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Research Article

Stretch and Recovery of Jersey and Interlock Knits

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Abstract

Stretch in garments enhances body comfort, fit and breathability [1]. Knits are reported to have more stretch than woven materials [2]. They got impetus with introduction of casual Fridays and casual wear in late 1990s in both personal and professional spheres. Cohen and Johnson ([4], 121) asserted that knits allow "more comfortable, form-fitting and easy-moving garments than those made from woven fabrics." Woven fabrics competed with knits by adding small percentages of spandex. Today, spandex is added to knits also. Even though the role of spandex in enhancing stretch is well documented, it is not clear what percentage is optimum after which stretch does not increase.

Knitted fabrics are created from interloping of yarns. Columns are called wales and rows are called courses. Weft knits have higher stretch in crosswise (between wales) than lengthwise (between courses) direction. However, a majority of previous studies did not discuss the impact of structural attributes on stretch and recovery of knitted fabrics. Generally, the fabrics that stretch should have good recovery also. However, none of the previous work reported on this for jersey and interlock knits. Tamanna, Suruj-Zaman, Modal, and Saha [11] reported that weight, thickness and count of the fabric impacted stretch and recovery of rib knits. Therefore, stretch and recovery of three jerseys and three interlock knit were examined. Impact of spandex percentage and dyeing were also studied.

Introduction

A literature review provided some basis for this investigation. Fletcher and Roberts [6] emphasized the importance of study stretch and recovery in knits. They examined nineteen plain knit and fifteen double knit fabrics. Findings revealed that plain knits stretched from 3-60% in length and 3-235% in width. However, recovery ranged from 46-100% in length and 55-100% in width. For double knit, stretch ranged from 3-45% in length and 6-136% in width. Recovery was 56-100% for length and 30-100% in width. For both knits stretch was more in weft direction but recovery range was better in the length direction. Chin, Barker, Smith, and Scruggs [1] reported that single jersey knits softer and lighter than interlock knits which were slick and tight. They also asserted that jerseys were better choice for summer and interlock knits for winter. Sadek, El-Hossini, Eldeeb, and Yassen [9] proclaimed that adding Lycra increased weight and thickness of the fabric but decreased air permeability. The researchers also found improvement in abrasion resistance, breaking strength, and extension. Eltahan (2016) asserted that percentage of Lycra in textile material influences physical attributes of textiles.

Senthikumar, Sounderraj, and Anbumani [10] stressed that extension level did not impact Dynamic Elastic Behavior (DEB). However, different stages of processing, loop length, linear density, and input tension did impact DEB. Maqsood, Nawab, Umar, Umair, and Shaker [8] stated that all knitted fabrics have stretch. However, all of them are not necessarily the best choice for compression garments. Among woven fabrics satin weave (4x1) had the highest stretch and recovery due to longer floats and fewer interlacements than other types of weaves. Umar, Hussain and Maqsood [8] found that elastane content contributed toward increasing course density and recovery percentage. However, it decreased the fabric stretch. Tamanna et al. [11] informed about the impact of fabric weight, fabric thickness, and fabric count on the stretch and recovery of knitted fabrics. They also reported that stitch length of 2.6 to 2.65 mm and weight range from 195-205 grams per square meter had the best stretch and recovery in their study.

Based on the literature review and availability of knits in the local fabric store, the following six hypotheses were developed.

Hypothesis 1: Increase in spandex percentage will enhance stretch percentage for jersey knit.

Hypothesis 2: Increase in spandex percentage will enhance recovery percentage for jersey knit.

Hypothesis 3: Two interlock knits with same fiber content will perform similarly for stretch and recovery.

Hypothesis 4: Polyester/cotton blend will perform differently from Rayon/nylon/spandex blend for stretch in interlock knits.

Hypothesis 5: Polyester/cotton blend will perform differently from Rayon/nylon/spandex blend for recovery in interlock knits.

Hypothesis 6: Methodologically, inter-operator differences will exist for jersey and interlock knits for stretch in the crosswise direction.

Hypothesis 7: Interlock (I1) and jersey (J2) knits with similar fabric count will differ from each Other when tested with Fryma Dual Extensiometer for stretch and recovery.

Hypothesis 8: No difference will exist between Fryma Dual Extensiometer and Industrial method for stretch for recovery of interlock and jersey knits.

Hypothesis 9: No difference will exist between Fryma Dual Extensiometer and Industrial method for recovery of interlock and jersey knits.

Methodology

Three Jersey and three interlock knits were purchased from the local fabric retail store. All fabrics were blends. Table 1 shows their knit type, fiber content and price per yard. ASTM standards were used to measure fabric count (ASTM D3775 -12), fabric thickness ((ASTM D1777 -16) and fabric weight (ASTM D3776 -17). All specimens were conditioned in accordance with (ASTM D1776-16),

Item	Fabric 1 Jersey 1 White	Fabric 2 Jersey 2 Red	Fabric 3 Jersey 3 Grey	Fabric 4 Interlock 1 Green	Fabric 5 Interlock 2 Cream	Fabric 6 Interlock 3 Blue
Fiber Content	91% Polyester Spandex 9%	95% Polyester Spandex 5%	88% Polyester Spandex 12%	65% Rayon 30% Nylon 5% Spandex	Polyester 60% Cotton 40%	Polyester 60% Cotton 40%
Price	$12.99/Yard	$14.99/Yard	$16.99/Yard	$16.99/Yard	$12.99/Yard	$7.99

Table 1: Fabric's Description.

Due to economic nature of the industrial method, it was used for three jersey and three interlock knits in the reported investigation. Operator one measured all fabrics for stretch and recovery. The work of students who correctly measured their specimens was selected for comparison to determine inter-operator differences.

Industrial ruler (Courtesy of Armine Ghalachayan) named HEVEAFILl SDN BHD was used to measure stretch and recovery. Details about method used are provided below Ghalachayan [7].

- Cut 5 specimens in 10"x10" dimension for wales and courses.
- Marked 2.5" vertical lines on both sides for lengthwise and crosswise specimens. (Figures 1 and 2).

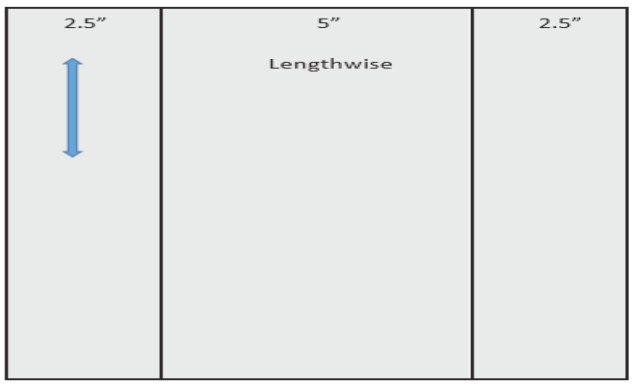

Figure 1: Directions for the lengthwise specimen.

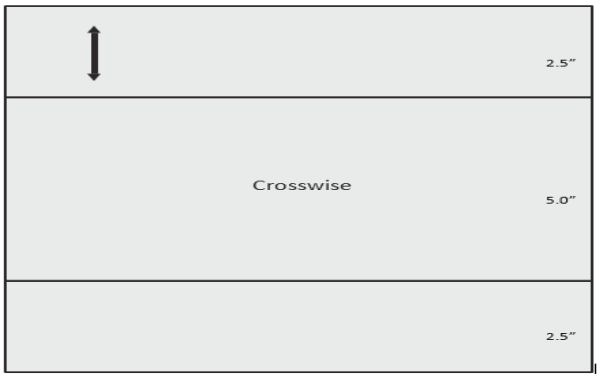

Figure 2: Directions for the crosswise specimen.

Held the fabric specimen in the middle five inches and stretch against the industrial ruler.

- Recorded the percentage of stretch from the ruler.
- For recovery percentage, measured five inch used for stretch after five minutes. Five minute's time used represents industry practice.
- Percentage was calculated by using formula given below.

100 (Stretched measurement after 5 minutes/original measurement)

For example, if stretched specimen's dimensions were 5.25 inches and original dimension was 5 inches, percentage of stretch will be 100(5.25)/5 = 105%

It suggests that fabric became larger than before. In other words, the textile grew and did not come back to its original size. One hundred percent recovery means that fabric came back to its original position after five minutes.

Preliminary investigation that compared measuring stretch between industrial ruler and Fryma Dual Extensiometer (BS 4294-1968) found that two methods were comparable. Tamanna et al. [11] mentioned that stretch and recovery are impacted by fabric count, thickness and weight. Therefore, Fryma Dual Extensiometer was used for two fabrics that had similar fabric count means (ASTM Book of Standards, 2017; ASTM D3775 -12) for jersey (106.2) and interlock (102) knits. Stretch and recovery test was completed using instructions by Chowdhary and Wroblewski [3]. Hypotheses were developed to compare two fabrics as well as two methods for stretch and recovery. Analysis of variance (F-test) was used when more than two groups were compared with follow-up of two group comparison, and t-tests were used to analyze the data where two groups were compared. Confidence level was established at 95%. For each of the selected structural and performance attributes five specimens were used (ASTM Book of Standards, 2017; [13]).

Results and Discussion

Findings from the descriptive statistics revealed that fabrics had mean thickness ranging from .48 to 1.0 mm, count for wales from 33-56, and for courses from 32-67. Fabric count for the selected knits ranged from 65-123.2. Fabric weight was between 122.991 - 386.474 grams per square meter. Table 2 provides specific details for each fabric.

Results from inferential statistics and hypothesis testing are provided below.

Hypothesis 1: Increase in spandex percentage will enhance stretch percentage for jersey knit.

Differences were significant for both crosswise ($F_{2, 12}$ = 107.999, p. <.000) and lengthwise ($F_{2, 12}$ = 15.177, p<.000) directions (Table 5). Stretch for three jersey fabrics ranged from 84-120%. It was same for 5% (120%) and 9% (120%) spandex but lower for 12% (84%) spandex in crosswise direction (Table 3). However, it was highest for 5% (100%) spandex followed by 12% (100%) and 9% 100.5) for the lengthwise direction (Table 4). Hypothesis 1 was rejected. None of the reviewed literature examined this relationship. Therefore, results could not be compared. Sadek et al. [9] reported that addition of Lycra increased thickness and weight. It was true for 5% and 12% spandex. However, athletic knit with 9% spandex was thinner and lighter than the 12% spandex. Umar et al. [12] found that addition of elastase increased course density and recovery percentage but decreased fabric stretch. No clear pattern was seen in the reported investigation. In crosswise direction, stretch was same for 5% and 9% Lycra blends. However, it was much lower for the 12% Lycra knit blend. For lengthwise stretch it progressed as 9%, 12% and 5%. It was highest for 5% and lowest for 9%. Similarly, no set pattern was found for recovery either. Tamanna et al. [11] reported that fabrics with weight between 195-205 grams per square meter had the highest stretch. It held true for Jersey 1, Interlock 3 and Interlock 2. All these fabrics had weight within the range recommended by Tamanna et al. [11]. Fletcher and Roberts [6] reported that for simple knits, crosswise direction has higher stretch than lengthwise direction. It was true for two of the three interlock knits that had spandex for the reported study.

Fabric	Fabric Thickness (mm)	Fabric Wales	Fabric Courses	Fabric Count	Fabric Weight g/m^2
Jersey 1	.48	56	67.2	123.2	122.991
Jersey 2	.696	39	67.4	106.2	239.213
Jersey 3	.776	43	46.4	89.4	257.553
Interlock 1	.920	48	54	102	386.474
Interlock 2	.948	33.2	33	66.2	201.497
Interlock 3	1.00	33	32	65	196.567

Table 2: Structural Attributes of Six Fabrics.

Fabric	Stretch Mean %	Stretch SD	Recovery Mean %	Recovery SD
Jersey 1	120	6.124	100.5	1.118
Jersey 2	120	2.236	105	0
Jersey 3	84	4.183	101	1.369
Interlock 1	47.2	2.168	100	0
Interlock 2	88	7.583	104.5	2.236
Interlock 3	101.2	1.095	111	2.236

Table 3: Stretch and Recovery of Jersey and Interlock Knits (Crosswise, Between Wales).

Fabric	Stretch Mean %	Stretch SD	Recovery Mean	Recovery SD
Jersey 1	46.8	6.124	100.5	1.118
Jersey 2	92.8	2.236	100	0
Jersey 3	73	4.183	100	1.369
Interlock 1	56.6	2.168	100	0
Interlock 2	29.2	7.583	100.5	2.236
Interlock 3	30	1.095	102.5	2.236

Table 4: Stretch and Recovery of Jersey and Interlock Knits (Lengthwise, Between Courses).

Hypothesis #	Statement	t/F Value and Significance	Accepted/ Rejected
1	Increase in spandex percentage will enhance stretch percentage for jersey knit.	Crosswise: F = 107.999 (p<.000) J1 x J2 = 0 J2 x J3 = 9.709* J1 x J3 = -15.177* Lengthwise F = 240.850 (p<.000) J1 x J2 = 14.110* J2 x J3 = 7.673* J1 x J3 = 7.079*	Rejected
2	Increase in spandex percentage will enhance recovery percentage for jersey knit.	Crosswise F = 29.209* (p<.000) J1 x J2 = .567 ns J2 x J3 = 5.563* J1 x J3 = 5.839* Lengthwise F = .250 (p=.783) ns	Rejected
3	Two interlock knits with same fiber content will perform similarly for stretch and recovery.	Stretch Crosswise t = 3.446* Lengthwise t = -0.895 ns Recovery Crosswise t = 4.111* Lengthwise t = -2.236*	Rejected
4	Polyester/cotton blend will perform differently from Rayon/nylon/spandex blend for stretch in interlock knits.	Crosswise t = -10.601* Lengthwise t = 21.49*	Accepted
5	Polyester/cotton blend will perform differently from Rayon/nylon/spandex blend for recovery in interlock knits.	Crosswise =-4.174* Lengthwise = .467 ns	Accepted
6	Methodologically, inter-operator differences will exist between jersey and interlock knits for cross-wise stretch.	See table 6. Accepted for 3 fabrics and Rejected for 3 fabrics	Rejected
7	Interlock (I1) and jersey (J2) knits with similar fabric count will differ from each other for stretch and recovery.	Interlock: t = -6.680* Jersey t = -5.531*	Accepted
8	No difference will exist between Fryma Dual Extensiometer and Industrial method for stretch for jersey and interlock knits.	Interlock: t = -.627 ns Jersey t = -.059 ns	Accepted

9.	No difference will exist between Fryma Dual Extensiometer and Industrial method for recovery for jersey and interlock knits.	Interlock: t = Infinity Jersey: t = 4.202*	Rejected

Table 5: Hypotheses Testing Outcome.

Hypothesis 2: Increase in spandex percentage will enhance recovery percentage for jersey knit.

Differences were significant for the crosswise direction ($F_{2, 12}$ = 29.209, p<.000) but not significant for the lengthwise direction (Table 5). The recovery was highest for the light weight, high count, and thinnest jersey (Table 2). Follow-up analysis revealed that fabric with 12% spandex (111%) differed significantly from those with 5% (105%) and 9% (100.5%) spandex. Differences were also significant with fabrics that had 5% and 9% spandex. Hypothesis 2 was rejected. None of the reviewed literature provided information on recovery of textile fabrics in context of spandex percentage in a blend. Therefore, results could not be compared. However, Fletcher and Roberts [6] reported that recovery is better in lengthwise direction. It was true for the reported study.

Hypothesis 3: Two interlock knits with same fiber content will perform similarly for stretch and recovery.

Both interlock knits differed from each other for crosswise stretch (t_8 = 3.446, p<.05) as well as the crosswise recovery (t_8 = 4.111, p<.05). See Table 5. However, two fabrics (60/40 polyester/cotton blends) did not differ for both stretch and recovery in the lengthwise direction. Cream (Interlock 2) had stretch of 88% and blue interlock had stretch of 101.2%. Recovery for cream interlock was 104.5% and for blue was 111. Hypothesis 3 was rejected. Both were 60/40 polyester/cotton blends. One had cream color and the other one had turquoise blue color. Recovery for interlock 2 was Interlock 3 has slightly higher thickness but lower weight and count than interlock 2 (Table 2). This could have contributed toward higher stretch and lower recovery for Interlock 3. Color was also the differing factor. It is possible that dyeing process and color had some impact.

Hypothesis 4: Polyester/cotton blend will perform differently from Rayon/nylon/spandex blend for stretch in interlock knits.

Differences were significant between two fiber contents for both crosswise and lengthwise stretch. Polyester/Cotton blend (I2) had higher stretch in crosswise direction (t_8 = 10.601, p<.05), and the rayon/nylon/spandex blend (I1) in the lengthwise direction (t_8 = 21.490, p<.05). Hypothesis was accepted. The results were consistent with Umar, Hussain and Maqsood [8] who found that elastane content decreased the fabric stretch. Fabric stretch for polyester/cotton blend (88%) was higher than rayon/nylon/spandex blend (47.3%) in crosswise direction. However, it was lower for polyester/cotton blend (29.2%) than the rayon/nylon/ spandex blend (56.6%) in lengthwise direction. Percentage of stretch is within the range established by Fletcher and Robert [6] for plain knitted fabrics. None of the reviewed literature tested relationship between polyester and rayon blends specifically. Findings from the reported research can serve as the basis of comparison for future research.

Hypothesis 5: Polyester/cotton blend will perform differently from rayon/nylon/spandex blend for recovery in interlock knits.

Differences were significant between two fiber contents for crosswise and non-significant for the lengthwise direction. Polyester/cotton blend had higher stretch in crosswise direction (t_8 = 10.601, p<.05), and the Rayon/nylon/spandex blend in the lengthwise direction (t_8 = 21.490, p<.05). Hypothesis was accepted. Rayon blend had 100% recovery in both directions. It could be function of heavier weight and higher fabric count for rayon blend than the polyester/cotton blend. The results were consistent with Umar, Hussain and Maqsood [12] who found that elastane content contributed toward increasing course density and recovery percentage. In the reported study, fabric with spandex had higher stretch in lengthwise direction and better recovery for both directions than the textile without spandex. The differences could be due to fiber content differences. However, it needs further testing to confirm so.

Hypothesis 6: Methodologically, inter-operator differences will exist for jersey and interlock knits for stretch in the crosswise direction.

It was hypothesized that there will be differences in measurement through industrial method due to possibility of varying stretching ability of various operators. Results revealed that it was true for three (J3, I2, I3) of the six knit fabrics (Table 6). However, differences were not significant for J1, J2, and I1. Hypothesis 6 was rejected. None of the previous research examined inter-operator variability. This research needs to be repeated to confirm these results. It is logical to expect differences in stretching ability of operators based on their age, sex and physical condition.

Fabric Label	Operator 1		Operator 2		Operator 3		t/F-Value
	Mean	SD	Mean	SD	Mean	SD	
J1	120	6.124	126	13.416	-	-	0.814 ns
J2	120	2.236	118	4.472	116	11.402	0.387 ns
J3	84	4.183	100	0.000	73	8.367	31.598 (p.000)
I1	47.2	2.168	48	14.405	38.2	2.280	2.073 ns
I2	88	7.583	92	3.367	57	2.739	72.111 (p.000)
I3	101.2	1.095	103.4	4.219	114	8.944	7.097 (p.009)

Table 6: Inter- Operator Differences in Stretch Measurement in Crosswise Direction.

Hypothesis 7: Interlock (I1) and jersey (J2) knits with similar fabric count will differ from each other for stretch and recovery.

Results revealed that differences were significant for both stretch (t_8 = -6.680) and recovery (t_8 = -6.680, p<.05). See (Table 7) for details. Hypothesis 7 was accepted. Jersey knit had significantly higher stretch than the interlock knit. However, interlock knit had better recovery than the jersey knit.

Item	Stretch I1	Stretch J2	Recovery I1	Recovery J2
Mean	46.4	120.4	103.6	107.71
Standard Deviation	1.342	0	13.283	1.279
t-value	-6.680*		-5.531*	
* P<.05				

Table 7: Crosswise Stretch and Recovery Data for Fryma Dual Extensiometer Testing Interlock and Jersey Knits with Similar Fabric Count.

Hypothesis 8: No difference will exist between Fryma Dual Extensiometer and Industrial method for stretch for jersey and interlock knits.

Results revealed that differences were not significant between two methods for jersey (t_8 = -.059, p>.05) and interlock knits (t_8 = -.627, p>.05) based on t-test analysis. Hypothesis 8 was accepted. None of the reviewed research compared these two methods. Findings of the reported study showed that results from two methods were comparable.

Item	Fryma Stretch I1	Industrial Stretch I1	Fryma Stretch J2	Industrial Stretch J2
Mean	46.4	47.2	120.4	120
Standard Deviation	1.342	2.168	13.283	2.236
t-value	-0.627 ns		0.059 ns	

Table 8: Stretch Data for Comparing Fryma Dual Extensiometer and Industrial Testing for Interlock and Jersey Knits.

Hypothesis 9: No difference will exist between Fryma Dual Extensiometer and Industrial method for recovery for jersey and interlock knits.

Recovery results from t-test analysis for jersey (t_8 = 4.202, p<.05) and interlock knits (t_8 = Infinity, p<.05) did not support the proposed hypothesis. Recovery based on Fryma Dual Extensiometer method showed significantly higher growth than the industrial method. In other words, recovery was 100% when industrial method was used. for both types of knits.

Item	Fryma Recovery I1	Industrial Recovery I2	Fryma Recovery J1	Industrial Recovery J2
Mean	120.83	100	107.71	105
Standard Deviation	0	0	1.279	0
t-value	Infinity		4.202*	

Table 9: Recovery Data for Comparing Fryma Dual Extensiometer and Industrial Testing for Interlock and Jersey Knits.

Summary and Conclusions

The reported research study yielded several useful findings that have merit from methodological considerations as well as content related information. First, increase in Lycra % does not necessarily improve stretch for all types of knits and fiber contents. Also, the increase in Lycra % may increase recovery and stretch differently in crosswise and lengthwise directions. Second, inter-operator variations should not be ignored. Third, different methods of measuring stretch and recovery may or may not yield different results. Fourth, fiber content can have an impact on stretch and recovery of knitted fabrics. Fifth, interlock knits of same fiber content may not have same results for both directions. Sixth, inter-operator differences are possible in measurement of stretch and recovery of jersey and interlock knits. Results were consistent with some of the work of previous scholars [4, 11, 12]. Their study examined rib knits as opposed jersey and interlock knits. It suggests that their finding from rib knit can also be extended to interlock and jersey knits. However, they were inconsistent with Sadek, et

al. [9] with regard to contribution of Lycra to thickness and weight of the fabric.

Implications for Future

The study can be extended to use other types of knits and fiber contents. Other available methods of measuring stretch and recovery could be used to understand their relative advantages and shortcomings. The reported study used consumer's perspective and purchased fabrics from the retail store. If the knit fabrics used can have strategically controlled fabric constructions, thickness and counts, results could be optimized for different end uses better. The study needs to be replicated and extended so that meaningful patterns could be extracted for optimized used of stretch and recovery for various end uses.

Following five questions may be raised to further enhance the credibility of understanding the stretch and recovery relationship for various structural attributes.

- Will adding different percentages of Lycra to fiber contents other than polyester yield different patterns?
- Will all natural and/or synthetics/regenerated fibers perform similarly for stretch and recovery, as well as other related performance attributes?
- How does blending of different fiber contents impact stretch and recovery?
- How will pique knit will perform for stretch and recovery as opposed to rib, jersey and interlock knits?
- How will introduction of Lycra impact care and durability variables?

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