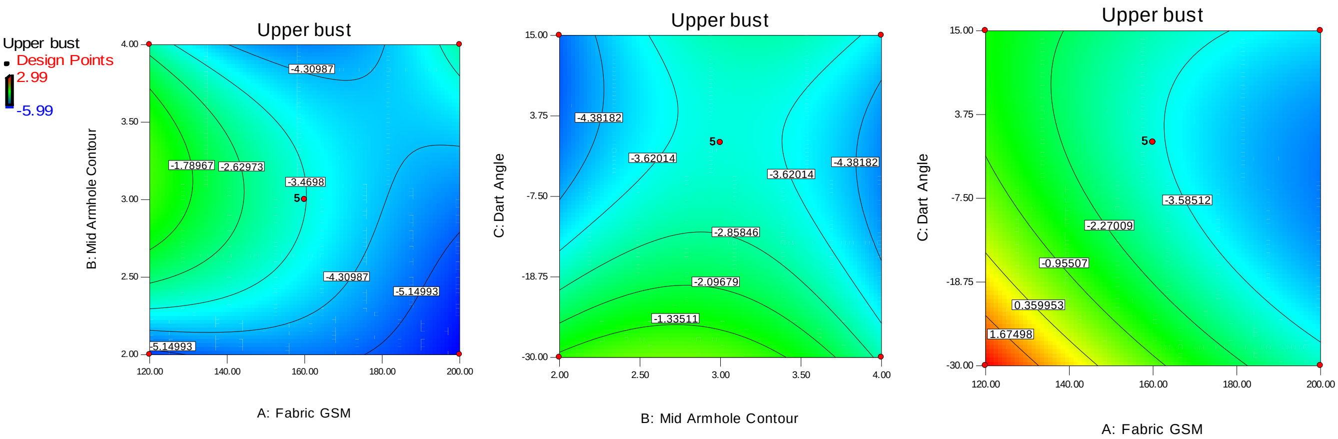


Figure 6. Effect of GSM, Mid armhole contour and dart angle on fit at upper bust

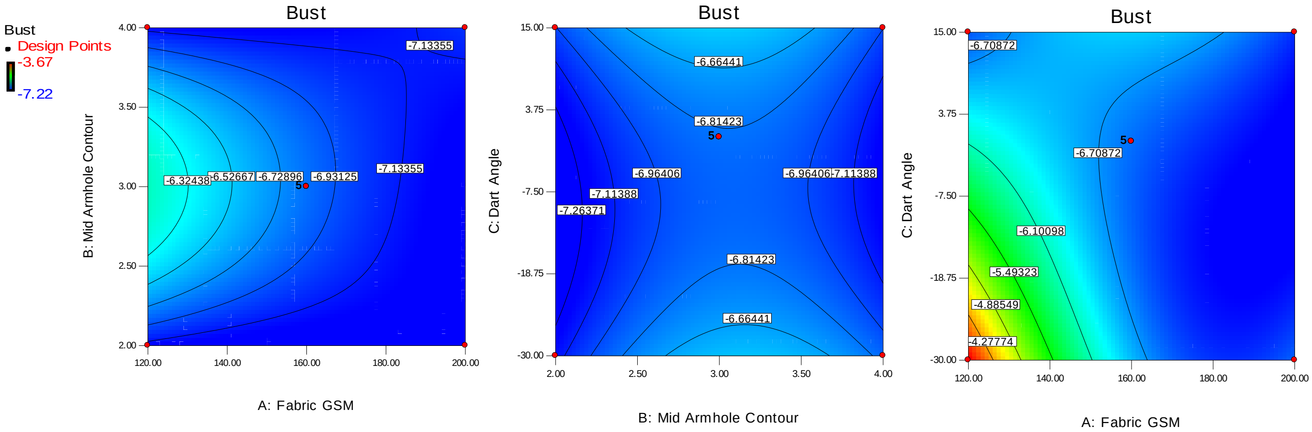


Figure 7. Effect of GSM, Mid armhole contour and dart angle on fit at Bust

3.3 Effect of fabric GSM, mid armhole contour, and dart angle on under bust

The Figure 8 shows the effect of fabric GSM, armhole contour and dart angle on garment fit on under bust. The Table 7 shows the model is at significant (p-value 0.0070 is lesser than 0.05). The fabric GSM and armhole contour shape provides significant effect individually, but the dart angle shows insignificant influence (p-value 0.1066>0.05) at 95 % level. At lower fabric GSM provides a sufficient degree of ease in the underbust region, whereas as increases in fabric GSM it exhibits strain in the underbust region.The shape of the armhole contour at A2 (3 cm),the under bust region have enough strain for the garment. Although the increases in the mid arm hole contour from 3 cm provides a optimum ease, which require for free movement of hand to the sports personnel.

3.4 Effect of fabric GSM, mid armhole contour, and dart angle on on waist and hip zones

The effects of fabric GSM, armhole contour and dart angle on the assessment of garment fit in the waist and hip regions are plotted in Figures 9 and 10, respectively. The statistical ANOVA analysis at Table 7 shows the model for the waist is significant (F-value 2.81 > p-value 0.0445) and the hip region is also significant (F-value 2.60 > p-value 0.05). The fabric GSM has a significant influence on fit at the waist zone (p-value 0.0230<0.05), but the pattern parameters do not influence this significantly. The quantum of ease is higher for lower fabric GSM and subsequently reduced for higher GSM. This could be due to the elongation property of interlock knitted fabric; as the GSM increases, elongation and recovery are reduced. Since the D2 and D3 dart positions are below the armhole, they provide less ease than the D1 position, which is only located in the armhole region. However, in the hip region, there is no significant difference in ease as a result of changing the pattern parameters and fabric GSM.

3.5 Optimized Values with Desirability Percentage

The optimal ease or strain that was fed before optimizing the final combinations of fabric areal density, armhole shaping, and dart placement is shown in Table 8. Upper arm movement is essential for racket sports, and a good amount of ease has been established as the target in the armhole and sleeve open region. Regarding the upper bust, bust, and under bust, sufficient strain is required, so negative ease has been given. The waist and hips are targeted with minimal ease to the body contour. The final optimized combinations were generated from design expert software and are given in Table 9. The optimized results obtained are with an areal density of 122.4 GSM, Mid arm hole contour of 3.69 cm, and a dart angle of -7.91˚ which showed the highest desirability percentage by considering several responses and factors. The desirability contour graph,virtual simulation of garments with color scale are also shown in Figure 11.A form fit no ease or tightness is indicated by the neutral colour scale. The hue of blue indicates looseness to very looseness, and yellow to red indicates tightness and strain. A garment is constructed from this combination to determine the subject's opinion of the fit with the help of a questionnaire prepared on a Likert scale. As shown in Figure 12, the opinion on the subject is that wearing the garment developed from the optimized combinations allows for excellent armhole movement and sleeve ease throughout the play without any restrictions. The underbust area is well fitted, and the flexibility and overall feel of the garment while playing are found to be excellent, which confirms the objective results of the simulation software that the garment meets the requirements of sportswear.

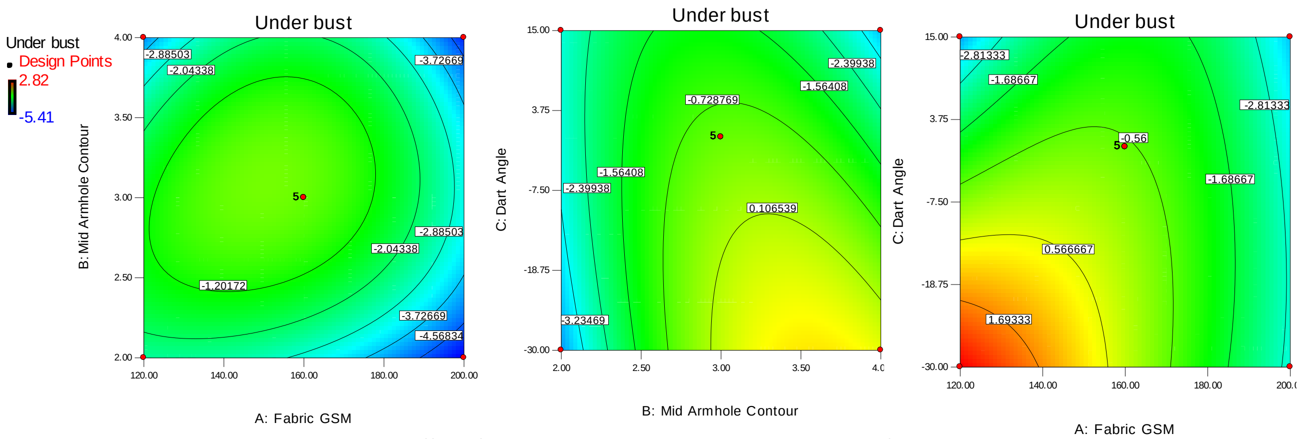


Figure 8. Effect of GSM, Mid armhole contour and dart angle on fit at under bust

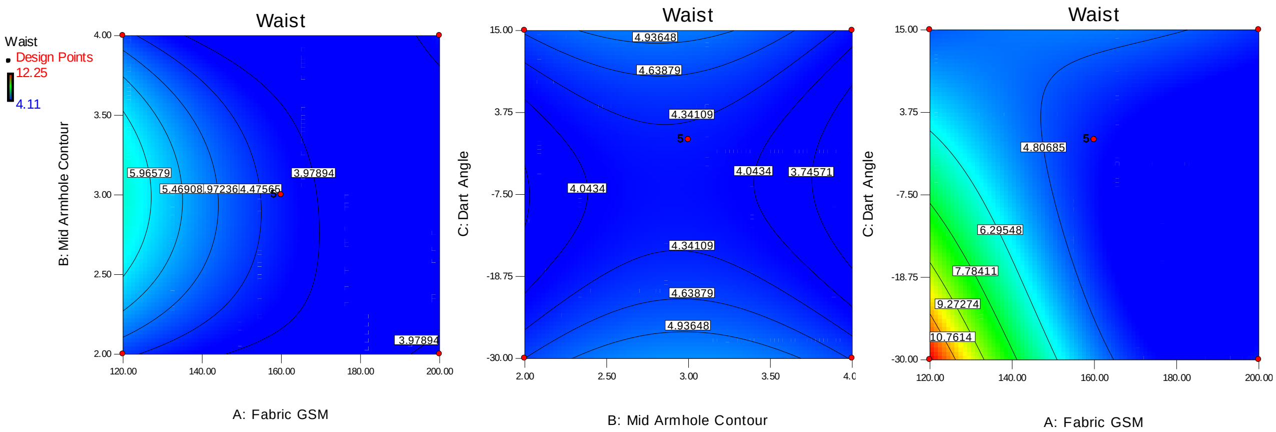


Figure 9. Effect of GSM, Mid armhole contour and dart angle on fit at waist zone

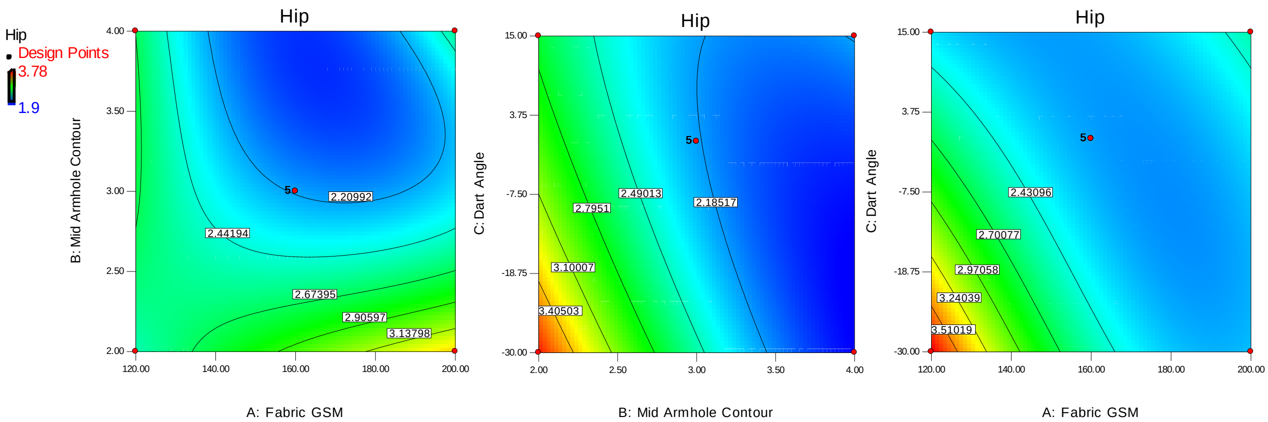


Figure 10. Effect of GSM, Mid armhole contour and dart angle on fit at hip zone

Table 8. Criteria considered for Optimal FIT of Sportswear

S.no	Criteria	Minimum limit	Maximum limit	Goal	Target ease, cm
1	Armhole ease	5.23	8.62	Target	6.9
2	Sleeve open	4.88	25.91	Target	6
3	Upper bust	-5.99	2.99	Target	-1.275
4	Bust	-7.22	-3.67	Target	-5.445
5	Under bust	-5.41	2.82	Target	-1.29
6	Waist	4.11	12.25	Minimum	4.11
7	Hip	1.9	3.78	Minimum	1.9

Table 9. Optimized combinations for fit of sportswear

Fabric areal density, g/m^2	Mid armhole contour, cm	Dart °	Armhole ease	Sleeve open	Upper bust	Bust	Under Bust	Waist	Hip	Desirability %
122.4	3.69	-7.91	6.92	8.02	-1.5	-6.15	-1.13	6.57	2.77	78.4
136.17	3.01	4.07	6.53	6	-2.26	-6.51	-1.01	5.21	2.35	76
136.03	2.99	4.02	6.54	6	-2.26	-6.51	-1.01	5.22	2.35	76
158.28	3.29	10.89	6.92	9.5	-3.22	-6.65	-1.29	4.65	2.11	74

Figure 11. Desirability percentage of the best combination and virtual simulation of Knitted top

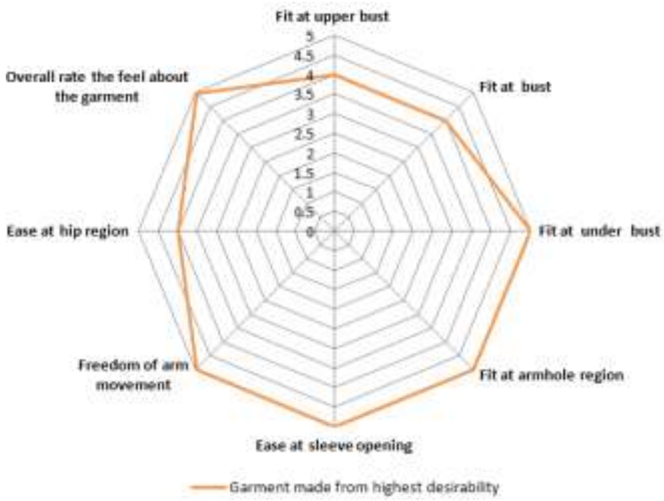


Figure 12 Subjective Assesment

4. CONCLUSION

An experimental investigation of the pattern parameters and fabric is carried out on a virtual platform to evaluate the fit for badminton sports apparel.The influencing parameters of the fit in the critical zones was studied. The response value is objectively quantified as the ease and strain in different fit zones. The key conclusions from the study are as follows:

CC BY NC ND

- In the armhole and sleeve region, the dart positioned in the armhole region influences a perfect fit by controlling the ease in the armscye region. This makes for good armhole movement, which is essential for racket sports activities. Regarding the sleeve open fit zone, the deeper mid armhole contour eventually results in sufficient ease in that zone.
- An increase in fabric yield leads to more tightness in the upper bust region, but a deeper mid armhole contour provides less strain. But in the bust region,the midarmhole contour of 3 cm provides sufficient strain in that region. For the under bust region, the dart positioned in the bust region provides sufficient strain in that region. Regarding the waist and hip zone, changes in pattern parameters and fabric yield do not reveal much difference in ease in that region.
- The shear properties affect the surface fitting characteristics of a garment, the fabric having a lesser yield the shear rigidity and shear hysteresis show lower eventually the fabric has an excellent ability to recover after it is shear and a better handle.
- The optimized combinations for achieving the perfect fit of the sportswear are: dart position angle -7.91˚, mid armhole contour 3.69 cm, and fabric GSM of 122.4. The subjective evaluation also confirmed the optimized values found objectively for the fit of the sportswear.
- Integerating the low stress mechanical properties of knitted fabric in virtual pattern development helps us determine the range of ease and strain in the different body zones; a quantified value has been found by changing the variables in patterns and fabric yield. This work also found that a novel attempt at changing material yield and pattern shape had a significant impact on the fit and ease or strain of the apparel in the critical zones, which can be quantified on the virtual platform.
- Digital technology has the potential scope for developing customized apparel products in a shorter lead time for the end-user client. Integrating the fabric's mechanical properties by virtual fitting will provide new directions by experimenting with upcoming styles and new textile fabric materials. This technology can contribute to the fit assessment of the garment for all age groups and sizes for selecting the best fit apparel to satisfy ergonomic and comfort wear from the wearer’s perspective.

Acknowledgement

The author wishes to thank Dr.K.Prakasan, Principal ,PSG College of Technology and Dr.P.Kandhavadivu,HOD-Fashion Technology for their help and encouragement in this work.The author wish to thank Dr.B.Giriraj, Principal and Dr.V.Chandrasekaran HOD-Apparel Technology of PSG Polytechnic College for their support in the work.

REFERENCES

1. Fan J,Yu W,Hunter L. 2004. *Clothing appearance and fit: Science and Technology.* England : Woodhead Publishing limited.
2. Varghese N, Thilagavathi G. 2012. Fit of sari blouse: Influencing parameters and assessment. *Journal of Textile and Apparel, Technology and Management* 7(4), 1-19.
3. Labat KL, Delong MR. 1990. Body Cathexis and Satisfaction with fit of apparel. *Clothing and Textiles Research Journal* 8(2),43-48.
4. Kim D E, Labat K. 2013. Consumer experience in using 3D virtual garment simulation technology. *Journal of the Textile Institute* 104(8), 819-829.
5. Shin E, Damhorst ML. 2018. How young consumers think about clothing fit?”. *International Journal of Fashion Design, Technology and Education* 11(3), 352-361.
6. Boorady LM. 2011. Functional clothing- principles of fit. Indian *Journal of Fibre and Textile Research* 36(4),344-347.
7. Zhi-Hua Hu,Yong-sheng Ding, Xiao-Kun Yu,Wen-Bin Zhang,Qiap Yan. 2009. A hybrid neural network and immune algorithm approach for fit Garment Design. *Textile Research Journal* 79(14),1319-1330.
8. Watkins P.2011. Designing with stretch fabrics. *Indian Journal of Fibre and Textile Research* 36(12),366-379.
9. Zümrüt Bahadir Ünal. 2020. An Investigation of Suit Choices of Men with Muscular Body structure.*Tekstil Ve Konfeksiyon* 30(4),296-301.
10. Jiaqi Yan and Victor E Kuzmichev, 2020. A virtual e-bespoke men’s shirt based on new body measurements and method of pattern drafting. *Textile Research Journal*, 90(19-20), 1-22.
11. Ancutiene K, Strazdiene E, Lekeckas K. 2014. Quality evaluation of the appearance of virtual close-fitting woven garments. *Journal of the Textile Institute* 105(3), 337-347.
12. Filgueiras A, Fangueiro R, Soutinho F. 2009. Drape behaviour of functional knitted fabrics for sport clothing. *Indian Journal of Fibre and Textile Research* 34(3),64-68.
13. Ancutienė K, Sinkevičiūtė D. 2011, The Influence of Textile Materials Mechanical Properties upon Virtual Garment Fit. *Material Science* 17 (2),160-167.
14. Fatkić E, Geršak J. 2011. Influence of Knitting Parameters on the Mechanical Properties of Plain Jersey Weft Knitted Fabrics. *Fibers and Textiles in eastern europe* 19(5),87-91.
15. Ashdown SP, DeLong M. 1995. Perception testing of apparel ease variation. *Applied Ergonomics* 26(1), 47-54.
16. Senthil Kumar M, Ashok Kumar L, Anbumani N. 2012. Design and Development of a pressure sensing device for analysing the pressure comfort of elastic garments. *Fibres and Textiles in Eastern Europe* 20(190), 64-69.
17. Mounir H, Khadijah Q, Hany A H, Ebraheem S, Mofeda A. 2012. Influence of Sportswear Fabric Properties on the Health and Performance of Athletes. *Fibres and Textiles in Eastern Europe* 20(4),82-88.
18. Manshahia M, Das A. 2014. High active sportswear – a critical review. *Indian Journal of Fibre and Textile Research* 39(4),441-449.

19. Suganthi T, Senthil Kumar P, Dipika V. 2017.Themal comfort properties of a Bi-layer knitted fabric structure for vollyeball sportswear. *Fibres and Textiles in Eastern Europe* 25(1),75-80.

20. Soyoung J.Song, Carol A Beard, Ksenia I Ustinova. 2015. The effects of wearing a compression top on trunk and golf club motions during golf swing . *Clothing and Textiles Research Journal* 34(1),1-13.

21. Indrie liliana, Mehmet mete mutlu, Nilay ork efendioglu, Tripa simona, Pablo diaz garcia, Miquel soler. 2019. Computer aided design of knitted and woven fabrics and virtual garment simulation. *Industria Texila* 70(6),558-563.

22. Hwang Shin SJ, Lee H. 2020.The use of 3D virtual fitting technology: comparison between sourcing agents contractors and domestic suppliers in the apparel industry.*International Journal of Fashion Design, Technology and Education* 13(3),300-307.

23. Sayem ASM, Kennon R, Clarke N. 2010. 3D CAD systems for the clothing industry. *International Journal of Fashion Design, Technology and Education* 3(2),45-53.

24. Lee E, Park H. 2017. 3D Virtual fit simulation technology: strengths and areas of improvement for increased industry adoption. *International Journal of Fashion Design, Technology and Education* 10(1), 59-70.

25. Sybille krywinski, Hartmut Rodel, Bandrea Schenk. 2001. Links between Design,Pattern Development and Fabric Behavior for clothing and Technical Textiles. *Journal of Textile and Apparel Management* 1(4),1-8.

26. McCartney J, Hinds B K. 1992.Computer Aided Design of Garments using digitized threee –dimensional surfaces. Proceedings of the institution of mechancial engineers,Part B: *Journal of Engineering Manufacture* 206(3),199-206.