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A pilot study: Evaluating the influence of knitting patterns and densities on fabric properties for sports applications

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Abstract

Various fabric properties are important for different sports applications. In order to improve fabric performance the focus is more on the material features of fabrics rather than the pattern. Fabric properties like moisture management, air permeability, and stretchability depend not only on the materials (the polymer) but also on their assembly in the fabric. Knitting pattern and density are two very important features in assembly which can influence fabric properties. In the case of compression garments, the type of knitting pattern (warp or circular) can complement the design and provide the most effective level of compression. The extent of moisture management and air permeability is generally influenced by the knitting density which relates to the spaces between the fabric fibres and create capillaries for wicking moisture and provide passage for air. This pilot study aims to explore the relationship between various fabric properties, fabric knitting patterns and densities.

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Keywords: Fabrics; knitting; density; moisture management; mechanical properties; compression

1. Introduction

The comfort and the durability of sportswear depend greatly on the fabrics used with comfort level of a fabric determined by its texture, smoothness and moisture management. The durability of sports garments will depend on the mechanical properties of the fabric. Sports garments require an appropriate level of material engineering where with considerations into material composition of fabric, type of yarn, fiber diameter as well as cross-section of fibers [1].

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Sport compression garments are an example of how fabric selection and implementation are able to enhance athletic performance and recovery. During activity, compression garments apply pressure which can decrease muscle oscillation and accelerate blood circulation in the locations covered by the fabric [2, 3]. Post exercise, compression garments promote the clearance of blood lactate and reduce the effects of exercise induced muscle damage (EIMD) which can improve an athlete's recovery process [4, 5]. This implies an athlete can resume training faster from wearing compression garments. In addition to improving performance and recovery, material researchers also incorporate UV protection, moisture management and antimicrobial properties into the fabric to enhance comfort.

The type of knitting patterns chosen in making the fabric makes a difference. The thinner the yarn used, the finer the surface texture. In contrast, the thicker the yarn, the more visible the stitches [6]. Naturally, the type of knits will affect the comfort level of the wearer. The most commonly used classes of knitting patterns consist of warp knitting and weft knitting (Fig. 1). Another class of less prevalent knits, is called a Circular knit.

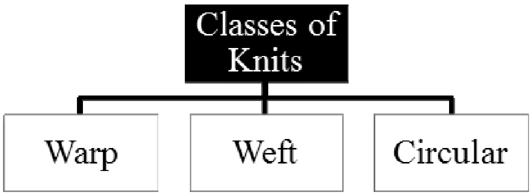

Fig. 1. Knits categorization

Warp knit is constructed in a way where the yarns are stitched lengthways, in a zig-zag pattern. The loops are interlocked in a lengthwise direction [7]. Due to its zig-zag knitting across different columns, the knits are usually done by machine. Contrastingly, weft knit is knitted by having the yarns stitched width-wise, across the fabric. Some examples of weft knits are plain knits or rib knits [8]. The third class of knits that is relevant to this project is circular knit. These knits can produce tube forms that are seamless [9], since most knitted garments are in tube forms such as arm sleeves or socks. Similarly to weft knits, circular knits can be done either hand-made or by machine.

Moisture management in sport fabrics essentially refers to how well material is transporting moisture out of the fabric and keeping the wearer dry during exercise. The moisture remaining in the fabric can further increase body temperature leading to more perspiration. The ultimate objective of managing moisture in fabrics is to ensure moisture is transported to the outer surface in the shortest possible time. Once transporting outwards, the moisture should spread to a large surface area and evaporate as fast as possible with the wearer experiencing a feeling of dryness [9]. The two important criteria tested for fabrics performance in this respect are:

1. One-way transport Index: fabric's ability to transport water from 'inside' to 'outside'. It is calculated with by relative amount (% weight) of water transported (across the fabric) as compared to fabric sample's weight.
2. Overall Moisture Management Capacity (OMMC): fabric's overall capacity to wick moisture from 'inside' to 'outside', spread and absorb it over the fabric's outer surface and dry. OMMC is a unitless quantity and usually ranges between zero to one.

2. Experimental details

A total of 12 fabric samples were obtained from various fabric suppliers which served different applications. The fabric samples were subjected to tensile testing and moisture management tests. Samples 1 to 9 represented sports compression garments and fabrics 10 to 12 represented other sportswear applications ranging from caps to T-shirts.

The knitting patterns of these fabric samples were identified through a Leica optical microscope at 1.25X magnification. Densities of the fabric samples were taken qualitatively from microscopy images and rated using a fabric density scale of 1 to 5 (Fig. 2), with 1 being the lowest density and 5 being the sample with the highest density.

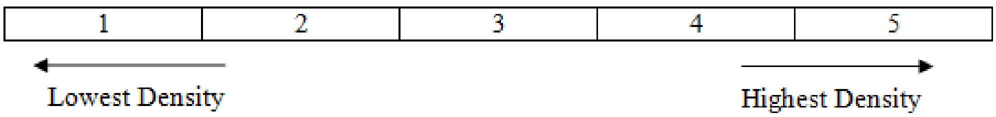

Fig. 2. Fabric density scale

Tensile testing was conducted using the Instron® 5567 and performed on the individual fabric samples. Each sample was shaped using a dumbbell cutter which allowed the sample dimensions to follow the ASTM D638-V standard. The samples were pulled at a rate of 20mm/minute.

Moisture management properties of the fabric samples were performed using Moisture Management Tester (MMT) from SDL Atlas Ltd. The samples were first cut into 8cm x 8cm pieces. Artificial sweat was dripped onto the fabric from a nozzle for 20secs, and data was collected for 2 minutes each time.

3. Results and discussion

All the fabric samples were tested for Overall Moisture Management Capacity (OMMC) and One-way Transport Index while fabric samples 1 to 9 were tested for mechanical tests including Modulus, Stress at maximum load and Strain at maximum load. The following table (Table 1) summarizes the values from all the tests performed on the fabric samples:

Table 1. Fabric properties as shown in the test results

Sample	Side	Knitting Pattern	Knitting Density (On a scale of 1-5)	OMMC	Accumulative one-way Transport index(%)	Average Modulus (MPa)	Average Stress at Max. Load (MPa)	Average Strain at Max. Load (%)
1	Inner	Circular	4	0.303	-2.64	0.239	15.66	10.17
	Outer	Warp	3					
2	Inner	Circular	4	0.047	-19.02	0.156	15.57	13.68
	Outer	Warp	3					
3	Inner	Circular	5	0.069	10.85	0.382	15.66	5.36
	Outer	Warp	4					
4	Inner	Circular	5	0.120	51.84	0.303	20.10	11.53
	Outer	Warp	4					
5	Inner	Circular	4	0.074	16.30	0.359	16.27	6.38
	Outer	Warp	3					
6	Inner	Circular	3	0.093	29.16	0.229	15.07	11.78
	Outer	Warp	2					
7	Inner	Circular	3	0.091	19.68	0.327	14.01	7.28
	Outer	Warp	2					
8	Inner	Circular	4	0.015	-51.10	0.277	16.17	8.60
	Outer	Warp	3					
9	Inner	Stockinette (Basic knit)	4	0.000	-87.25	0.054	8.51	17.50
	Outer	Stockinette (Basic knit)	4					
10	Inner	Warp (Basic)	1	0.57±0.03	125.97±10.14	-	-	-
	Outer	Warp (Basic)	1					
11	Inner	Warp (Stockinette)	4	0.67±0.07	482.7±90.15	-	-	-
	Outer	Warp (Stockinette)	4					
12	Inner	Warp (Basic)	3	0.78±0.001	874.9±10.79	-	-	-
	Outer	Warp (Basic)	3					

3.1 Knitting patterns

Knitting pattern is believed to have an effect on a fabric's mechanical properties and compression characteristics. Eight (samples 1 to 8) out of the nine samples tested for mechanical tests, which had circular knit, showed higher modulus (0.156 to 0.382 MPa) while sample 9 (with basic stockinette knit) showed much lower modulus (0.054 MPa). This implies that a circular knitting pattern could have better mechanical (and resulting compression) properties than basic stockinette knitting patterns.

The effect of knitting pattern on moisture management properties is not very clear as other parameters, such as the type of fabric, also contribute significantly to fabric's moisture management properties. Moreover, for samples 1 to 9, the two layers had different knitting patterns making it difficult to establish a trend based on knitting pattern. From the limited results, trends exist showing warp knitting relating to increased moisture management properties (both OMMC and One-way Transport Index).

3.2 Knitting density

In general, circular knits have higher densities than warp knits. The effect of knitting density on any of the mechanical properties tested in this study did not show any trend among the first nine samples (samples 1 to 9).

For moisture management properties, samples 1 to 9 did not show any trend with knitting density, with all of them showing very low OMMC (Overall Moisture Management Capacity) and One-way Transport Index. Among samples 10 to 12, higher density may be related to better moisture management properties (both OMMC and One-way Transport Index). This can be attributed to the requirement of sufficient capillary pressure (which can be created by smaller gaps) for fabric's wicking action, a critical part of moisture management properties.

4. Conclusion

Currently, our results indicate no prominent trends in mechanical properties of samples in relation to knitting densities. The circular knitting pattern tends to show superior mechanical properties when compared to a warp knitting pattern. Among compression fabrics, there currently seems to be no specific effects on moisture management properties when different knitting densities of the fabrics are compared. However, warp knitting tends to be a more effective knitting pattern for moisture management than circular knitting. Warp knit fabrics also seem to follow a trend: 'higher the density, better moisture management by the fabric'.

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