LOCALIZED COMPRESSION CLOTHING FOR IMPROVED SPORTS PERFORMANCE

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Abstract: *Compression garments are elastic, body-moulded suits with an engineered compression gradient that can be worn as an upper, lower or full-body piece. Compression garments plays an important role in optimizing the performance of a sports person in terms of speed, strength and stamina. The use of compression clothing has become popular, as they increase power, improve recovery and enhance athletic performance in a variety of sports and also reduce the effects of delayed onset muscle soreness in the days following strenuous exercise. Compression sportswear worn by elite athletes to enhance performance is based on compression therapy which was widely used for treating venous disorders. Recent research with athletes has shown that compression garments may provide ergogenic benefits for athletes during exercise by enhancing lactate removal, reducing muscle oscillation and positively influencing psychological factors. This study reveals the performance evaluation of a localized compression garment developed with varying pressure at different areas of the body. Localized compression garment is designed and developed in such a way that, it produces localized compression effect in the specific area with the required interfacial pressure. Different composition of compression fabric made of polyester microfiber, lyocell and elastane has influence on the generated interfacial pressure. During field trial, usage of medium and higher elasticity fabrics showed a reduction of 90% in the muscle movement as analyzed through EMG. The experiment resulted with 9% increase in the performance of the volunteers during running and cycling..*

Keywords: *Compression garment, sportswear, bilayer fabric, interface pressure, electromyography*

1. Introduction

Compression garments plays an important role in optimizing the performance of a sports person in terms of speed, strength and stamina. Compression garments are elastic, body-moulded suits with an engineered compression gradient that can be worn as an upper, lower or full-body piece. An ideal compression garment is designed to provide localized compression, comfort, proper fit and stretch, optimize skin contact, absorb humidity and yet light and enduring and hence regarded as "the second level of human skin" by researchers [1,2]. The use of compression clothing has become popular, as they increase power, improve recovery and enhance athletic performance in a variety of sports and also reduce the effects of delayed onset muscle soreness in the days following strenuous exercise. [3] When pressure is applied by garments, it compresses the soft tissues at a right angle. The pressure is applied increases the blood flow by increasing the hydrostatic pressure on tissues mechanically. When the compression garments are used, the applied pressure on the skin increases the interstitial fluid pressure around the capillaries and consequently assists in the transport of excess fluid back into the circulation (veins). Which further assist the local muscle blood flow, which leads to increased tissue oxygenation and enhanced muscle function [4].

Compression garments are effective in reducing the swelling and inflammatory processes associated with muscle damage [5,6]. This, perhaps, is because compression of the limb creates an external pressure gradient reducing the space available for swelling [7]. A number of other claims that may explain improved performance and recovery have been proposed. These include reduced muscle oscillation and enhanced muscle pump function thought to reduce venous pooling, improve venous return and enhance the removal of metabolites. As early as the beginning of the 1990s, Harman and co-workers found that by tightening the bandages on weightlifting athletes' knees, the vertical force output at the athletes' feet were significantly increased (amount: 11.4±2.7 kg), while sports performance also indicated that wearing the bandage added 1RM for the athletes' squat thrust exercises [8,9].

The first sports-related study concerning compression equipment was performed by Berry and MacMurray in 1987. They found that the lower limbs' blood's lactic acid decreased after high intensity exercise while wearing compression garments, which contributed to fatigue recovery [10]. Since then, scientists have begun to study the relationship between sports compression garments and fatigue. Most of the compression clothing for athletes are designed with light or mild pressure levels with one layer. Elastane fibers commonly used in compression garments in two ways; i) by wrapped by a natural or synthetic fibers, ii) directly woven in to fabric [11]. Since elevated skin and body temperature or hyperthermia may cause impaired endurance performance, there is a potential risk of decreased performance while wearing compression clothing in hot conditions during endurance exercise [13].

2. Materials and methods

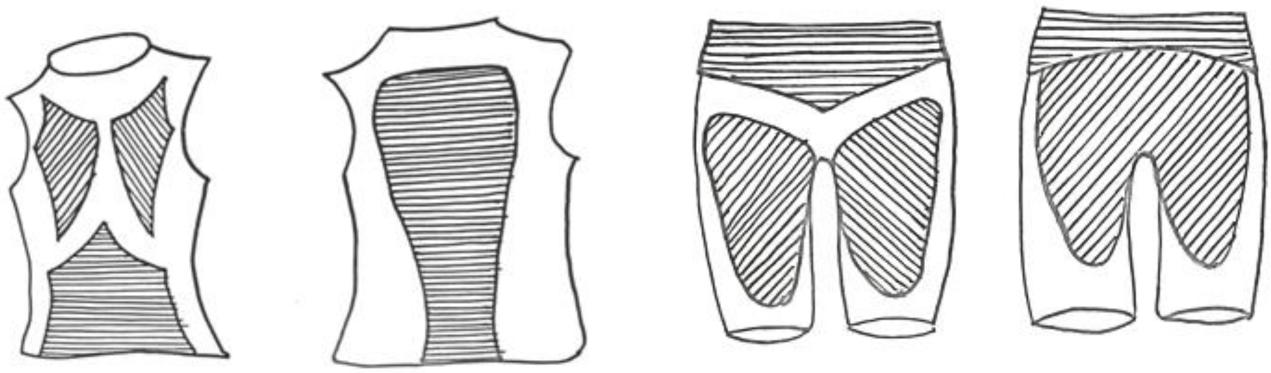
The Polyester microfiber yarn, Lyocell and Elastane yarns were sourced from the local outlets from Tirupur, Tamil Nadu, India. The fibers were knitted as double layered single jersey plaited fabric with different proportion by altering their linear densities as provided in table 1. The face side of the fabric is made of Lyocell which has better moisture absorbency and the back side is made of Polyester microfibre which is hydrophilic, in such a way that these layers are distinct and separate yet integrated with the other.

Table 1. Fabric Specification

FABRIC TYPE	COMPOSITION	CPI	WPI	GSM	THICKNESS (mm)
Lower elasticity fabric	Polyester micro fibre-75 Denier, Lyocell -65 Ne Elastane- 20 Denier	51	34	237.0	1.65
Medium elasticity fabric	Polyester micro fibre-75 Denier, Lyocell -65 Ne Elastane- 40 Denier	57	39	309.0	1.89
Higher elasticity fabric	Polyester micro fibre-75 Denier, Lyocell -65 Ne Elastane- 70 Denier	60	41	425.0	1.95
Commercial fabric	Nylon, Elastane	62	35	256.0	0.95

2.1 Design concept of compression sports wear

Shorts and tops having a localized compression effect for practicing a sport in which the legs are moved repetitively, in particular running or cycling, are constituted by stretchable textile pieces by assembling together three types of pieces. The upper body compression garment without sleeve has its compression zone in the chest and abdomen as shown in the figure1. This style of garment is mostly worn by athletes. In the figure below, the shaded area is constructed using medium elasticity fabric and the un shaded area is constructed using low elasticity fabric.



1 (a) 1 (b) 1 (c) 1 (d)

Figure 1(a) & 1(b) Front and Back of Upper Body Garment without Sleeve, Figure 1(c) & 1(d) Front and Back of Shorts

The lower body compression garment shorts are from waist to above knee length. The shorts have its compression zones in hip, thigh and buttocks as shown in the figure.2. In this figure, the shaded area is constructed using high elasticity fabric and the un shaded area is constructed using low elasticity fabric.

2.2 Preparation and physical property analysis

The measurements for the compression garment is 65% of the original measurement cut and constructed using class 500-overegde stitch and finished with the class 300 –lockstitch. The double layer fabrics developed with different elastic proportions are analyzed for pressure exerted, air permeability (ASTM D737 – 2008), water vapour permeability (ASTM E96-80), bursting strength (ASTM D 3786), abrasion resistance (ASTM D 4966), tensile strength (ASTM D5034 – 2006), elongation (ASTM D 5035), elastic hysteresis (ASTM D 4964), thermal conductivity as per lee's disk method (ASTM D 7340), moisture content and drying time (AATCC 199-2011), wickability (AATCC 197-2011), spreading rate ()AATCC 198-2011) and electromyography.

2.3 Pressure evaluation

Pressure exerted on different parts of the body was measured using Kikuhime pressure sensor with self-inflatable balloon, which is capable of measuring pressure up to 200 mmHg. Electromyography was used to measure muscle activation via electric potential, referred to as (EMG), which was traditionally used for medical research and diagnosis of neuromuscular disorders.

2.4 Field trial analysis

The main objective of the field trial is to compare the muscle movement of the volunteers wearing the developed compression garment and commercial sportswear. Muscle activation was investigated using an EMG, with and without wearing localized compression garments during running. In order to standardize the running process, the mean normalized running velocity was maintained around 5-7 m/s per minute.

- Running trials were carried out at same speed for both with and without wearing the developed compression garment and EMG signals were recorded.
- Major muscle activations were represented by the processed EMG signals through entire recording.
- Interfacial pressure generated at the specific area during stretch and relaxed state is measured using Kikuhime pressure sensor.

3. Results and discussions

The compression required at different parts of the body has been studied and the level of pressure required at those specific areas are, i) at lower thigh – 10 mmHg, ii) Upper thigh – 8 mmHg, iii) Upper body (abdomen and chest) – 15-20 mmHg. The blend analysis of different fabric composition used in this study is represented along with their physical properties in Table 2.

Table 2. Analysis of fabric properties and blend proportion

Tests	Lower elasticity	Medium elasticity	Higher elasticity	Commercial fabric
% Polyester micro fibre	63.3	60.3	58.9	60.4
% Elastomeric fibre	2.3	8.3	10.9	8
% Regenerated cellulose	34.4	31.4	30.2	31.6
Interfacial pressure mmHg	6-10	13- 16	17-21	-
Air Resistance (Kpa s/m)	0.16	0.2	0.36	0.72
Air permeability ($cm^3/cm^2/s$)	77.84	62.28	34.59	17.29
Thermal conductivity (w/m/k)	0.0074	0.0062	0.0037	0.0054
Water vapour permeability ($g/m^2/day$)	1146	1028	1035	1065
bursting strength (lb/in^2)	120	170	186	210
weight loss%	2.3809	1.9601	1.8181	2.3255
Moisture content %	4.33	3.57	3.49	3.03
Spreading area(cm^2)	3.28	3.05	2.51	0.66
Drying rate in (hour)	4.2	4	3.8	2.9
Wickability (mm)	190	200	210	270
Length wise strength (Kgf)	11.98	12.92	13.49	16.65
Length wise elongation (%)	148.77	198.57	284.6	233.69
Width wise strength (Kgf)	14.85	14.23	17.54	17.98
Width wise elongation (%)	294.01	247.64	348.29	300.37

The blend proportion analysis revealed that the commercial fabric had 60.4 % of polyester and 31.6% of regenerated cellulose content along with 8% of elastane in it. With this aspect, the low medium and higher elastic percentage fabric were designed with 2, 8 and 10% elastane content. The interfacial pressure generated by different elastic fabric ranges from 6 – 21 mmHg and meets the required level of pressure as analyzed prior. Hence the compression fabrics with different range of elasticity were used in specific areas of garment for providing localized compression effect.

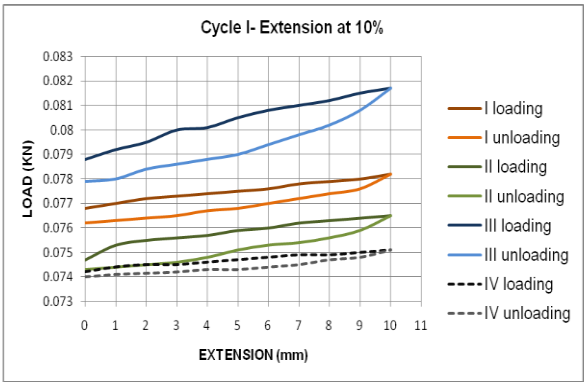
The physical property analysis revealed that the increment in elastane content from 2% to 10% had played a major role on the fabric properties. As the percentage of the elastane increases in the structure, the structure becomes tighter. In consequences, the pores between the yarns and with in the yarns got reduced. This results in an increased air resistance to the fabric. The air and water vapour permeability values of the low elastic fabric are higher than the high eleastic fabric. However, the commercial fabric has less air permeability and higher resistance than the all the developed fabric. But at the same time the reduction in permeability or inter and intra space reduces the thermal conductivity values of the fabric. Higher the elastane content higher will be the fabric tightness, thickness and less porosity and so reduced thermal conductivity of the fabric. The commercial fabric has thermal conductivity similar to medium elasticity fabric. The results of sadak et al, are in line with the findings of our research, they mentioned that the increment in elastane percentage increases the thickness and reduces the air permeability [15].

In the case of weight loss percentage, moisture content and spreading area, the increment in the elastane percentage plays a significant contribution. The increase in elastane percentage, reduces the weight loss percentage, moisture content and spreading area. This might be due to the increased thickness and compact structure. The commercial fabric had higher weight loss similar to developed low elastane fabric and the moisture content approximately closer to higher elastic fabric. In the case of spreading rate, the developed fabrics were far superior than the commercial fabric. This is one of the important factors for motivating the capillary wicking of the fabric [16]. Drying rate depicts the rate of weight loss of a wet fabric with respect to time expressed as a percentage. It is very important parameter in the case of sportswear, as the dampness created in the fabric will lead to reduced body heat and creates tiredness [17]. As the structure became compact in the high elastic fabric with 10% elastane content, the fabric compactness increases resulting in reduced drying rate. The lowest drying rate noted for the commercial fabric compared to all the developed fabric.

The less inter yarn space in the compact structure leading to reduced spreading rate and increased wickability. Spreading area is a measure of the extent to which a drop of water spreads on the surface of the fabric and it is a measure of the moisture management capability of the fabric. The spreading area and the moisture evaporations has great amount of link. The reduction on the spreading area subsequently shows a reduced moisture transport. The increment in the wicking might be a consequence of the closer fabric structure. The tight structure with lesser inter and intra yarn spacing increase the traverse wicking of the material. The strength and elongation percentage of the compression fabrics increases with elastane content both in length wise and width wise directions.

3.1 Elastic hysteresis

The elastic hysteresis of different fabric composition is shown in the figures 6 for lower elasticity fabric (I), medium elasticity fabric (II), higher elasticity fabric (III) and commercial fabric (IV) respectively. From the above figures, it is seen that the elastic hysteresis is very negligible and all four fabrics for three cycles and recover to their original dimension after relaxation and thus the elastic recovery is approximately 100%.



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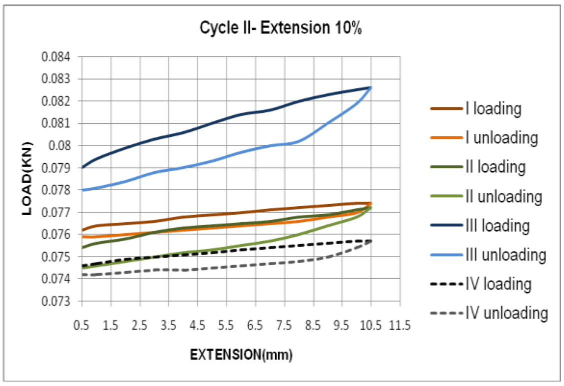

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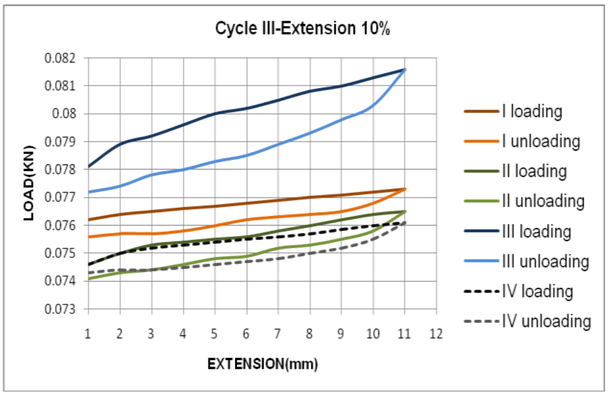
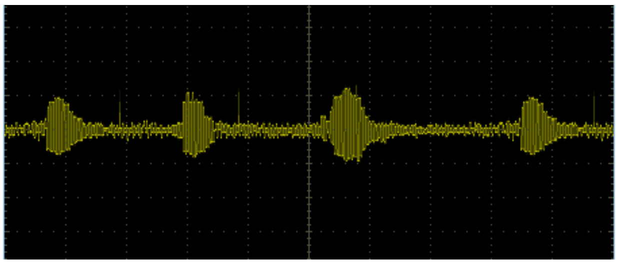


(c)

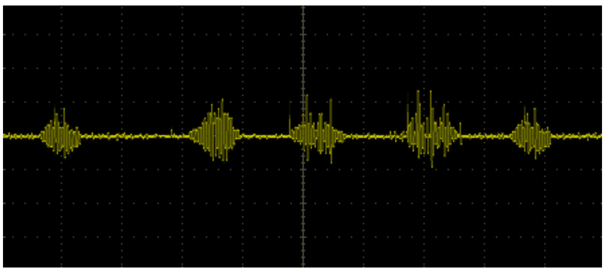
Figure 3. Elastic Hysteresis at a) Cycle I, b) Cycle II and c) Cycle III - Extension 10%

3.2 Evaluation of muscle activity

Measuring muscle activation via electric potential, referred to as electromyography (EMG), has traditionally been used for medical research and diagnosis of neuromuscular disorders. Muscle activation was investigated using EMG, with and without wearing localized compression garments during running. The muscle activation is recorded as a graphical output and the amplitude in volts.



(a)



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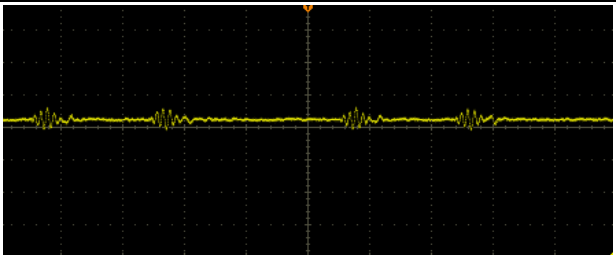

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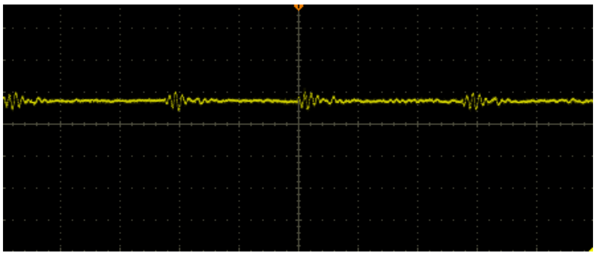


(d)

Figure 4. a) Muscle activation without wearing compression garment; b) for lower elasticity fabric; c) for medium elasticity fabric; d) for higher elasticity fabric

The figure 4 a) shows the muscle activation during running without compression garment. From the graph it can be observed that the muscle movement is high with the recorded amplitude of 2.00 V. The figure 4 b) shows the muscle activation while wearing lower elasticity fabric during Running and the amplitude measures 500 mV. Even with low elasticity fabrics, the muscle activity seems to be reduced to great extent and the amplitude is reduced to 500 mV. The figure 4 c) shows the muscle activation during running while wearing medium elasticity fabric. The amplitude is still reduced to 200 mV. The figure 4 d) shows the muscle activation during running while wearing higher elasticity fabric and the amplitude noted was 100 mV. By analyzing the muscle activation using EMG, it was found that the participant without wearing localized compression garment presents a larger muscle activation volume than wearing a localized compression garment. Comparing all the three elasticized fabrics, the higher and medium elasticity fabric showed 90% reduction in the muscle movement. Since, the part of the muscles' activities (muscle tuning) were proven to reduce soft tissue resonance, it is proposed that the soft tissue vibration was crucial for the energetic running. The compression garment could reduce muscle vibrations during human locomotion and these findings were in line with the previous researchers [19-21]. Hence, compression garments can be used to reduce soft tissue vibrations, prevent unnecessary muscle tuning activities and decrease energy consumption.

3.3 Field trial

Field trial was carried out to analyze the performance of the sports person with/without wearing localized compression garment. The participant was made to run on a treadmill with a speed of 5-7 m/s and also perform cycling and the average distance covered per minute was recorded. The interfacial pressure generated during normal and stretched conditions are also recorded. As observed from literatures [14, 22], the optimal pressure gradient which would generate fastest venous flow on specific areas of human body are shown in the Table 3.

Table 3 optimal pressure level

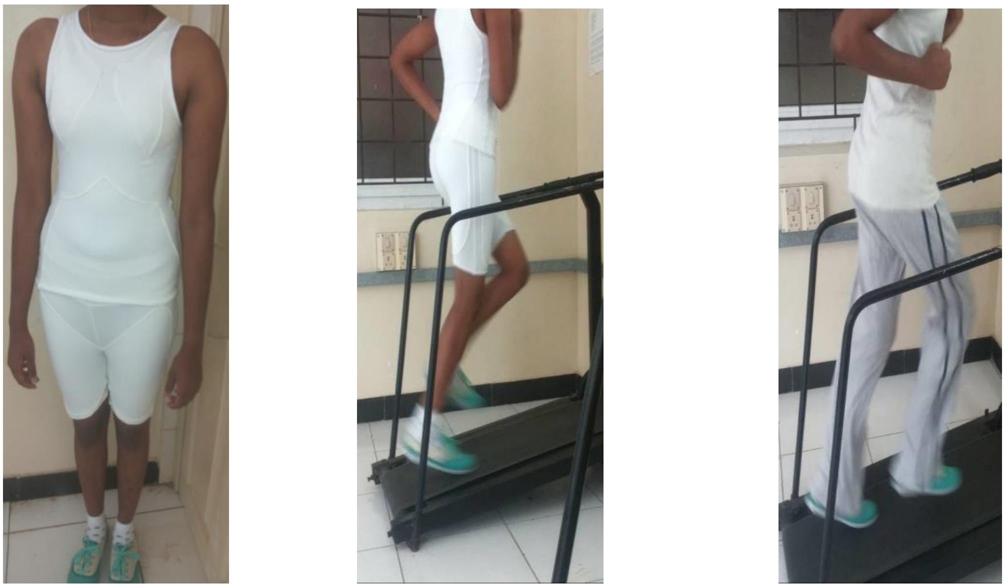
SPECIFIC AREA	OPTIMAL PRESSURE GRADIENT(mmHg)
Ankle	18
Calf	14
Knee	8
Lower thigh	10
Upper thigh	8
Upper body	15-20

The graduated pressures generated by commercial branded sport garments ranges from19.0-30.0 mmHg at the ankle to 17.6-25.0 mmHg at the calf and to 9.1-18.0 mmHg at the thigh but these claims are not substantiated by any research. The degree of pressure produced by a compression garment is determined by a complex interrelation between the following principle factors: the construction and fit of the garment; structure and physical properties of its materials; the size and shape of the part of the body to which it is applied; and the nature of the sporting activity undertaken. [14] The interfacial pressure generated during normal and stretched level while using the developed garment was measured using Kikhume pressure sensor and is listed in the table 4 below. The measured interfacial pressure is well within the optimum pressure and is sufficient to generate venous flow. The required level of pressure in the specific areas has been exerted by the developed localized compression garment and during field trial it was found that the participant exerted more muscle power without localized compression garment.

Table 4. Interface Pressure during Field Trial

SPECIFIC AREA	NORMAL(mmHg)	STRETCH(mmHg)
Upper thigh	10	14
Under thigh	11	12
Abdomen	14	16
Chest	12	14

During field trial it is observed that the sports person could cover more distance in a specified period of time and the duration of effective activity also increased. The distance covered per minute without wearing the localized compression garment was 360 m and the same while wearing compression garment is around 395m. An improvement of 8.8% in the performance could be observed. Similarly during cycling also the performance increased around 10%. Compression garments provide ergogenic benefits during training and athletic performance, these proposed benefits include an increase in strength and power as well as improved endurance performance. Advantages are thought to be achieved via a number of mechanisms, which include increase in muscle oxygenation resulting from improved blood flow to the muscle and reductions in muscle oscillation thought to reduce the severity of fatigue. Use of compression garments can reduce concentrations of blood lactate when worn both during and after strenuous exercise.



(a) (b) (c)

Figure 5. Field trial images, a) Garment appearance, b) with normal garment and c) with developed Localized Compression Garment.

The experiment shows that, there is a significant increase of nearly 9% in the performance of the wearer. Hence, during running and cycling it is more advantageous to wear localized compression garment where less muscle activation is occurring thereby enhancing the performance of the wearer. If compression clothing is worn during prolonged exercise, the athletes will benefit from improved lactate elimination, reduced muscle pain, damage and inflammation during recovery. These processes are likely due to reductions of muscle oscillation during exercise, improvements in clearance of metabolites through improved blood flow, lymphatic outflow and reduced space for swelling. Potentially, this might improve recovery and enhance subsequent performance. Cycling performance seems to be more positively affected by compression clothing, A potential benefit of compression clothing is displayed during the immediate recovery from intense cycling and running since blood lactate concentrations were reduced during this period. Compression appears to exert positive effects on perceived leg or muscle soreness and delayed onset of muscle fatigue following running and cycling. The positive impact appears mostly within the following 24 h after exercise if compression clothing is worn during running.

4. Conclusion

Localized compression garment is designed and developed in such a way that, it produces localized compression effect in the specific area with the required interfacial pressure. Different composition of compression fabric made of polyester microfiber, lyocell and elastane has influence on the generated interfacial pressure. It is observed that with increase in elastane% and elastane stretch, the fabric becomes compact and thick with higher thermal resistance and reduced permeability to air and moisture vapour. As the elastane % increases, the moisture content, spreading area and drying rate are higher but the wickability is lower. During field trial, usage of medium and higher elasticity fabrics showed a reduction of 90% in the muscle movement as analyzed through EMG. The experiment resulted with 9% increase in the performance of the volunteer. Hence, it is more advantageous to wear compression garments, where less muscle activation occurs, thereby enhancing athletic performance.

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