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Structural effect of polyester SCY knitted fabric on fabric size, stretch properties, and clothing pressure

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Abstract

This study facilitates an effective design and development of various high stretch compression products by analyzing fabric size, stretch properties, and clothing pressure for various knit structures. Four types of fabrics were knitted with polyester SCY (Single Covered Yarn). Then fabric size including weight and thickness, stretch properties (stretch, elastic recovery), and clothing pressure were then measured, to analyze their interrelation. A comparison of fabric size indicated that yarn floating caused reduction in both course and wale-wise specimens; in addition, yarn overlapping caused a release in course-wise and shrinkage in wale-wise due to tuck. The high density caused by shrinkage in the course-wise due to yarn floating rather than overlapping influenced the weight and thickness of knitted fabrics. Yarn floating reduced course-wise elasticity and increased wale-wise elasticity in the fabric stretch test; however, yarn overlapping reduced elasticity in both directions. The elastic recovery analysis indicated that the recovery value gap among four specimens decreased over time. In comparison clothing pressure, 'plain-float' fabric showed higher clothing pressure than 'plain', while the pressure value of 'plain-tuck' was similar to 'plain'. Dimensional change in course-wise had a greater effect on clothing pressure than in wale-wise in the correlation among fabric size, stretch properties and clothing pressure. Weight and thickness change exerted a strong influence on clothing pressure which vertically presses down the body. The clothing pressure value of knitted specimen having a lower stretch ratio was higher in course-wise.

Keywords: Clothing pressure, Compression garment, Stretch properties, SCY (single covered yarn)

Introduction

Garment pressure is an essential component of clothing comfort (Yamada and Matsuo 2009). An appropriate clothing pressure maximizes the efficiency of physical exercise and heals hypertrophic skin burn scars. The degree of clothing pressure depends on material, design, wearing type, and physical features; in addition, stretch properties represents a significant mechanical property of clothing material that influences clothing pressure. Stretch properties are measured as the percentage of fabric stretch and fabric growth, recovery.

Lyle (1977) indicated two types of stretch fabric: comfort stretch (25–30 %) and power stretch (30–50 %). Stretch fabrics are specifically used in the design of active sports clothing, swimsuits, and athletic clothing. In some current uses, power stretch fabrics are required to have higher extensibility and quicker recovery. Compression therapy utilizes medical compression garments and functional body shaping underwear design that are made with high stretch fabric.

Fabric elasticity depends on fiber extendibility as well as structure. An interlooped structure provides knitted fabric a better elasticity than woven fabric. A loop pulled horizontally in knitted fabrics extends by the whole length; however, a loop pulled vertically extends by half its length (Brackenbury 1992). Human skin can be extensible from 20 to 200 % due to physical movement. Therefore, it is possible to develop compression products which can exert the exact required pressure on the body utilizing the elasticity of knitted fabric. However, an appropriate structure should be selected, arranged and used for specific body parts when designing compression products because different knit structures show different stretch properties even in the same fabric.

Many research performance studies have analyzed clothing and material stretch properties. For example: garment patterns using knitted fabrics (Heo 2003; Kim and Suh 2005; Kim et al. 2012; Oh 2010), the relationship between mechanical properties of material and clothing pressure (Anand et al. 2013; Jeong 2008; Jung and Ryu 2002; Rhie 1992), and the effect of clothing pressure on the body (Baek and Choi 2007; Bruniaux and Lun 2012; Lee 2005). However, there has been limited research on the relationship between structural characteristics of high stretch knitted fabric and clothing pressure. High stretch knitted fabric is often used as a material for the compression garments because compression garments should fit very tightly to apply a firm and even pressure on skin. The pressure level of high stretch knitted fabric depends on knit structure, yarn composition, and knitting type; however, little is known about the correlation of fabric size, stretch properties, and clothing pressure of high stretch knitted fabric (Sang and Park 2011).

Previous research reviewed the type of knit structure and characteristics of commercially available compression garments (Sang and Park 2013). Knit structures were also classified into four groups in terms of three primary knit loops in previous research (Sang and Park 2013). This study now facilitates the design of high stretch compression garments and the development of various products by analyzing dimension features, stretch properties, and correlation of clothing pressure for high stretch knitted fabric to offer a proper knit structure appropriate for the demands of phased compression.

Methods

Knitting structure selection

Four kinds of knitted fabrics, (P, PF, PT, and PFT), were used as test specimens. They were basic knit stitches in four groups classified in previous research. Specimen 'P' was knitted using plain (or knit) technique only. Specimen 'PF' and 'PT' were knitted using float (or miss) and tuck respectively on a plain structure. Specimen 'PFT' was knitted using float and tuck technique on a plain structure.

Specimen size and making

To measure fabric size and pressure of seamless knitted specimen, the average upper arm circumference of Korean women in 30–60 s was selected as a standard body part for easy measuring regardless of curvature, hardness, and human muscle. Garment fit decides the pressure exerted on the skin. A reduction of 15–20 % is commonly applied to the patient’s circumference measurements for the design of a compression garment (Anand et al. 2013; Ng and Hui 2001). This study applied a 20 % reduction rate to the body part circumference that created a specimen size 22.5 cm in circumference and 15 cm in length. The density of plain stitch 9.06 courses/cm × 17.72 wales/cm was applied to all specimens; subsequently, four specimen types were knitted with the same number of course and wale: 204 courses × 266 wales. The detail structure of each specimen is illustrated in Fig. 1.

Specimens were knitted in 100 × 100 cm size to test stretch properties. All specimens were knitted by a computerized flat-bed machine (SSG-122SV, SHIMA SEIKI MFG., LTD. Japan) due to ease of control with the same loop size and low knitting speed. We selected a Polyester Single Covered Yarn (SCY) commonly used for compression products materials in the Korean market for this study (Table 1).

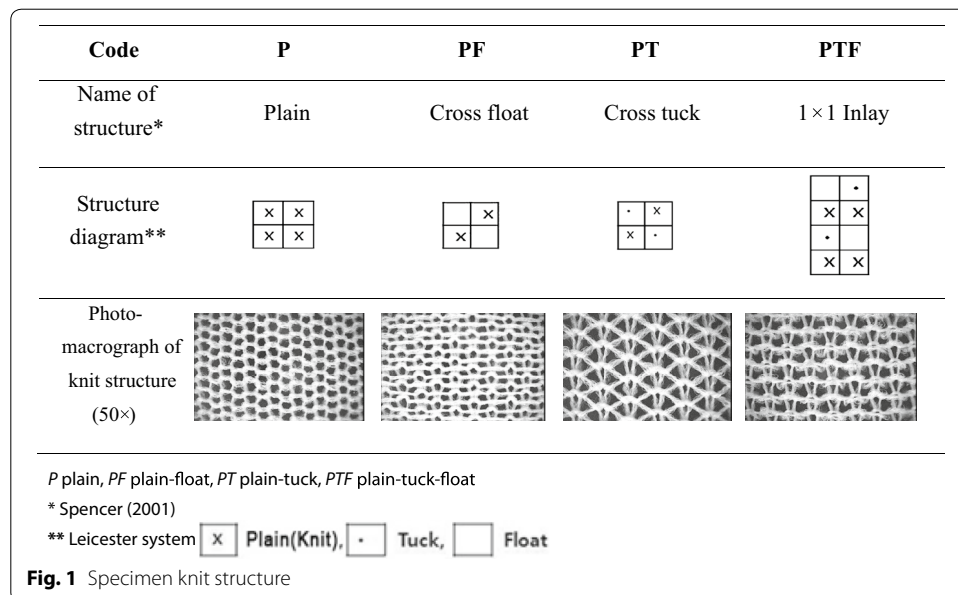


Table 1 Characteristics of yarn in specimen

Type	Fiber composition	Doubling and twisting condition	Ply
Polyester	Polyurethane 40 D	Spandex 3.3 × ^a	2 ply
SCY	Polyester 75 D/36 F	460 TM	
40/75 R/W		11,200 RPM	

^a 3.3 ×, spandex wrapped spirally with polyester under the elongation ratio of 3.3 times
 SCY single covered yarn, R/W raw white, TM twist per meter, RPM revolutions per minute

Dimensional test

Specimens were conditioned in a standard atmosphere of $20 \pm 2^\circ\text{C}$ and $65 \pm 2\%$ R.H. for at least 48 h without rinsing and were taken by KS K 0105:2011 standard for testing. Length in the wale and course direction of specimen were measured by KS K ISO 22198:2014 standard; subsequently, thickness and weight test method followed KS K ISO 5084:2011 and KS K ISO 0642:2013 standard.

Stretch properties test

ASTM D 2594-2004 (2008) standard test method for stretch properties of knitted fabric was applied under the form-fitting stretch percentage points to test the stretch and elastic recovery of specimens,

Clothing pressure test

Clothing pressure was measured by the air-packing method equipment (AMI 3037-2-2B) developed by SANKO TSUSHO Co., Ltd. Japan (Fig. 2). A plastic cylinder 22.5 cm size in circumference was adopted in this test. The cylinder surface was covered by extended knitted specimens, with the interfacial pressure between specimen and cylinder recorded at the center marked location of the circumferential line. The interfacial pressure of each specimen was averaged after being measured forty times at the same cylinder location at one second intervals.

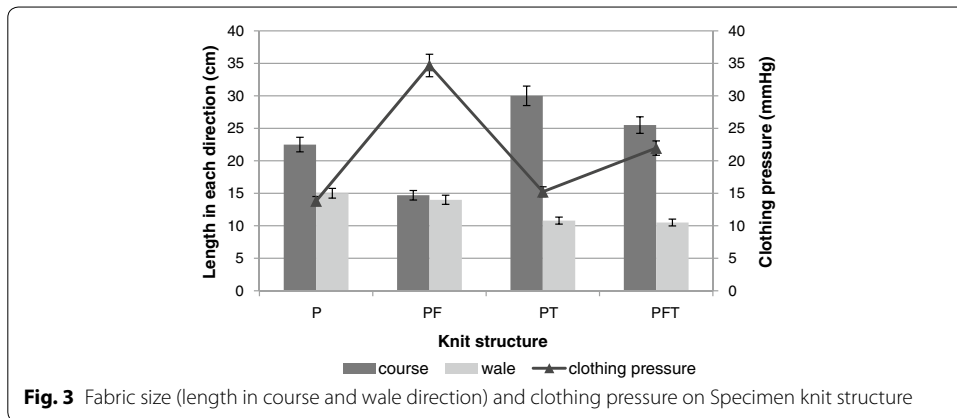
Results and discussion

Dimensional change

The dimensional change of knitted specimens was shown in Fig. 3. 'PF' was reduced by 34 % in course-wise and 6 % in wale-wise compared to 'P'. The wales of 'PF' are drawn closer together by floats because the loop of miss stitches tends to display faint horizontal lines; consequently, course-wise reducing occurred. The high stretch of material added to reducing along with the structural and characteristics of material both led to reducing in wale-wise. 'PT' was observed 25 % increasing in course-wise and 28 % reducing in wale-wise. Spencer (2001) mentioned that tuck loops reduce fabric length because the higher yarn tension and held loops pull on yarn from adjacent loops. Course-wise increasing occurred because tuck loops also pull the held loops downwards and spread outwards; consequently, the dimensional change of 'PT' in this study and Spencer's

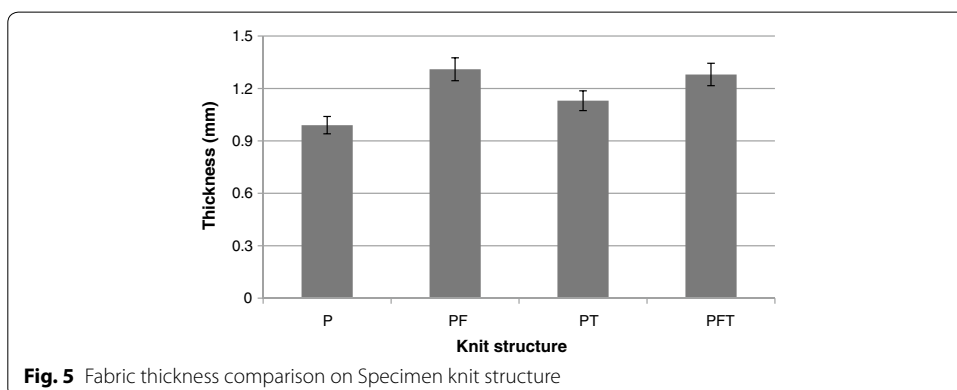
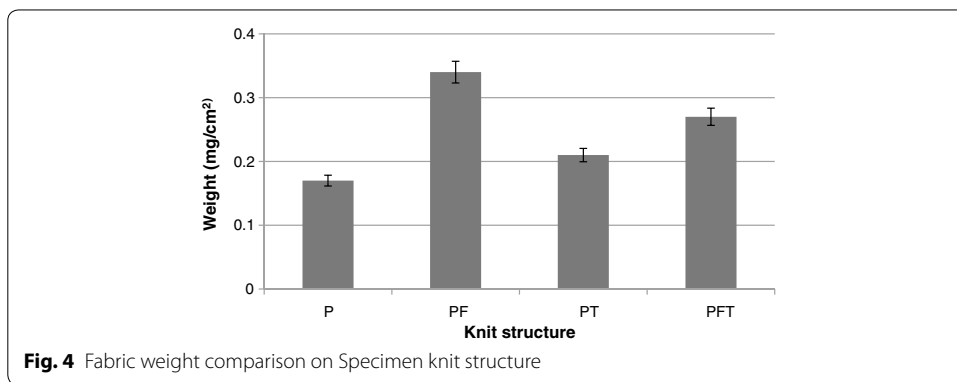


Fig. 2 AMI 3037-2-2B clothing pressure equipment (SANKO TSUSHO Co., Ltd. Japan)



description about tuck stitch coincides. The dimensional change in ‘PFT’ showed an 11 % increase course-wise and 30 % reduction wale-wise. The combing of knit structure provides greater fabric stability both wale-wise and course-wise.

Figures 4 and 5 show knit specimen changes in weight and thickness. The heavier weight of knit specimen was, the thicker its thickness was in descending order ‘PF’, ‘PFT’, ‘PT’, ‘P’. Thickness and weight of specimen were influenced by density change caused by reducing and increasing fabric size. Thus, high density caused by floating in course-wise causes more knitted fabric weight gain than by loop overlapping.



Stretch properties

Figure 6 indicated that the stretch value decreased in all structure and direction except wale-wise of 'PF' compared to 'P'. Course-wise, 'PF' showed a sharp decrease (67 %) while 'PT' showed a 7 % relatively small decrease. It seems that the material effect by stretch properties added to the reducing cause by yarn floating in 'PF'. Stretch properties of yarn restricted increasing in 'PT'. Wale-wise indicated a 29 % 'PF' increase versus a 32 % 'PT' decrease to show that the tuck stitch structure which held the loops reduced the stretch value. There was a value decrease 34 % in course-wise and 24 % in wale-wise each for 'PFT'. The stretch value in course-wise is influenced by yarn floating rather than loop overlapping while stretch value in wale-wise is caused by loop overlapping versus yarn floating.

There was no significant value change on knit structure and direction in elastic recovery (Fig. 7a, b). The recovery value gap among knitted specimens was lower at 1 h than at 60 s. The stitch loops bent and restricted by the external force loop of stitch take on a form of stability and shape retention in over time.

Correlation with clothing pressure, fabric size and stretch properties

Figure 8 shows the clothing pressure on each specimen knit structure. The clothing pressure value of 'PF' was higher 60 % than that of 'P'; however, the clothing pressure value of 'PT' was higher 9 % than 'P'. The degree of clothing pressure vertically exerted on the body depends on course-wise dimensional changes of knitted fabrics. The result measure value of clothing pressure of 'PFT' was 21.96 mmHg which is higher 37 % than 'P' due to the combined fabric structure with yarn floating and overlapping.

Figure 3 shows the clothing pressure and the size of knitted specimen; in addition, a reduced size led to a consistently higher course-wise clothing pressure. A similar trend was also found in correlation with clothing pressure and stretch of knitted specimen (Fig. 6). The observed clothing pressure value of knitted specimen having lower stretch ratio was also higher course-wise; however, there was no significant tendency between clothing pressure and stretch ratio in wale-wise.

The correlation with clothing pressure and elastic recovery ratio (Fig. 7a, b) indicated no distinct difference recovery ratio among knit structures compared to clothing pressure value. Further research with a higher stretch knitted fabric than used this study

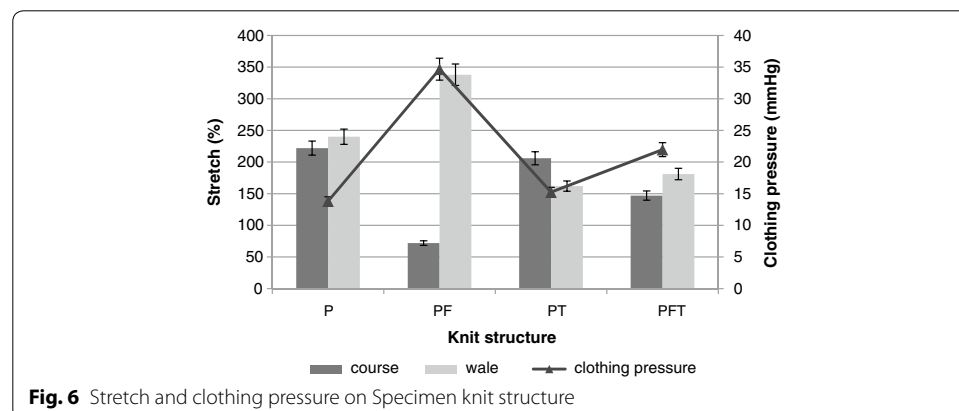
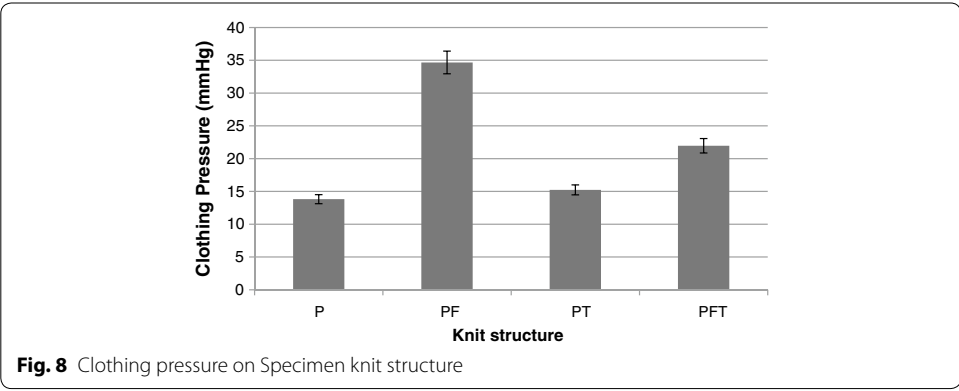
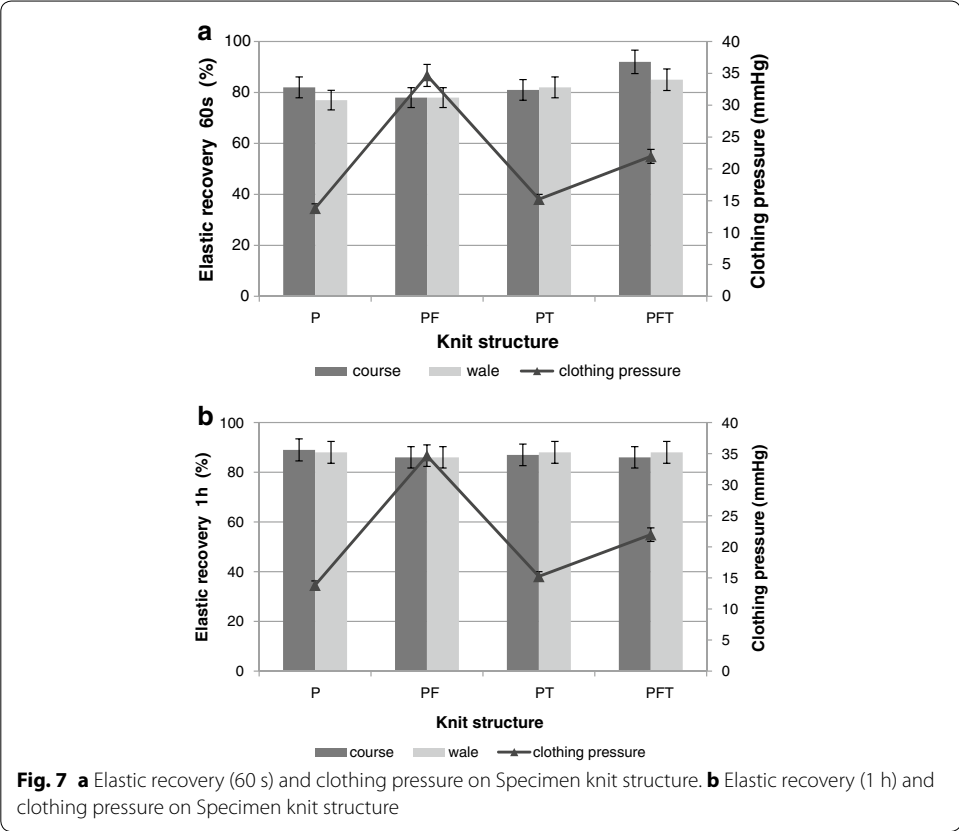


Fig. 6 Stretch and clothing pressure on Specimen knit structure



should be used to define the relationship between clothing pressure and the elastic recovery of high stretch knitted fabric.

Conclusion

Garment pressure is related to the clothing material’s interaction with the body, and is based on how material stretches and recovers vis-a-vis fabric structure. This study compared the size and stretch properties of high stretch knitted fabric with different structures and analyzed the correlation with clothing pressure.

Miss of yarn caused shrinkage in both course and wale-wise of knitted samples due to drawn closer together yarns by the floats. Yarn overlapping caused release in course-wise and shrinkage in wale-wise due to tuck. High density caused by shrinkage in the course-wise due to floating of yarn rather than overlapping had a greater effect on the weight and thickness of knitted fabrics.

Miss of yarn reduced course-wise elasticity and increased wale-wise elasticity of high stretch knitted fabrics; however, overlapping of yarn reduced elasticity in both directions. In elastic recovery, the gap of recovery value among knitted specimens was lower at 1 h than at 60 s with no significant recovery value change. Accordingly, the size change by knit structure influenced stretch properties.

Clothing pressure measurement by knit structure indicated that the clothing pressure value of 'PF' was higher than 60 % that of 'P'; however, there was no significant pressure value change between 'PT' and 'P'.

The dimensional change in course-wise had more effect on clothing pressure than in wale-wise for the correlation among fabric size, stretch properties and clothing pressure; consequently, a smaller size course-wise resulted in higher clothing pressure. 'PT' had slightly higher value than that of 'PF' for elastic recovery. The clothing pressure value of 'PF' was higher than 'PT', because weight and thickness change of 'PF' was heavier and thicker than the 'PT' that exerted a strong influence on clothing pressure vertically press down on the body.

This paper proposed an appropriate knit structure and arrangement approach in consideration of fabric size and stretch properties of high stretch knitted fabric and correlation with clothing pressure. The analysis results verified that a variety of clothing pressure effects could be implemented by a combination of knit structure using principles of knitting and a proper knit structure arrangement when designing compression garments based on economics. This paper provides meaningful market data for the effective development of more diverse garment compression-related products along with the localization of manufacturing for functional and medical compression garments.

Authors' contributions

JSS designed and carried out the experiments, analyzed the data as well as drafted the manuscript. MSL and MJP guided and helped in feedback and comments in final format of the paper. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

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