PERFORMANCE OF COMPRESSION GARMENTS FOR CYCLISTS

The Textile Institute's International Conference on
ADVANCES IN FUNCTIONAL TEXTILES

25-26th July 2013 Chancellor's Hotel and Conference Centre, Manchester, UK

Authors: Venkatraman, P.D., Tyler, D.J., Ferguson-Lee, L., and Bourke, A.

Manchester Metropolitan University
Department of Clothing Design and Technology
Hollings Faculty, Old Hall Lane, Manchester, UK M14 6HR

Abstract

Base layer compression garments had been used by professional cyclists to enhance their performance. To date there is significant body of evidence relating to compression modalities in treating patients suffering from leg ulcers. However, research relating to sportswear compression garment is varied and inconclusive, a few research suggested benefit to athletes or aid recovery from exercise. This depends on a number of factors such as material (fabric/garment design, interaction), athlete (body shape, intensity of use, fitness, and perception) and type of sport or use (intensive or casual). The current research intends to establish a knowledge base by exploring the performance of garments using a combination of laboratory investigations and wearer perceptions. Four commercially available compression garments were evaluated for its performance. These include two professional brands (SKINS, RAPHA) and retail brands (Sub-dual and Sports Direct Muddyfox). The pressure profile of these garments was investigated on participants using Tekscan pressure sensors on various points (lower limb). Wearer trial investigated their perceptions for its fit, comfort, ease of wear, tactile sensation, and overall satisfaction. Various textile parameters evaluating garment durability, comfort, colourfastness and stability facilitated in determining its efficacy. In addition, wearer trials were conducted to measure physiological measurements. Overall, professional compression garments performed better compared to standard products. Suitable inferences drawn from these preliminary findings enabled to ascertain the performance of compression garments and aid in further development.

Keywords: Compression garments, pressure profile, Tekscan, performance, wearer trial perception

For correspondence: p.venkatraman@mmu.ac.uk

Introduction and background

Professional cycling in the UK has increased in the recent years encouraged by national cycling events, Tour de France, and World Cycling Championships 2013, Belarus. The rising interest in sports activities has increased the demand and expectations for active sportswear. British Cycling (2008) stated that Sport England had declared cycling as the second fastest growing sport in England because of Tour de France and Beijing 2008 Olympic Games that saw Sir Chris Hoy breaking several records. According to Mintel (2012), London Olympics 2012 will increase sports retailing, Adidas an official partner of Olympic believes that games will generate £100 million in revenue. The games have also inspired many to become physically active and involve in mass participation. Women were targeted to reduce the gender gap in participation. Mintel (2012) also added that sports clothing and footwear market was valued at £4.8 billion in 2011, a growth of 18% since 2006, forecasts indicated that the market will be worth £5.9 billion by 2016. According to NPD group (global provider of consumer and retail market research), cycling is the biggest sporting goods market worldwide. It further stated that global sales were US $46 billion during 2012, an increase of 4% since 2009. Recently London School of Economics published a report on the economic value of cycling in the UK that estimated country's GCP or 'Gross Cycling Product' was around £2.9bn, or £230 per cyclist (Bikeradar, 2013).

At elite level, improved individual performance during a tournament or a game is intensive such that compression of muscles to support and enhance muscle alignment and improving the efficiency of muscle movements are essential. The adage of strapping the injured part assists in recovery of injury. In recent times, there has been an increase in usage and demand for compression garments for cycling. Bike racers wear skin-tight garments, which they believe offers less wind/air resistance and is aerodynamic. A professional cycling kit includes, bib shorts, cycling shoes, short sleeved jersey, base layer vests, fingerless gloves, socks, and cap.

The compression garment in healthcare tightens around the muscle area that is affected to accelerate blood flow to the heart. The blood is then pumped back to the area, through high pressure arteries but trickles through the low-pressure veins as well. The added pressure then forces the blood in the veins to accelerate around the damaged area, thus assisting the healing process. Professional athletes in the 1980s came to realise that compression garments could be useful, and benefit athletes (Bastone, 2013).

Compression garments and their performance

Glanville and Hamlin (2012) noted that many athletes employ compression garments whilst exercising, during rest and sleep breaks. Research has shown that compression garments could reduce muscle oscillation, while improving circulation and venous return. Blood flow velocity is enhanced, increasing arterial perfusion, while decreasing lactate and creatine kinase (a neuromuscular disorder). Wallace et al (2008) stated that there were relatively few studies about compression garments, but recent research with athletes has demonstrated that compression garments may provide performance-enhancing benefits during exercise and increased lactate removal, reduced muscle oscillation and resulting psychological factors.

Equmen, a compression brand claimed that compression garments would improve wearer's core alignment, stability and temperature. This means that the bones can support the body with reduced stress and so the muscles can focus upon efficient movement without excess tension (WSA, 2011). Duffield et al (2010) stated that there was no improvement when sprinting athletes wore compression garments, but did improve the psychological effect during recovery. Duffield et al (2010) further added that no improvement was recorded in performance during exercise days and that improvements post exercise were lacking. These claims remain untested and are very difficult to ascertain the effectiveness of compression garments. Research studies lack clarity, the studies reported highly noticeable differences, but most focused on different factors such as psychological, posture and lactate reduction. Research studies were conducted on small bouts of high intensity exercise, while more research into long distance cycling compression could indicate whether compression garments would make an impact on cyclists during cycling and recovery.

Major market players in cycling compression garments include SKINS, 2XU, and Rapha. SKINS (2013) claimed that their high performance garments consider all compression levels that are needed to increase oxygen to working muscles. Garments engineered to provide the correct level of surface pressure to muscle groups and all garments have a warp knit with spandex, for specific levels of stretch for controlled compress. Garment aid moisture management with multiple yarns used for strength and resistance to tearing.

2XU is another highly popular compression garment brand with athletes; 2XU compression technology offers a number of benefits such as improved circulation, reduced damage, faster recovery, Deep-Vein Thrombosis (DVT) protection, increased performance, heightened agility, increased protection and comfort (2XU, 2013). 2XU properties are the same as SKINS but neither manufacturer specified seams or panels. The garments that are being used for experimental work and wearer trials should be examined for seams and panels. But do seams and panels actually make a difference or, could a seamless compression garment be better for performance, in terms of less drag.

Rapha Racing Ltd use supplier, M.I.T.I spa, to produce specialist warp knits with thermal properties. The fabrics used in Rapha cycling tights are a double-layered warp knit fabric, Thermoroubaix Cool made with Thermocool. The Rapha fabric is specialised in quality and functionality, made specifically with cycling and running apparel in mind. Rapha winter tights, designed to be worn over cycling shorts with a chamois. The tights include thermoroubaix fleece lining, making it a heavier weight but staying breathable. Front panels are windproof and the hard–wearing seat panel fabric has abrasion resistance, water-repellency properties, including reinforced stitching. There is a lightweight mesh back for breathability, whilst rear leg and chest fabric panels are thinner to decrease overheating. Flat-lock stitching off-set seams prevents chaffing (Rapha, 2013). Giordano (2013) also produces custom made cycling garments for major cycling events.

Liu and Little (2009) have constructed a model to understand comfort and to optimise compression garments. The model includes, physiological, physical properties, psychological and psychophysical and psychophysiological properties. Liu and Little (2009) stated that cycling athletes perspire 14 times more than those performing an indoor activity, while a cyclist’s metabolic heat increases six times more. This affects athlete’s performance and their physiological response, resulting in production of sweat, whereby men perspire 20% more than women do. Hence, sweat management is significant to aid comfort for intensive sports such as bike racing.

Downer and Cassidy (2011) stated that mountain biking and road cycling clothing have to endure environmental factors, such as weather conditions whilst ensuring that the garment can provide comfort, warmth and breathability. The garment should be very resilient and abrasion resistant, as the wearer may fall off the bike or have to be protected from debris such as tree branches. Glanville and Hamlin (2012) conducted an experiment into lower body compression garments on a 40 km cycling time trial performance to inquire about the positive effects it may have on the wearer. The study compared a SKINS hip to ankle length tights with placebo garments but the wearers were informed that they were all compression garments. The wearers were also advised on hydration techniques for the 40 km exercise, were denied food and advised to wear the garments in the shower. The study proved that the SKINS garments provided marginal improvement compared to the placebo and that the improvement to muscle blood flow that was detected may be arterial, rather than venous changes with compression.

Wallace et al., (2008) stated that research with compression garments proved blood lactate concentration during vigorous cycling. Research by Berry and McMurray (1987) witnessed a very noticeable reduction in blood lactate levels with compression stockings worn by fit males when cycling. Chatard et al (2004) confirmed this research but with twelve elderly trained cyclists and noticed plasma volume as well. Wearing compression garments for an 80-minute rest period after a 5-minute vigorous cycle can significantly improve performance and recovery.

Regulations for bike racing clothing

Garments intended for professional bike racing significantly differ from recreational cycling. This is highlighted in the regulations below.

- Back, elbow, knee and shoulder protection are produced with rigid materials.
- There must be protection for the nape of the neck and the cervical vertebrae.
- Padding on shins and thighs
- Broad full-length trousers must be made from rip-resistant material incorporating protection for the knees and calves, or broad-cut shorts made from rip-resistant material plus knee and calf protectors with a rigid surface.
- Long sleeved shirt
- Full finger gloves (British Cycling, 2013)

Garments used in professional bike racing

A range of garments (Figure 2a - 2c) are available for professional cycling this include sleeve jersey, sleeveless jersey, long sleeve jersey, jacket, vest, long and short sleeve skin suits, bib shorts, tights and knickers.

Figure 1 A professional cyclist, (Source: Image courtesy of Giordana)

Figure 2a Range of cyclist garments

Source: Giordana (2013)

Figure 2b Range of cyclist garments

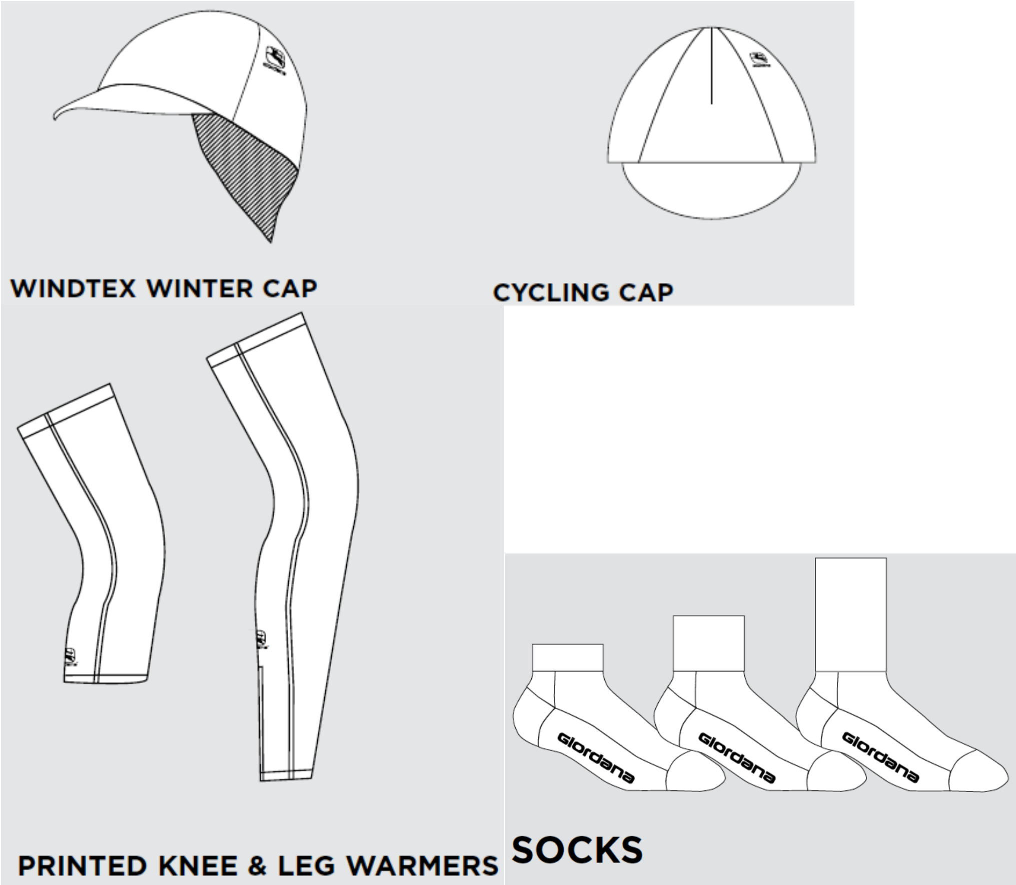


Figure 2c Range of cyclist garments

Requirement of fabrics for cycling

The fabrics used for cycling are functional and specific to the athlete's requirements. The garments are designed for summer and winter season. The warp knit fabrics in summer season are intended to offer breathability, lightweight, UV protection, able to dry quickly, dimensionally stable and offer stretch and recovery. The garments are skin tight and form fitted. Fabrics for winter include fleece knits for providing warmth, and are predominantly long sleeve jersey. The cycling kit also includes wind resistant jacket with fabrics that are wind resistant, breathable, and offer comfort to the wearer. Some of the main properties of the fabrics for cycling include:

1. Optimum heat and moisture management
2. Permeable to air and moisture
3. Lightweight and durable
4. Ability to offer stretch and recovery
5. Anti-static
6. Anti-microbial
7. Dimensionally stable
8. Quick drying
9. Ultra-violet rays protection

10. Water repellent
11. Wind resistant

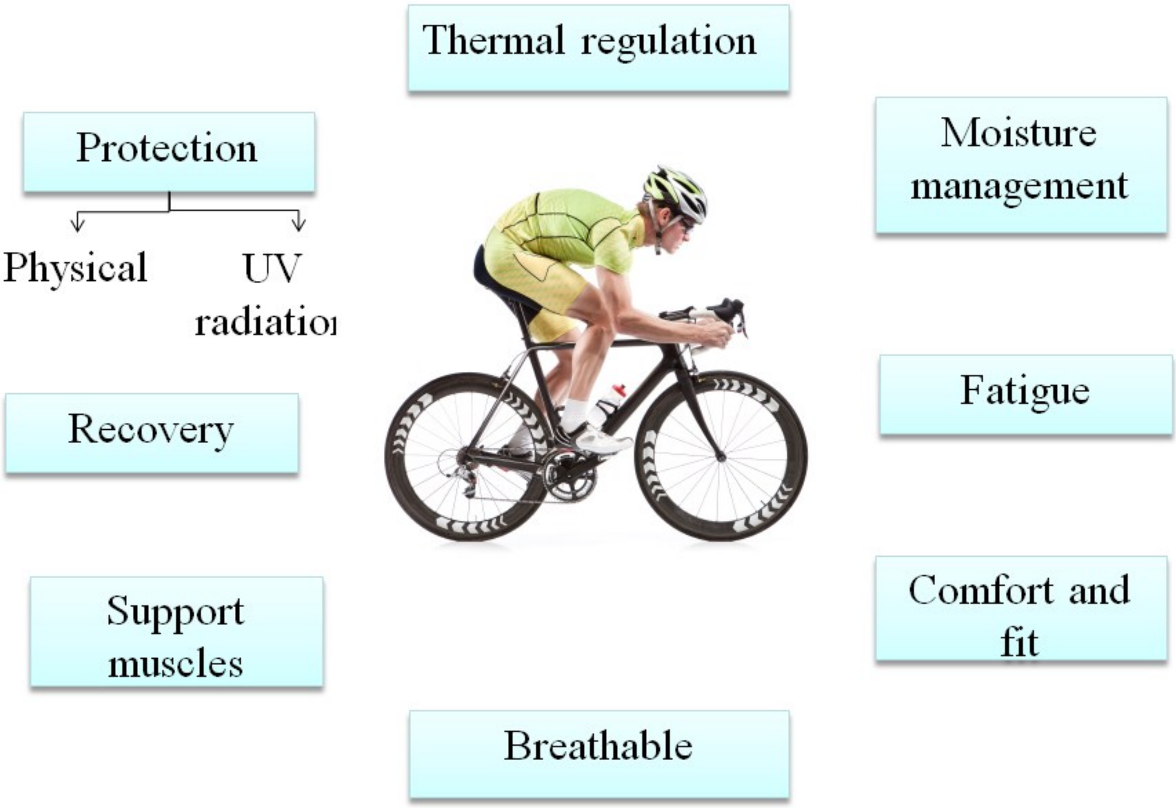


Figure 3 Requirements of cycling clothing

Figure 3 illustrates the requirements of fabrics intended for cycling. Cyclists prefer protection for their lower and upper limb during a cross country ride. In addition, it is also necessary to protect them from UV radiation during summer events. For instance, Schoeller's Coldblack® UV protector reflects visible and invisible sunlight, a minimum of UPF 30 protection (Schoeller, 2013). One of the most important features of compression garment is to aid the recovery of muscle from strain. Maton et al., (2006), research on fatigue recovery reported that compression garments did not increase fatigability and elastic compression garments did not improve force recovery during rest following static fatiguing voluntary contractions. Young (2009) patented garments with fabric panels isolating specific muscle groups and aid in blood circulation and prevent soft tissue injury. It is necessary to have garments that quickly wick the sweat from the body as athlete's produce more sweat than any other indoor activity (Liu and Little, 2009). Schoeller's 3XDRY® offers such a property, whereby the fabric absorbs perspiration and distributes over a large surface. It also repels stain, water droplets and dirt in the outer surface. Hence the fabric offers three functions – water repellent, absorb perspiration, and dries instantly providing a cool effect to the wearer. These fabrics designed for cycling should be breathable with the ability to manage moisture offer comfort to the wearer. It can be inferred that fabrics intended for cycling should be multi-functional and performance-oriented that can offer a multitude of properties to the wearer when needed.

Leg muscles are the main source of power and endurance, during cycling a cyclist uses the following muscles:

- Gluteal muscles – bottom area pushing pedals at the top of a stroke.
- Quadriceps – large muscles at the front of thigh that straighten the leg when pushing the pedal down to the ground
- Calf muscles
- Hamstrings – located at the back of the thigh, working with calf muscles lifting the pedals up from the bottom of a stroke

There are support muscles working together with leg muscles, such as upper muscles engaging with handlebars used and terrain dependent. For example, a hill climb will encounter handlebar pressure so biceps enhance power. Back and abdominal muscles are also important to stabilise cyclists whilst riding. (Yake, 2011)

Some of the injuries incurred from cycling

1. Neck (48.8%),
2. Groin/bottom (36.1%) - due to pressure during prolonged sitting
3. Knee (41.7%)
4. Lower back (30.3%)

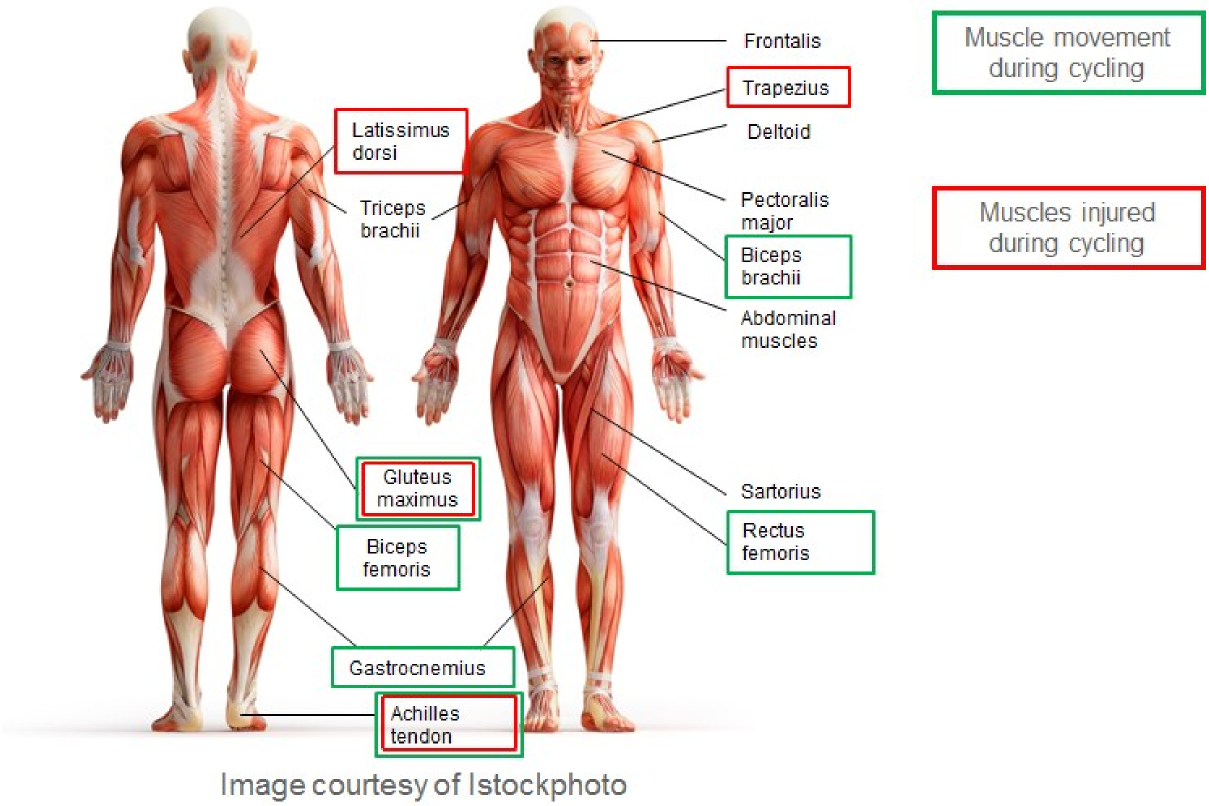


Figure 4 Muscles affected/injured during cycling

Figure 4 above indicates muscle movement during cycling and muscles injured during cycling. It is therefore necessary to ensure specific muscle groups are provided sufficient support, to aid in blood circulation or assist in reducing soft tissue injury.

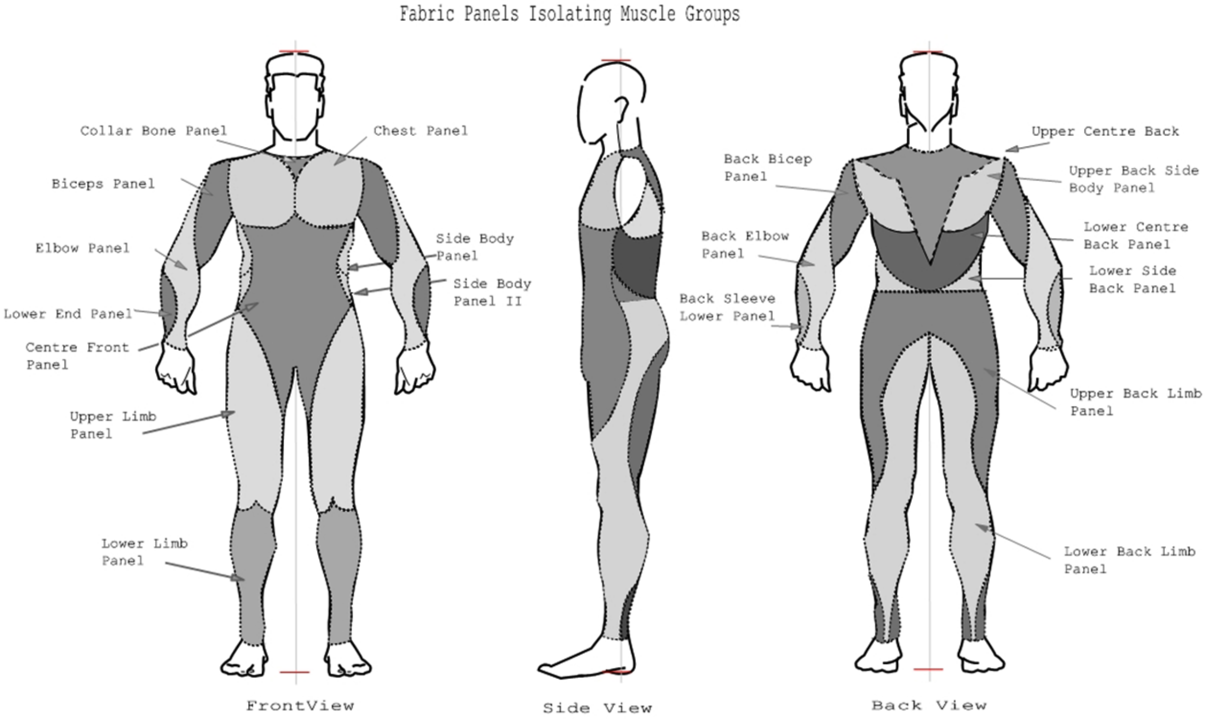


Figure 5 Fabric panels for various muscle groups (source: MMU)

Compression garments are made of fine knitted fabric that contains 80-75% polyester or nylon and 20-25 % elastomeric filaments, which stretch and recover back to their original shape during physical movements of the body. In a typical flat knit, stretch fabrics can be produced using inlay and body yarn (elastomeric yarn) that imparts stretch-ability to the fabric. A recent US patent (Young, 2009) on manufacture of compression garment for sportswear highlighted the number of panels required to isolate and support specific muscle groups and aid in blood circulation or assist in reducing soft tissue injury. It also added that panel shapes and seams correspond to various muscle groups for a whole body compression garment.

Table 1 Fabric Panels for specific muscle groups

Front view	Collar bone panel
	Biceps panel
	Elbow panel
	Lower end panel (arm)
	Centre front panel
	Upper limb panel
	Lower limb panel

	Side body panel I and II
	Chest panel
Back view	Back bicep panel
	Back elbow panel
	Lower back end panel
	Lower back limb panel
	Upper back limb panel
	Lower side back panel
	Lower centre panel
	Upper back side body panel
	Upper centre back panel

During this study, various fabric panels of a full-body compression wear are proposed that contains 19 different panels (front and back). A recent research (Allsop, 2012) investigating the pressure profile using Tekscan pressure sensors identified that when a compression wear made of more number of panels, that are sewn together, the pressure applied by the garment on to a specific muscle group is not uniform. Hence, the lesser the number of sewn fabric panels the better the pressure applied. This is presented in Figure 5 where fabric panels are designed based on the specific muscle groups as highlighted in Figure 4.

Factors affecting sports performance

Cycling sports requires endurance and preparation, and there are many factors affecting the overall performance of the wearer. During this research three core factors have been highlighted, clothing/material they wear, athlete's capability and intensity of sport. Compression garments are designed to intimate contact with the human skin; hence there is interaction of garment with athlete. This obviously depends on the musculature, microclimate of the fabric, and physiological response of the athlete that depends on the intensity of the sport.

Figure 6 Factors affecting sports performance

Methodology

The paper discusses a range of research activities undertaken to assess the performance of compression garments for cyclists. Consumer perspectives were enquired with cycling enthusiasts and cycling club at Manchester Metropolitan University. Two different assessments were carried out, survey 1 compared leggings from two brands, sub-dual and Skins and survey 2 explored the performance of cycling tights and jackets from Rapha and Sports Direct Muddyfox. Survey 1 explored the fabric properties and conducted a wearer trial to assess the comfort, aesthetics, fit, tactile sensation and overall satisfaction of the garment. Garment performance was evaluated according to British Standards. Survey 2 evaluated the compression garments particularly leggings from Sports Direct and Rapha. Tekscan pressure sensors were used to monitor the pressure profile of these garments. The pressure sensors were placed in the anterior part of the thigh to explore the pressure profile characteristics of garments. In addition, physiological measurements were measured to ascertain athlete's performance whilst wearing a compression cycling clothing.

Consumer perspectives on cycling

A questionnaire comprising of 10 questions relating to perspectives of professional cyclists were probed. The questions include their preference to fabrics; fabric weight, use of innovative technology in cycling gear, does technology enhances performance, garment design, and important aspect of garment designing. It was distributed to Sports Direct assistants, general cycling enthusiasts and the Manchester Metropolitan Cycling Team. The survey was responded by 40 participants. The results are discussed in the section below.

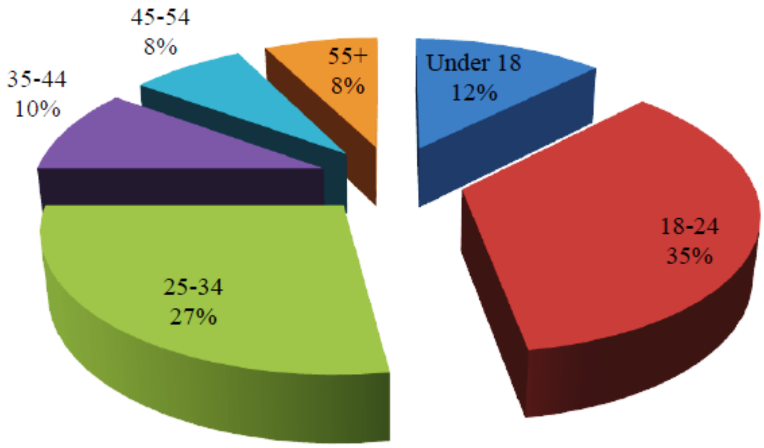


Figure 7 Participant demographics

It can be noted that from the above pie chart the participant's age range varied from under 18 to 55 years. It is interesting to note that majority of participants (62%) were in the age group of 18-24 and 25-34 and 10% were 35-44 years. The chart below (Figure 8) shows that men were interesting in cycling compared to women.

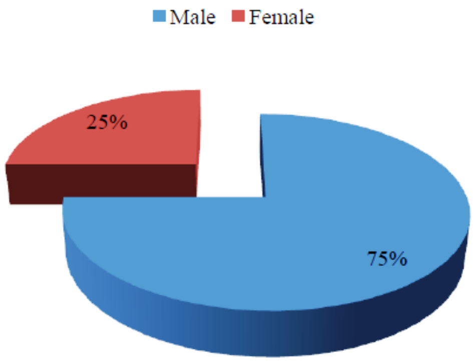
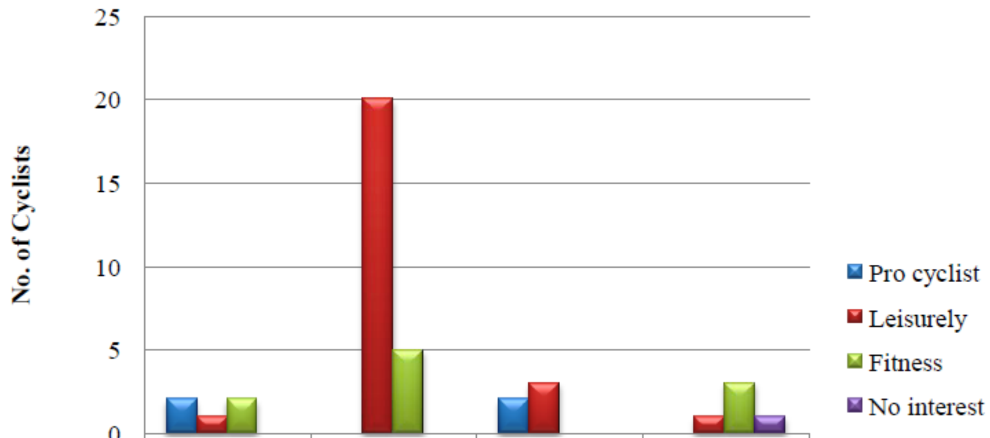


Figure 8 Participant demographics by gender



	MMUCC	General	Rapha	Sports Direct
Pro cyclist	2	0	2	0
Leisurely	1	20	3	1
Fitness	2	5	0	3
No interest	0	0	0	1

Figure 9 Participant breakdown

The participants were also probed about their reasons for cycling, and it can be revealed that 50% of general respondents (n=20) practice cycling for recreational purpose and a minority of (n=5) prefer to cycle for maintaining their fitness. Among MMU cycling club, there were pro-cyclists and fitness participants. Similarly in Rapha there were two pro-cyclist and three respondents were practicing cycling for leisure.

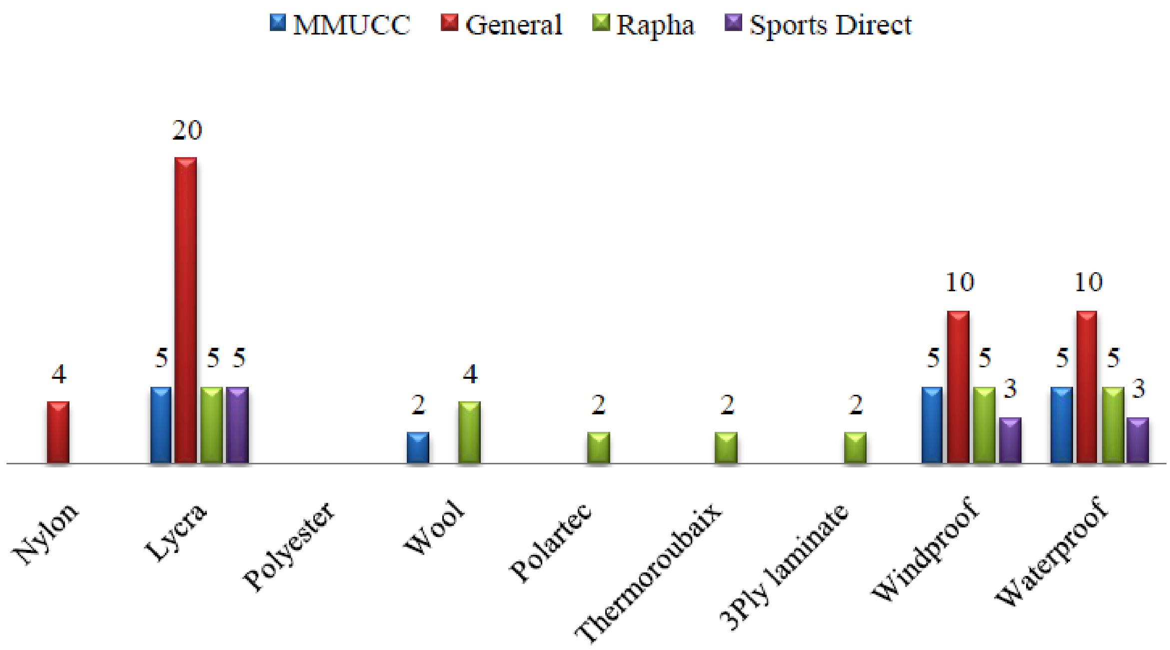


Figure 10 Participants preferred fabrics

Survey respondents also responded to their choice of fabrics in their garments. It can be noted that most preferred garments with certain amount of lycra or elastane. Some respondents reported that they preferred laminated fabrics, wool blends and fabrics that offers thermal insulation. In addition, respondents also preferred windproof and water proof fabrics. It was interesting the cyclists did not prefer polyester based fabrics. It can be inferred that participants expect performance from these fabrics based on the fibre content.

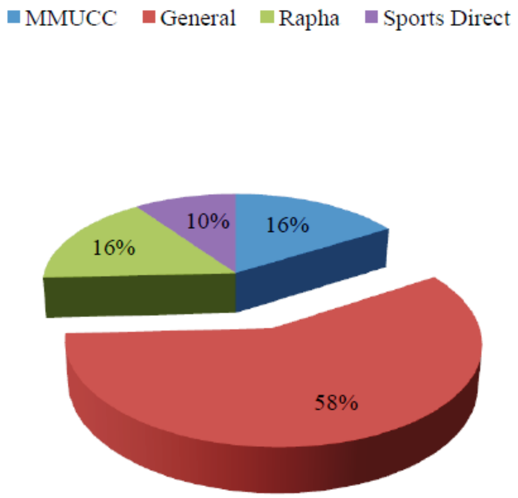
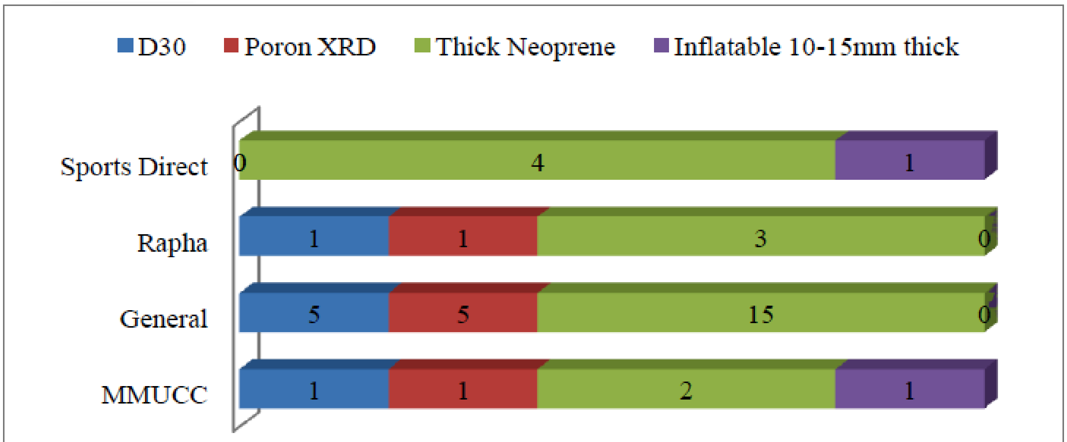


Figure 11 Importance of fabric weight in garments

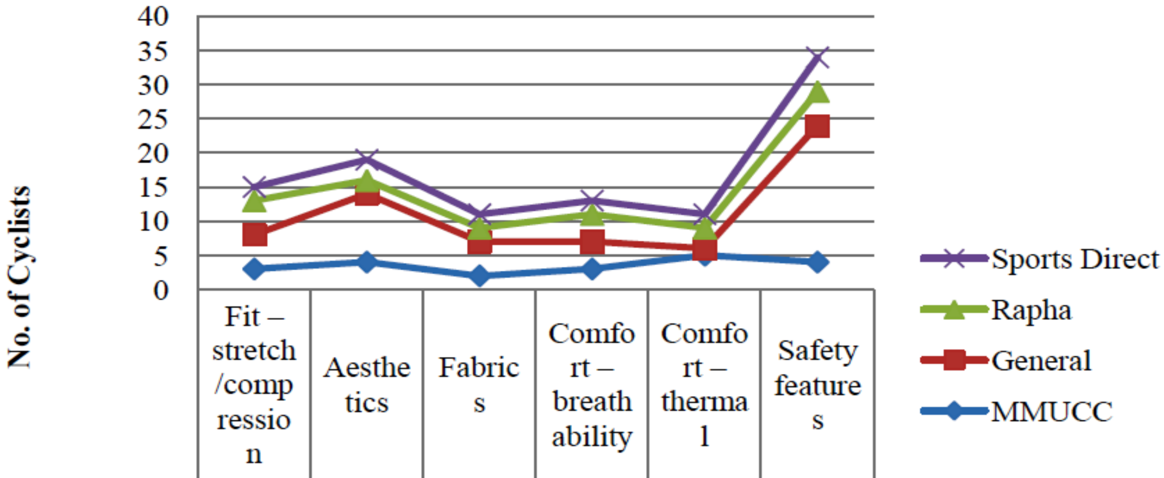
Respondents reported that fabric weight is important while selecting their clothing for cycling be it for leisure or competition. 58% of general participants, 16% MMU cycling club and Rapha cycling enthusiasts reported the same. This demonstrated that cycling garments should be made from light weight fabrics which is functional and performance specific.

The participants were also enquired if they preferred any specific technologies during cycling (for eg. protection). Most participants (n=24) reported that they would prefer neoprene in their cycling gear for protection, a few participants (n=7) preferred Poron XRD and seven participants preferred d3O. A minority of participants also reported that they would prefer 10-15 mm thick inflatable pads.



	MMUCC	General	Rapha	Sports Direct
D30	1	5	1	0
Poron XRD	1	5	1	0
Thick Neoprene	2	15	3	4
Inflatable 10-15mm thick	1	0	0	1

Figure 12 Preferred technologies in cyclist garments



	Fit – stretch /compression	Aesthetics	Fabrics	Comfort – breathability	Comfort – thermal	Safety features
Sports Direct	2	3	2	2	2	5
Rapha	5	2	2	4	3	5
General	5	10	5	4	1	20
MMUCC	3	4	2	3	5	4

Figure 13 Cyclists garment requirements

Participants were asked about their garment requirements (Figure 13) and it was interesting to note that fit, compression, aesthetics, comfort and breathability was important. Among other garment requirements, safety feature was the most sought property among the respondents. It was surprising to note that MMU club did not prefer safety feature in their garments. From the above survey it can be inferred the cycling garments have to perform to a wide range of conditions and this include, thermal comfort, moisture management, light weight, form fit, safety, breathable, and above all garments should have innovative technologies to protect them from injuries.

Survey 1: comparison of sub-dual and Skins compression tights

Figure 14 Subdual compression tights

Two male leggings Sub-dual and Skins (images shown in Figure 14 and 15) were explored for their physical parameters. It can be noted that both garments were dissimilar in their appearance particularly their fabric panels and design. The results are summarised in Table 2. Sub-dual garment was made from 82% nylon and 18% elastane and had a tricot warp knitted structure. The garment had reflective prints in their side panel as seen in Figure 14 and elastic waist band. Skins garment is made of 75% nylon and 25% elastane, solution dyed, and is a tricot warp knit. Skins fabric was lighter than sub-dual. Bursting strength of Skins was 133 kPa compared to 73.0 kPa. This revealed that Skins fabric resisted rupture such as fingers or thumbs or any device pushing against the fabric. Seam strength of Skins was 151.3 N compared to 98 N for Sub-dual. With regard to stretch and recovery, Skins garment had lesser extension compared to sub-dual however; the relaxation was good compared to sub-dual. This meant that sub-dual garments would not return to original shape when subjected severe stretch, whose relaxation extension was 5.3% for warp and 3.3 for weft respectively. Skins garment was dimensionally stable compared to sub-dual. Both garments achieved a pilling grade 4 that indicated the fabric had minor surface fuzz. Colourfastness to perspiration was also evaluated and it revealed that both garments results obtained staining scale rating two indicating that a significant amount of staining did occur. Nylon fabric test strip scored 3/4 for both garments, which was a significant result as both garments are nylon blend. For both the garments the colour was not fixed properly and it stained during the test, which meant the garment would stain when an athlete perspired during an intense activity.

Figure 15 Skins Compression Tights

Table 2: Garment Performance – Survey 1: Sub Dual and Skins

<table>
<tr><th colspan="2">Parameter evaluated</th><th>Sub Dual Compression tights</th><th>Skin tights</th></tr>
<tr><td colspan="2">Fabric Weight (g/m^2)</td><td>250</td><td>236</td></tr>
<tr><td colspan="2">Fabric Thickness (mm)</td><td>0.67</td><td>0.60</td></tr>
<tr><td colspan="2">Bursting strength (kPa) BS EN 13938-2: 1999</td><td>73.0</td><td>133.0</td></tr>
<tr><td colspan="2">Seam Strength (N)</td><td>98.0</td><td>151.3</td></tr>
<tr><td rowspan="4">Stretch and recovery (%) (BS 4294-1968)</td><td>Warp Extension</td><td>146.0</td><td>106.0</td></tr>
<tr><td>Weft Extension</td><td>193.0</td><td>120.0</td></tr>
<tr><td>Warp Relaxation</td><td>5.3</td><td>4.0</td></tr>
<tr><td>Weft Relaxation</td><td>3.3</td><td>0</td></tr>
<tr><td colspan="2">Dimensional stability (BS EN ISO 5077:2008)</td><td>Warp -1% / Weft 1%</td><td>Warp / Weft 0%</td></tr>
<tr><td colspan="2">Pilling grade (BS EN ISO 12945)</td><td colspan="2">4</td></tr>
<tr><td colspan="2">Colourfastness to perspiration
Stain scale (BE EN ISO 105-E04:2009)</td><td colspan="2">Alkali 2 to 5
Acid 2 to 5</td></tr>
</table>

Wearer trial: Sub-dual and Skins compression tights

Wearer trials were conducted using two male participants of similar age and professional level. The participants undertook an hour-long vigorous mountain cycle with one participant wearing the standard garment A (sub-dual), and the other participant wearing the professional garment B (Skins). The questionnaire assessed various garment parameters including comfort, aesthetics, fit and overall satisfaction of garment at different time intervals:

- 0 hours (T0): whilst wearing
- 30 minutes (T30): during wearing the garment
- 60 minutes (T60): removing the garment
- 4 hours after cycling (T0): re-wearing the garment

The results for various sections of the survey are visually illustrated. It can be noted that garment A was comfortable to wear at the start compared to garment B, however, after 30 minutes of wearing the garment, garment B was more comfortable than A, again when removing the garment after an hour of workout, Garment B was more comfortable compared to garment A. This could be attributed to its design and fabric stretch properties. However, it was quite surprising to note that garment A was comfortable after four hours of cycling. With regard to aesthetics garment B was better than garment A due to its panel design. This could be noticed from Figure 17 that at various intervals garment B had aesthetically good appearance than garment A.

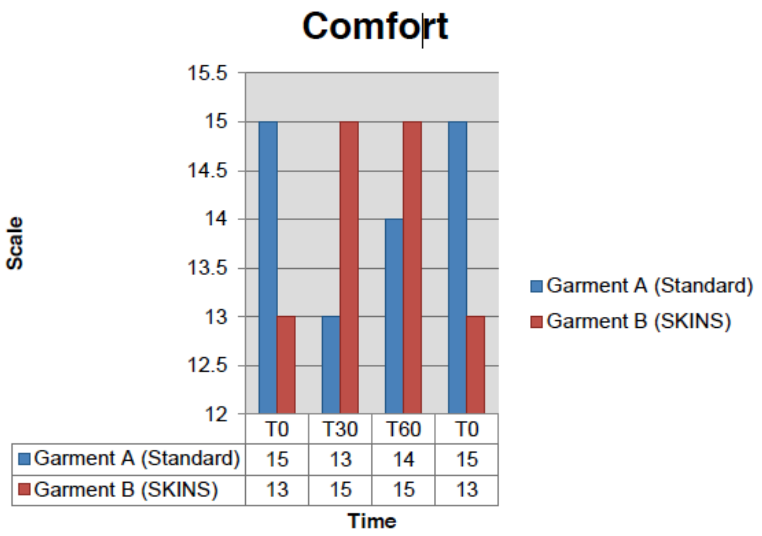


Figure 16 Wearer trial – Comfort

Garment fit is significant in cycling and it is interesting to note that both garments performed well with only marginal difference between them at various intervals of the trial. Garment B was marginally better than garment A.

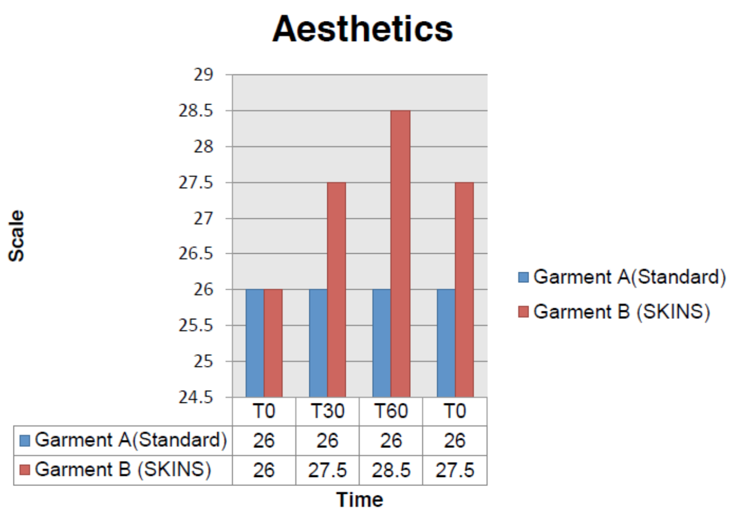


Figure 17 Wearer trial – Aesthetics

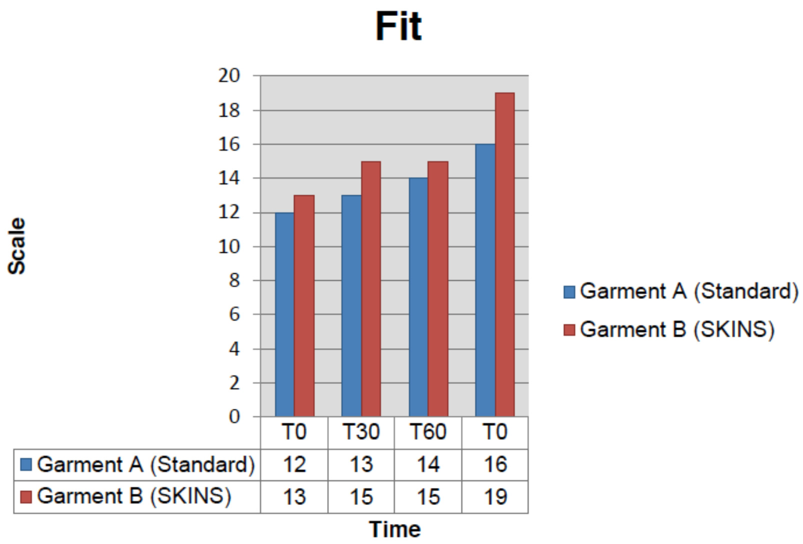


Figure 18 Wearer trial – fit

Tactile sensation discusses the importance of fabric stickiness, clamminess, fabric softness, and fabric stiffness during cycling. The tactile sensation results indicated that garment A had issues with softness and clamminess. The discomfort factor was due to sweat, as this was noted only during and after cycling. This could indicate that the wicking properties are not excellent. For garment B, tactile sensation results were good to excellent but with a minor issue concerning clamminess whilst re-wearing the garment. This indicated that both garments had some issues with clamminess and could be due to wicking.

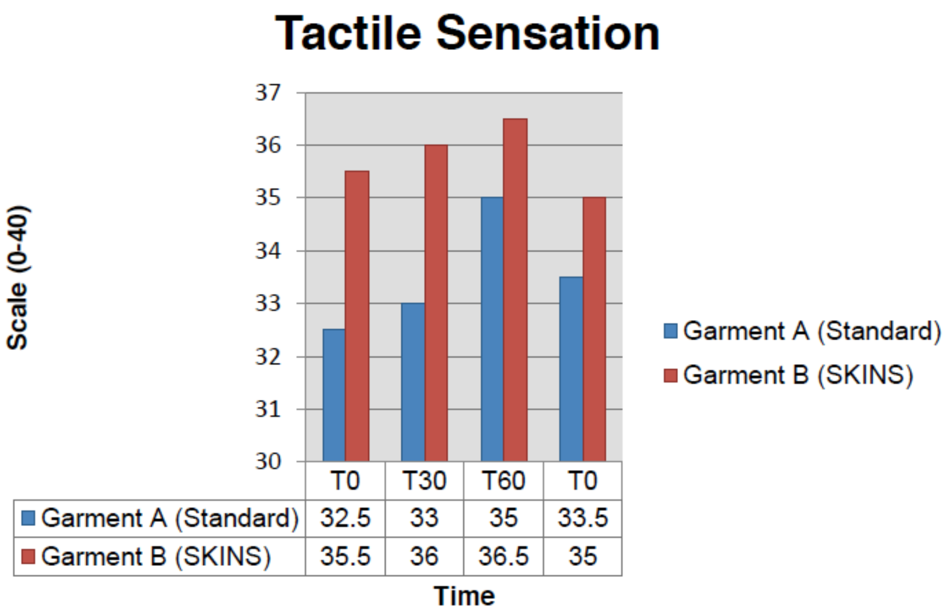


Figure 19 Wearer trial – tactile sensation

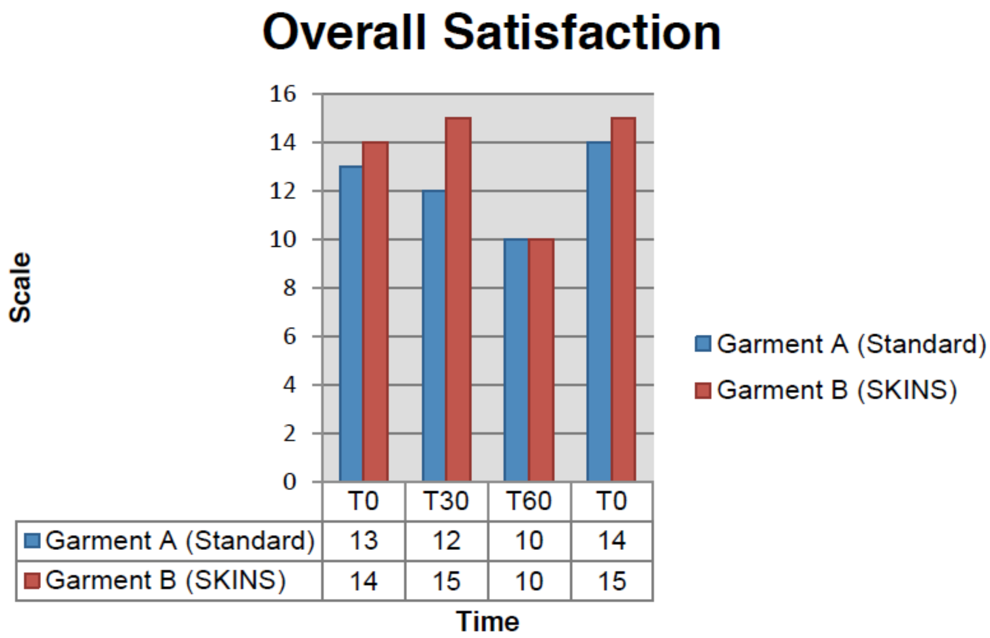


Figure 20 Wearer trial – overall satisfaction

The overall satisfaction of the garments were generally good, however, marginal difference were noted particularly during wearing the garment, garment B was better than A. The situation was similar after four-hour intensive cycling garment B was satisfactory than garment A. The main concern for garment A for poor low overall satisfaction score was due to its design, shape, style and performance. Participants also reported that both the garments offered good application of pressure.

Tekscan pressure sensors were placed in the anterior part of the lower limb inches away from knee in the thigh region as shown. The pressure distribution was assessed at three levels of forces, 0, 75 and 150 Watts.

Figure 21 shows that pressure is applied central part of the thigh, where the pressure exerted is approximately 12-13 g/cm^2 whilst at its sides; the pressure is less than 10 g/cm^2. It can be noted for garment A that at 75 Watts more pressure is exerted to the cyclists compared to 0 and 150 W.

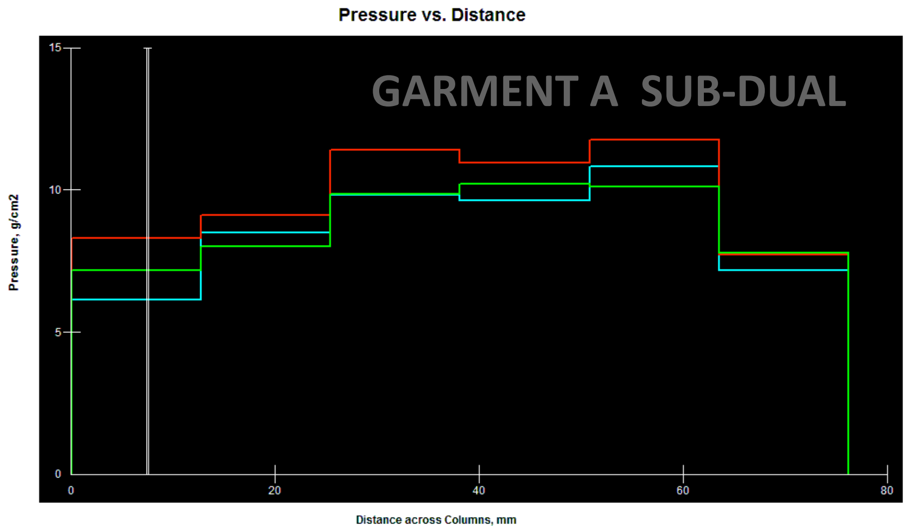
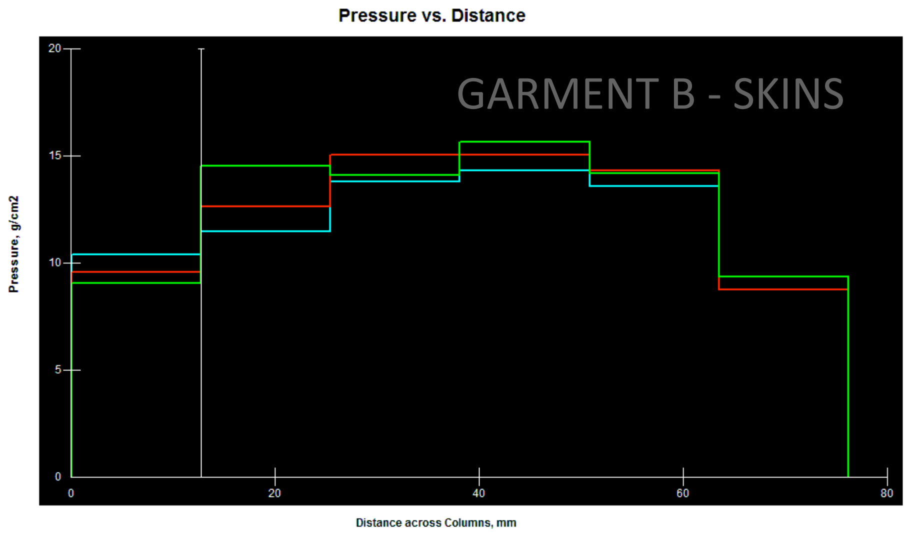


Figure 21 Tekscan Output – Pressure vs distance Garment A

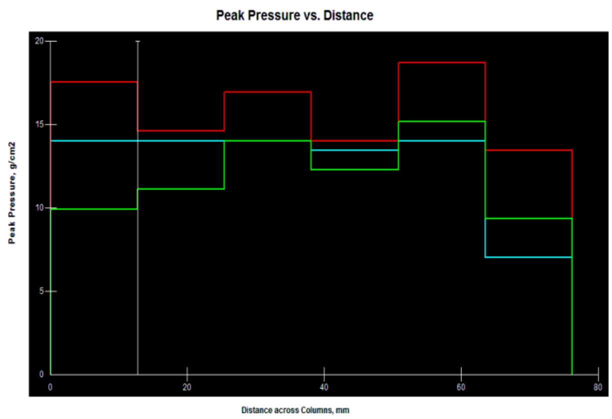
Compared to garment A, the Tekscan pressure profile for garment B in the thigh region exerts uniform pressure, again more pressure is applied in the central part and it gradually reduces at both the sides of the thigh. The maximum pressure applied was in the region of 13-16 g/cm^2, which is marginally higher than garment A.



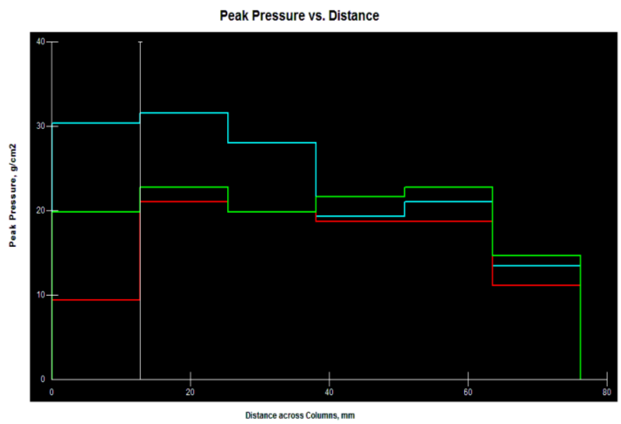
Pressure vs. distance plot

Note: during cycling at various levels (0 Watts Green; 75 Watts Red; 150 Watts Cyan)

Figure 22 Tekscan Output – Pressure vs distance garment B



Garment A Sub-dual



Garment B Skins

Figure 22 Peak pressure vs. distance plot

Note: during cycling at various levels (0 Watts Green; 75 Watts Red;150 Watts Cyan)

It can be noted from the above Tekscan outputs that peak pressure with garment A was in the region of 10 – 18 g/cm^2. High pressure was applied at 75W force compared to 150 W. However, with regard to garment B the pressure applied at 150 W was 30 g/cm^2 that are significantly higher than garment A. There is clear distinction between various force acting on the cyclist (0, 75 and 150W) that during 150W (cyan) pressure applied is higher than 0 W (green).

From the above survey, inferences can be drawn between garment A and B with regard to fabric/garment performance; wearer trial perspectives and Tekscan pressure profile. The garment B was light weight, thin, had good resistance to bursting force, seam strength, good stretch and recovery and resistance to pilling. The only concern with garment B was with regard to colourfastness to perspiration, where colour staining was noticed. Wearer trial perspectives was interesting where five factors relating to garment satisfaction were enquired and it was noted that garment B was marginally better in comfort, aesthetics, fit, tactile sensation and overall satisfaction than garment A. Finally, the Tekscan pressure profile characteristics revealed that pressure distribution was uniform and higher for garment B than A. This can be noted from peak pressure plot vs distance plots.

Survey 2: Comparison of Sports Direct Muddyfox and Rapha

Two garments Sports Direct Muddyfox and Rapha cycling tights were explored for their performance. The images of garments are visually presented in Figure 23 below with front, back and close-up view of garment. Sports Direct cycling tights are economically priced suitable for mass market. The garment has chamois to promote seated padding with less finishing and lack of quality. Rapha winter tights designed to be worn over cycling shorts with a chamois. The tights include thermoroubaix fleece lining, making it a heavier weight but staying breathable. Front panels are windproof, and the hard–wearing seat panel fabric has abrasion resistant, water-repellent including reinforced stitching. There is a lightweight mesh back for breathability, whilst rear leg and chest fabric panels are thinner to decrease overheating. Flat-lock stitching off-set seams prevents chaffing. In comparison to the Sports Direct tights, a greater attention to detail was noticeable. Features of the product include pre-bent knees for improved fit and small details such as reflective areas to protect the cyclist in dull weather conditions. Unlike the Sports Direct cycling tights, the Rapha winter tights are cut perfectly, resulting in a comfortable garment.

Front view

Back view

Front view chamois

Back view chamois

Figure 23 Sports Direct 'Muddyfox' Cycling Tights

Front view

Rear view

Front view

Rear view

Figure 24 Rapha Racing Thermoroubaix Tights

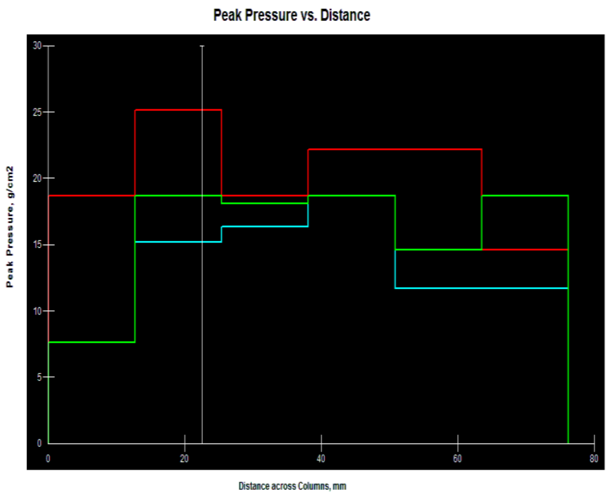
Table 3: Garment Performance – Survey 2: Rapha and Sports Direct

Parameter		Rapha	Sports Direct
Water Vapour Permeability		Non-permeable	Non-permeable
Air Permeability Cc/sec	Tights	25	30
Spray rating	Tights	2 (fabric affected; droplets observed)	1 (wetting the whole fabric)
Abrasion resistance	Tights	5000 and 10,000 rubs no signs of broken fibres	5000 rubs Lot of piling 10,000 rubs fabric fluffy and faded exposing yarns
Bursting Strength kPa (distension in mm)		422 (51.0)	105.3 (70)
Stretch and Recovery (%) Tights			
Warp Extension		62.0	103.0
Weft Extension		115.0	119.0
Warp Relaxation		-13.0	-3.2
Weft Relaxation		- 9.0	-4.5

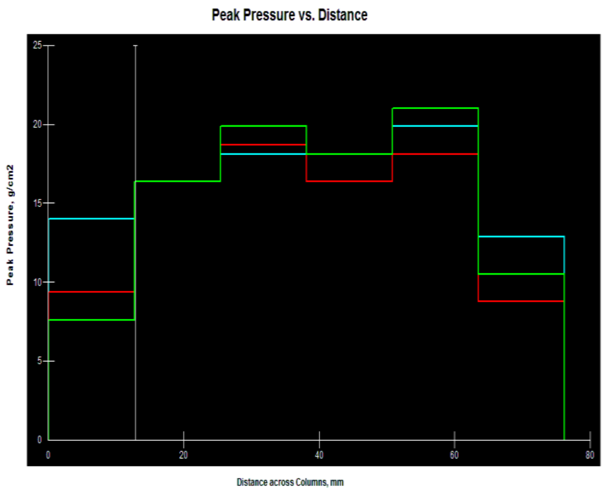
It can be noticed that both the garments are non-permeable to water, however the air permeability for Rapha was 30 cc/sec compared to 25 cc/sec for Sports Direct tights.

However, both the garments fared poorly in spray rating test, where Rapha scored a rating ‘2’ that meant the fabric had affected whilst spraying and water droplets were observed. Sports Direct scored a rating score of 1, which meant fabric was not repellent and wetting the fabric completely. Abrasion resistance is very important in cycling as garment is subjected to severe wear and tear during its use, Rapha performed well, as there were no major signs of broken fibres at 10,000 rubs, whilst Sports Direct performed poorly were fabric faded and exposing yarns at 10,000 rubs.

Rapha garment had good resistance to bursting pressure, whose bursting strength was 422 kPa as against 105.3 kPa. Stretch and recovery was important for compression garments during its usage, particularly when using on a continuous basis. Rapha garments had higher warp extension compared to Sports Direct, with regard to relaxation Sports Direct was lower than Rapha. This meant the garments return to its original position after removal of deformation and Sports Direct garments were dimensionally stable marginally when compared to Rapha.



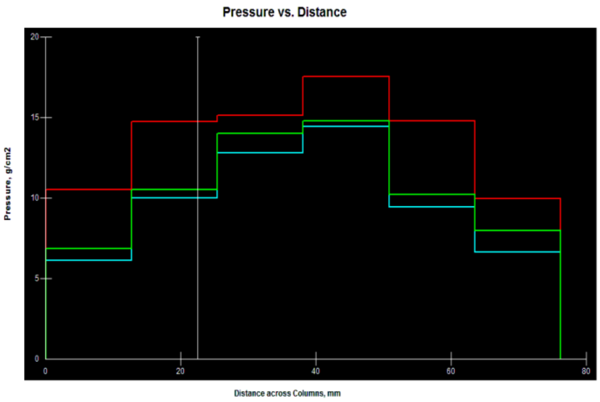
Garment A – Sports Direct



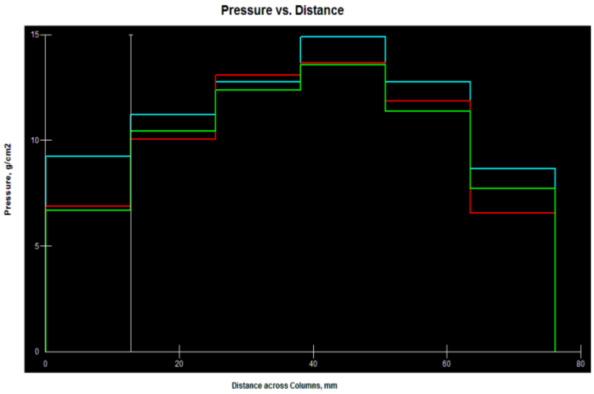
Garment B – Rapha

Figure 25 Peak pressure vs distance survey 2
Note: during cycling at various levels (0 Watts Green; 75 Watts Red;150 Watts Cyan)

Tekscan output for Rapha and Sports Direct reveal pressure profile in the thigh region. Similar to previous survey, the participants were subjected to cycling at three level, 0, 75 and 150 W. Figure reveals that peak pressure for Sports Direct are in the region of 7.5 - 25 g/cm^2 and is inconsistent, where high and low pressure were observed. However with regard to Rapha the peak pressure was low compared to Sports Direct, however the pressure applied was uniform across various cycling levels. High pressure applied in the central part and gradually reduces at both the sides of the pressure sensor.



Garment A – Sports Direct



Garment B – Rafa

Figure 26 Pressure vs distance – survey 2
Note: during cycling at various levels (0 Watts Green; 75 Watts Red;150 Watts Cyan)

Pressure profile for both the garments was similar with marginal differences between them. The pressure applied increases with the force applied during cycling (Rapha), as peak pressure was high for cyan (150W) and low for green (0W). However, the pressure applied varied for Sports Direct, high pressure is applied at 75W and the peak pressure was 116-18 g/cm^2.

Wearer trials: Physiological measurements

Physiological measurements were an important feature of measuring the performance of athletes whilst cycling. In this study, a cyclist was subjected to Scandinavian Protocol (for 30 minutes) which has stages of increasing levels from 0 to 400 W designed to assess the maximum oxygen up take during intense cycling. The heart rate was measured as part of the protocol. As shown in the Figure, the participant wore a standard bib shorts and a short sleeve jersey during the trial. The maximum oxygen up take was 3.41litres/min and respiratory exchange rate (RER) was 1.07. As a rule of thumb, RER value above 1.0 signifies the athlete have used their glucose reserve, whilst RER value <1 signifies the athlete is using sugar levels or glucose reserve. Prior to the study, the athlete's food diary was monitored and during the trial, a bottle of mineral water was consumed. It can be observed from the plot below that as the task of cycling increases from 0 to 300 W the amount of oxygen up take increases gradually.

Figure 27 Wearer trial participant

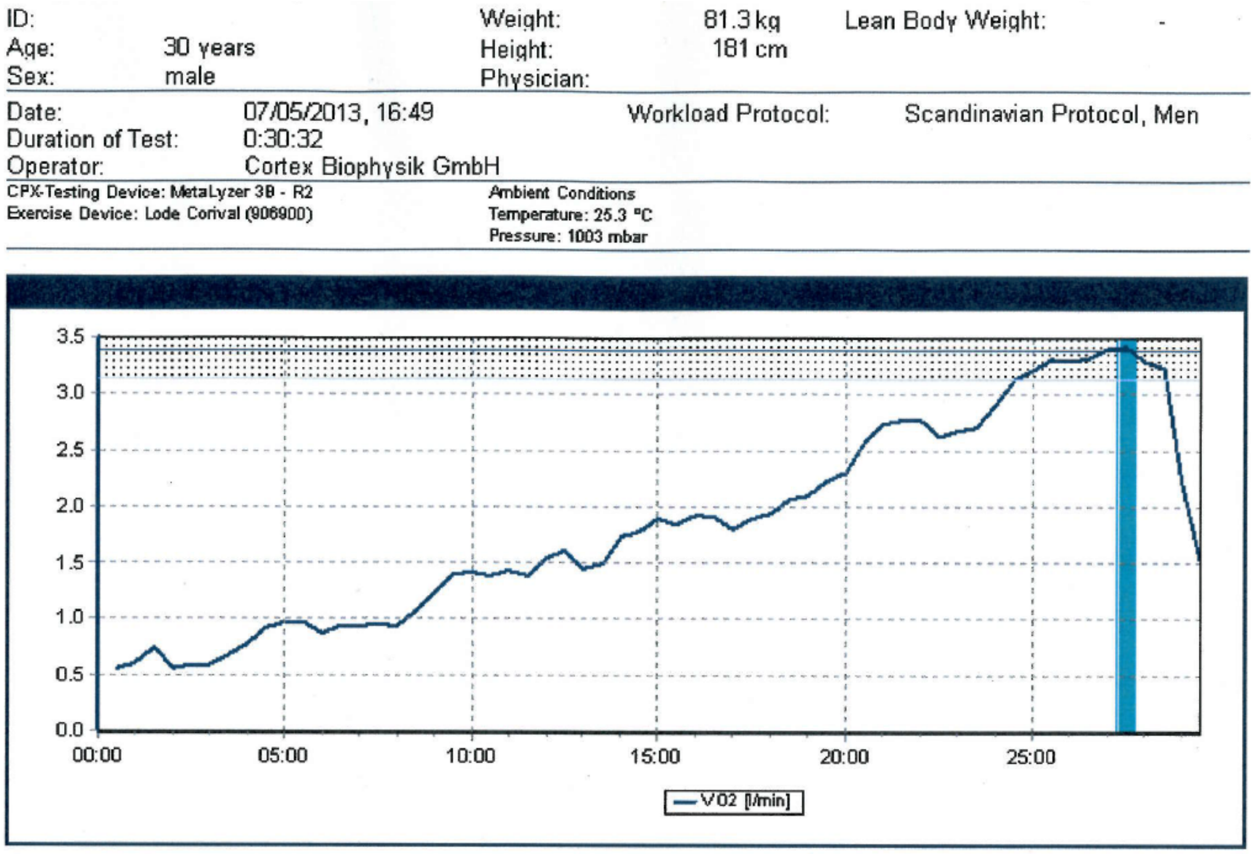


Figure 28 Physiological measurements – Maximum oxygen up take

Summary

The cycling clothing market will continue to increase due to health benefits and upward trend among urban population. Professional cycling garments will continue to develop in the next decade or so, particularly in providing support and improving comfort. Effectiveness of compression garments for cycling are yet to be ascertained. Most research focus on various specific outcomes and factors and it makes it difficult for the user to isolate the performance and assist in their garment selection. However, the user wearing a compression will have a psychological edge over its competitors. Garments that are tailor made to athlete's body shape will continue to offer increased fit, comfort and satisfaction. Garments designed to isolate various muscle groups will also continue to develop. More innovative fabric technologies are anticipated in the next few years to suit various athlete requirements. Cycling garments are multi-dimensional and performance oriented. It is necessary to know various factors that affect sports performance (garment, athlete preparation and intensity of the sport). There is also a rationale to be aware of requirements and regulations of cycling sportswear while design and development. It is also necessary to know the frequent injuries that cyclists incur and design garments that offer protection particularly for knee, groin, neck and lower back.

Survey extracting perception of cycling enthusiasts revealed that athletes' prefer light weight functional clothing that has innovative technologies, offers protection, aesthetically pleasing, and enhances their comfort and performance. Cycling enthusiasts also added that they prefer fabrics that are multi-layered, that stretch and offer wind resistance and water repellent. It was also evident that men were pre-dominant in cycling compared to women.

Survey 1 explored the performance of two compression tights Sub-dual and Skins. Various physical parameters were investigated, which revealed that Skins garment was much better in the overall performance (resistance to bursting force, seam strength, stretch and recovery and resistance to pilling). Tekscan pressure measurements assessed the pressure applied by the garments. The pressure applied by Skins was more uniform compared to Sub-dual. Survey 2 investigated two compression tights Rapha and Muddyfox from Sports Direct. Rapha was intended for professional athletes whilst Sports Direct was intended for fast fashion mass market. The performance of Rapha was much better than the Sports Direct (air permeability, bursting strength and resistance to abrasion). However, both the garments performed poorly in spray test. The pressure profile for Rapha and Sports Direct was similar, however marginal differences were observed in favour of Rapha were pressure applied was more uniform as compared to Sports Direct garment. The above two survey indicated the market for compression garments for cyclists is wide and untested. The performance of high market garments designed for pro-cyclists outperform fast fashion products. However, discussions with athletes revealed that most entry level cyclist purchase fast fashion garments initially before investing on a cycling gear.

The research indicated that using the user survey information, further physiological measurements including maximum oxygen up take, hear rate, lactate level, muscle fatigue and body sweat will be monitored to establish performance of compression garments for cyclists and to establish the base line knowledge in the design and development of professional cycling garments. It is anticipated that the current research approach implementing the laboratory investigations of garments, user perceptions to monitor opinion, wearer trial and physiological measurements to quantify the effectiveness of compression garments will offer a well-informed sound platform in the design and development of functional cycling garments.

References

1. Bastone, K. (2013). Compression Wear: In a Tight Spot. [ONLINE] Available at:
   http://www.bicycling.com/training-nutrition/training-fitness/tight-spot. [Accessed 20
   March 13]
2. Berry, M.J. and McMurray, R.G., (1987), 'Effects of graduated compression stockings on blood lactate following an exhaustive bout of exercise', American Journal of Physical Medicine, Vol. 66, No. 3, pp. 121–32
3. Bikeradar, 201), A forum for bike riders, Online portal, Accessed June 2013
4. Schoeller, (2013), Coldblack Sun Reflector – UV protector, Schoeller Technologies AG, Switzerland
5. WSA (2011). Comfortable Compression, WSA Performance and Sports Materials, Vol. 17, no. 4, pp. 28-29
6. 2XU, (2013) Benefit, [ONLINE] Available at: http://www.2xu.com/pwx/pwxbenefits. asp. [Accessed 05 March 13].
7. Allsop, C.A. (2012). An evaluation of base layer compression garments for sportswear, MSc Thesis, Manchester Metropolitan University, Manchester, UK
8. British Cycling (2008), Online Portal, www.britishcycling.org
9. British Cycling. 2013. 2013 Mountain Bike Rulebook. [ONLINE] Available at:http://www.britishcycling.org.uk/road/article/bcst_rulebook_and_constitution . [Accessed 05 March 13]
10. Wallace, L., Slattery, K., and Coutts A.,(2008). Compression garments, do they influence athletic performance and recovery, University of Technology. Sydney, Australia. pp. 1-3.
11. Chatard, JC, Atlaoui, D. et al. 2004, 'Elastic stockings, performance and leg pain recovery in 63-year-old sportsmen', European Journal of Applied Physiology, 93(3), pp. 347–52
12. Downer, E and Cassidy, T., (2011), Cycle clothing from a lifestyle perspective International Journal of Fashion Design, Technology and Education Vol. 5, No.1, pp.34-43
13. Duffield, R. Cannon, J. and King, M. (2010) 'The effects of compression garments on recovery of muscle performance following high-intensity sprint and polymetric exercise', Journal of Science and Medicine in Sport, Vol. 13, Issue 1, pp136-140.
14. Giordana, (2013), Online portal, www.giordana.com accessed on May 2013
15. Glanville, K., and Hamlin, J, (2012), Positive effect of lower body compression garments on subsequent 40 km cycling time trial performance, Journal of Strength and Conditioning research, vol. 26, no.2, pp- 480-86.
16. Liu and Little, (2009), The 5Ps Model to optimise compression athletic wear comfort in sports, Journal of Fiber Bioengineering and informatics, Vol. 2, No.1, pp- 44-52

17. Yake A., (2011), The best compression garments for sport, www.livestrong.com, accessed on 5th March 2013
18. Young, G., (2009), Compression garment or method of manufacture, US patent 2009/0113596A1
19. Maton, B., Thieney, G., Dang, S., Trac, S.,. Bassez, S., Wicart, P., and Ouchene, A., 2006), Human muscle fatigue and elastic compressive stockings. Eur J Appl Physiol, Vol.97, pp-432–42
20. Mintel (2012), Sports Clothing and Footwear - UK - August 2012, Mintel
21. Rapha (2013) Online portal, www.rapha.cc accessed on June 2013
22. SKINS (2013). Online portal, www.skins.net, accessed on June 2013