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The role of knit stitch pattern and stitch length (SL) on the elongation and moisture management properties of seamless knitted fabrics for optimization of sports bra strap design

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Background

- Seamless knitted garments acknowledged as the future of next-to-skin apparel
  - Sports bras category has seen an influx of seamless knitted designs
- Starr (2002) found that elasticity, absorbency, and durability are important considerations for sports bra materials
  - Challenge: restricting breast movement during exercise
- Bra straps can have far reaching impacts
  - overly tight straps found to cause discomfort and potentially shoulder and neck pain and headaches (Cha, 2012; Pearse & Nanchahal, 2002)

Purpose of the Study

- Investigate the effect of SL and different patterns on seamless knitted fabric properties as applied to sports bra strap functionality.

Literature

- Previous research on bra straps indicates their elastic property, friction property, and the length and the width of the elastic fabric strips have impacts on the breast support and functional performance (Zhang et al.,2021)
- Kane et al. (2007) investigated textile comfort via measurements of four factors: (1) softness, (2) ability to absorb moisture, (3) air permeability, and (4) dissipation of heat and insulating properties
- Marmarali et al. (2017) concluded that with lower knit stitch size, stitch spacing is reduced and this allows the knitted garment to be denser, more compact, and compressive.

Literature Gap

- No studies have been found to investigate the role of knit stitch length on fabric properties that influence functionality of bra straps, such as fabric elongation, breathability, and moisture management.

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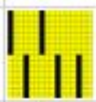
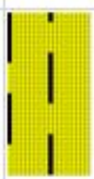
Experiment: Step 1

SL was set at 70, a default value for knitting sports bras, and twenty different stitch patterns commonly used for seamless knitted activewear were tried

Table 1. Knit structure and physical properties of the six fabric samples with SL=70.

Pattern #	Fabric Image (Technical front)*	CAD stitch design repeat**	Number of tuck stitches in 576	Density (courses/inch x wales/inch)	Thickness (mm)	Weight (gms)	Air permeability (l/m²/s)	Tensile strength			
								Breaking force		Elongation	
								N	SD	E (%)	SD
1			288	4656	0.78	3.22	133	53.76	2.62	302	3.29
7			288	4691	0.79	3.23	125	45.86	3.99	207	93.9
8			144	3647	0.81	3.1	278	47.71	3.45	241	6.65
10			90	3593	1.12	3.28	275	30.76	1.6	199	7.89
11			216	4537	1	3.54	267	45.14	2.49	226	8.99
12			40	3144	1.11	3.06	275	18.07	0.43	171	4.56

**Distance between 2 black lines on the ruler is 1mm*

***Legend: yellow pixel= jersey stitch, black pixel= tuck stitch*

****576 is the smallest repeat that includes all samples (Uyanik et al., 2016)*

Experiment: Step 2

- Air permeability and elongation data, patterns #8, #10, #11 and #12 were selected, and knitted tubes with SL=110 and SL=125 were knitted in these four patterns, relaxed, scoured and dried
- A 4x3 experimental design was used in this step, with two independent variables: knit stitch pattern and SL.

Table 2 . Physical properties of the 4 stitch patterns by 3 different SL, representing the samples of Step 2.

Pattern #	SL	Density (courses/inch x wales/inch)	Thickness (mm)	Weight (gms)	Air permeability (l/m2/s)	Tensile strength			
						Breaking force		Elongation	
						N	SD	E (%)	SD
8	70	3647	1.14	3.1	156.59	47.7	3.45	241	0.07
	115	4340	1.57	3.29	222.07	37.5	4.21	300	0.12
	125	5588	1.62	3.58	215.78	27.46	0.48	361.5	0.03
10	70	3593	1.12	3.28	181.78	30.76	1.60	199	0.08
	115	4480	0.95	3.42	183.09	23.35	1.08	269	0.06
	125	5136	0.98	3.34	179	24.07	1.61	307	0.25
11	70	4537	1	3.54	267	45.14	2.49	226	0.09
	115	4550	1.17	3.6	231	41.55	2.09	278	0.04
	125	6951	1.18	3.68	250	39.61	8.34	313	0.32
12	70	3144	1.11	3.06	275	18.07	0.43	171	0.05
	115	4096	1.14	3.1	226	16.67	0.87	330	0.30
	125	4891	1.26	3.23	267	16.36	0.44	352	0.18

Results

Table 3. One-way ANOVA results of the effect of pattern on air permeability, breaking force and elongation.

Dependent variable	p-value	Tukey HSD result
Air permeability	< .001	7 < 1 < 11 < (10 = 12 = 8)
Breaking force	< .001	12 < 10 < (11 = 7 = 8) < 1
Elongation	< .001	(12 = 10 = 7 = 11 = 8) < (11 = 8 = 1)

One-way ANOVA test results are shown in Table 3.

Results

Source	Degree of Freedom	F	p-value	Tukey HSD result
Model	11	317.40	< .001	
Pattern	3	296.23	< .001	10 < 11 < 12 < 8
SL	2	390.37	< .001	70 < 115 < 125
Pattern * SL	6	303.66	< .001	
R2	.970			

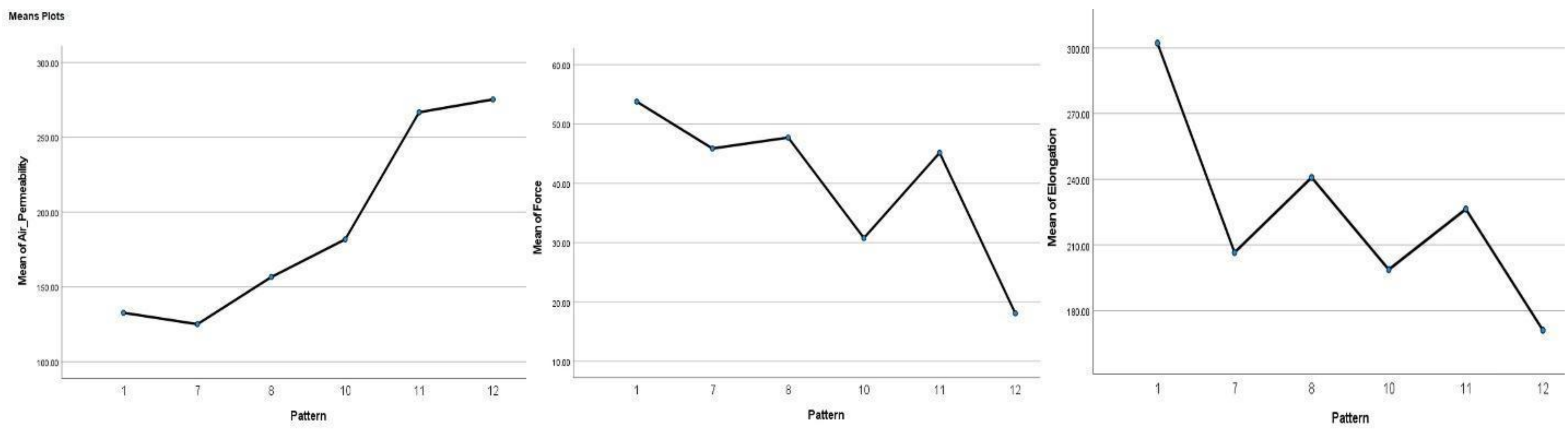
Table 4. Two-way ANOVA result of the effects of pattern and SL on thickness

Results

	Source	Degree of Freedom	F	p-value	Tukey HSD result
Air Permeability	Model	11	41.40	< .001	
	Pattern	3	110.39	< .001	10 < 8 < (11=12)
	SL	2	4.11	< .019	(115=70) < (70=125)
	Pattern * SL	6	19.33	< .001	
	R2	.808			
Elongation	Model	11	67.43	< .001	
	Pattern	3	18.60	< .001	(10=11)<(11=12) <8
	SL	2	301.73	< .001	70 < 115 < 125
	Pattern * SL	6	13.75	< .001	
	R2	.939			
Breaking Force	Model	11	65.48	< .001	
	Pattern	3	196.58	< .001	12 < 10 < 8 < 11
	SL	2	38.51	< .001	125 < 115 < 70
	Pattern * SL	6	8.91	< .001	
	R2	.938			

Table 5. Two-way ANOVA results of the effects of pattern and SL on air permeability, elongation, and breaking force (p-values)

Data Collected



(a) (b) (c)

Figure 1. Step 1 results for: (a) air permeability, (b) breaking force, and (c) elongation coefficient for patterns #1, #7, #8, #10, #11 and #12, at SL=70.

Data Collected

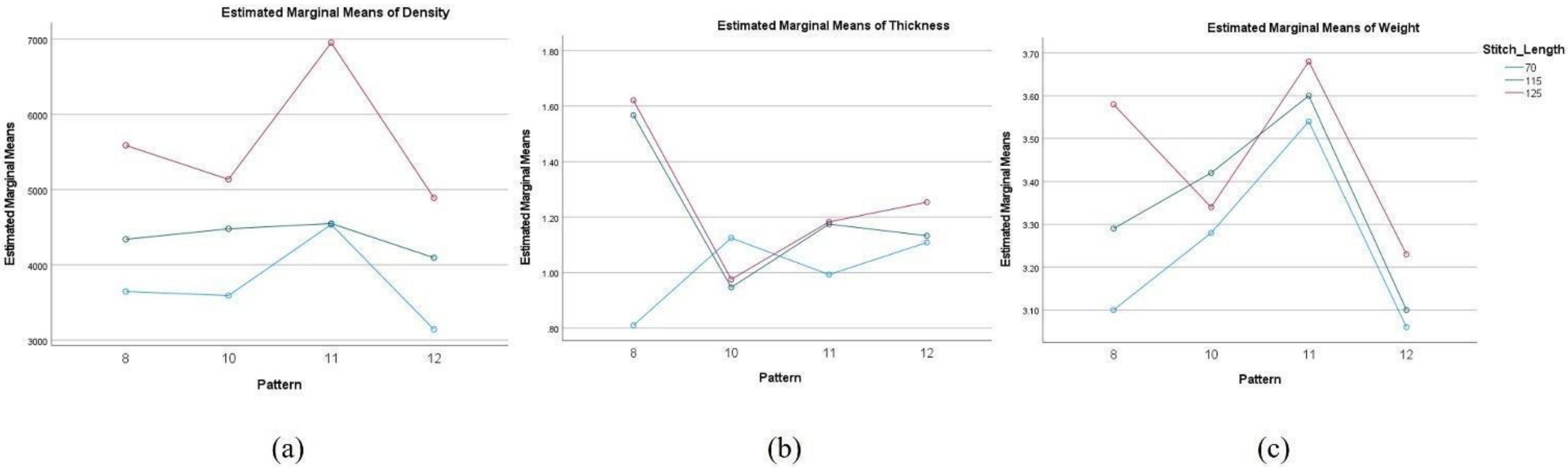


Figure 2. Estimated marginal means plots for the four patterns and three SL values for:

(a) fabric density, (b) thickness, and (c) fabric weight.

Data Collected

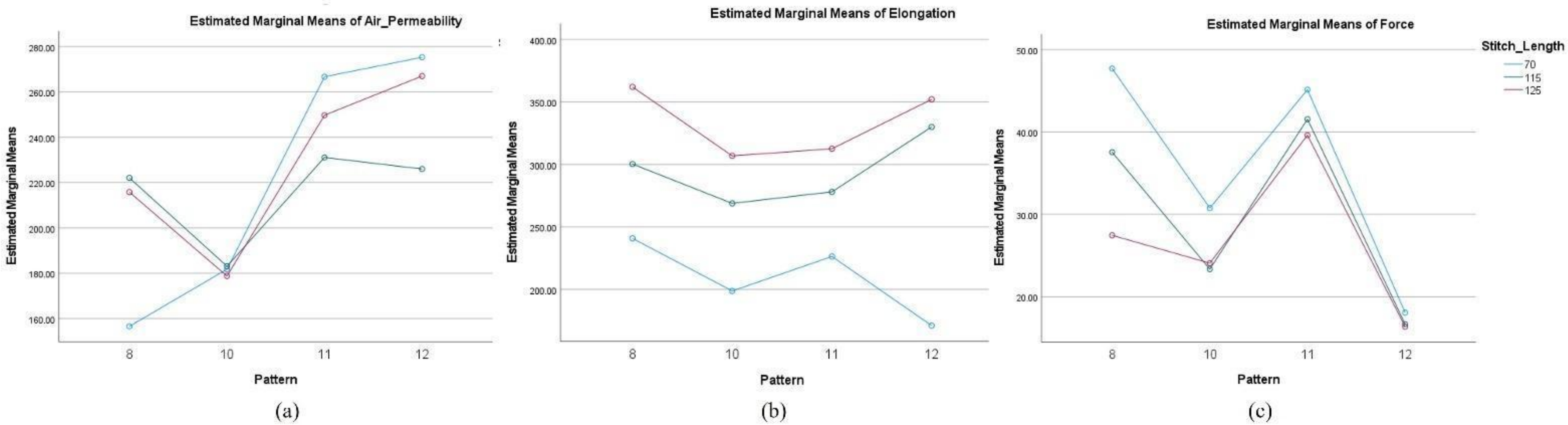


Figure 3. Estimated marginal means plots for the four patterns and three SL for: (a) air permeability, (b) elongation coefficient, and (c) breaking force.

Data Collected

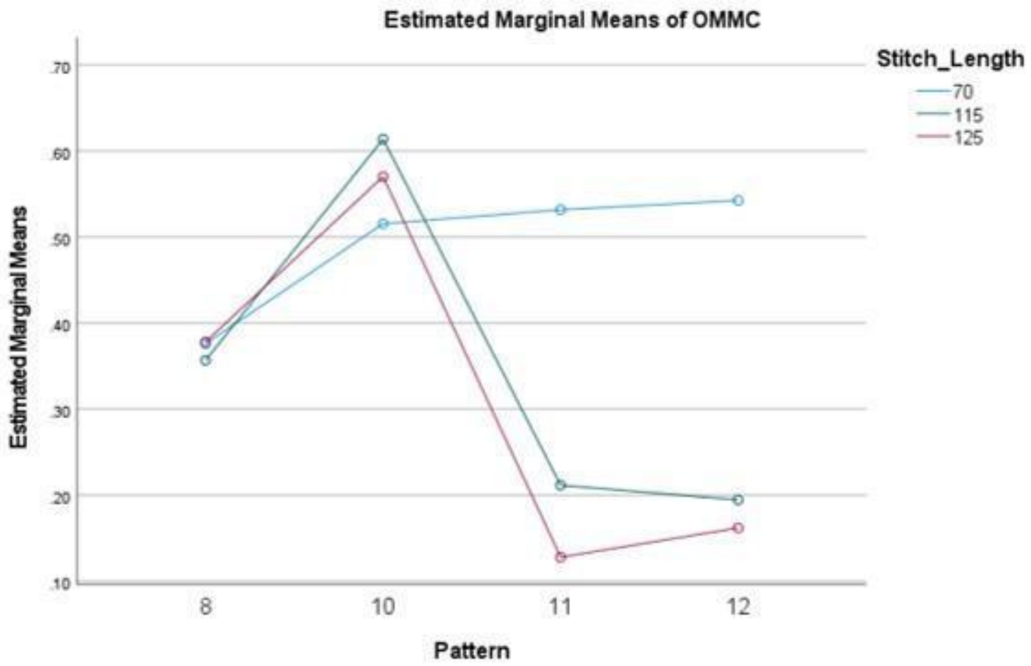


Figure 4. Plot for estimated marginal means for OMMC for each pattern and SL.

Further Studies

The results of this research offer a scientific background that could help sports bra designers in selecting appropriate knit stitch patterns and stitch size parameters, advancing the functionality of sports bras and improving women's wellbeing and lifestyle.

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