THE EFFECTS OF WEARING WHOLE BODY COMPRESSION GARMENTS (SKINS™) ON RUNNING ECONOMY
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ABSTRACT

**Background:** In the current competitive sporting world compression garments are being suggested to improve athletic performance. There have been several mechanisms noted to why compression garments may enhance performance ranging from, increased blood circulation, oxygen delivery and utilization, reduced VO$_2$ slow component and muscle oscillation and proprioception.

**Aim:** The aim of this study is to observe the effects of whole body compression garments (WBCG) upon running economy

**Participants:** ($n = 8$) Male athletes (Mean ± SD) age: 21± 0.9 (yr); height: 179.7 ± 3.5(cm) body mass: 80.6 ± 8.2 (kg); VO2max: 53.9 ± 3.5 (kg/ml/min) volunteered to participate in the current study. The participants were recruited from the University of Wales Institute, Cardiff’s (UWIC) sports teams.

**Design:** A cross sectional designed study

**Methods:** Two sub-maximal tests at 50% and 80% of the participants VO$_2$ max were completed with and without WBCG. During these tests, breath by breath gas analysis, heart rate and rate of perceived exertion were taken. All tests were performed in the Exercise Physiology and Kinanthropometry Laboratory at The University of Wales, Institute Cardiff

**Results:** No significant difference was found in either oxygen consumption or the slow component. However a significant difference was found in heart rate and rate of perceived exertion.

**Conclusion:** Wearing WBCG does not have a significant effect upon running economy. It was show that there may have been a slight improvement in the slow component but no significant data was observed. However WBCG do influence a decrease in heart rate and a perceived belief that they make the exercise easier.

**Key Words:** Compressive Garments, running economy, oxygen consumption, slow component, rate of perceived exertion, heart rate
CHAPTER I
INTRODUCTION
1.0 INTRODUCTION

In today’s ever evolving sporting environment, gaining an advantage over your opponent is top of the list for many athletes. With success being so critical, in many forms, athletes are willing to undertake many strategies to improve performance. There has been some suggestion that the application of compression garments may supply this benefit.

Traditionally compression garments have been used in medical treatment for a variety of circulatory conditions. It has been shown to help patients by providing an improvement in venous circulation, a reduction in blood pooling and through increasing the volume of fluid transferred in the lymphatic system (Agu et al., 2004; Benko et al., 1999; Ghandi et al., 1984; Mayberry et al., 1991). Although the application of compression garments has been investigated thoroughly in medical research, and has shown to be beneficial, there has been minimal research within a sporting context and it remains unclear whether or not any physiological effects conferred by compression garments could influence an athlete’s performance.

Much of the research that has been conducted has provided a hazy view point, with conflicting results and suggestions. Studies have suggested that several benefits lie within the application of compression garments (Lambert, 2005), however many of these studies have been commissioned by garment manufactures, which may have resulted in by manufactures which may have resulted in a bias in the way in which results have been interpreted and published.

However, the literature that exists has suggested that wearing compression garments has an influence on body temperature (Doan et al., 2003) and an improvement in endurance through oxygen delivery and utilization, also aiding the athlete to withstand fatigue (Chatard et al.,
Along with this, compression garments may provide support in muscle oscillation and proprioception, in return increasing power output and improving running economy (Perlau et al., 1995). Other research has demonstrated that compression garments can also aid in the prevention and speed recovery from injury. In this regard, it has also been proposed that recovery is aided by wearing compression garments as an increase in blood flow promotes the rate at which blood lactate can be cleared. However while this research does imply a development in sports performance it is very limited in several aspects.

1.1 Determinants of Running Economy

In many endurance sports the athlete who can compete more economically has a greater chance of being more successful (Daniels, 1985). The less O$_2$ required to complete a certain exercise intensity will allow athletes to work for greater periods of time without such a demand on their aerobic respiration system. It has been established that running economy is influenced by physiological and biomechanical factors (Morgan et al., 1989). Running technique and body temperature will both have a direct influence upon the economy at which an athlete will employ when exercising.

Running economy is measured during a steady state as there is a delay in physiological parameters (Astrand & Rohahl, 1977). The time recommended for steady state to be achieved is around 3 minutes at a set intensity (Morgan, 1989).

1.2 Body Temperature

Maintaining a level and ideal body temperature during exercise is a vital a physiological aspect of sporting performance. The thermoregulation system which is employed to regulate the body temperature works as a thermostat (usually set at 37°C ± 1°C), which employs a number responses when temperature change occurs (Charkoudian, 2003).
Heat resulting directly from metabolic processes and the environment can cause great stress on the body when exercising. Blood is distributed towards the skin to maintain core body temperature, as a high core temperature has been implicated as a primary cause of fatigue due to the metabolism of glucose being affected (Hargreaves *et al.*, 1996).

During exercise in cold conditions the blood volume is kept nearer the core. Muscular activity is induced to generate heat, as it noted that muscles with an optimal temperature work more productively (Astrand and Rodahl, 1977; Berk and Ekblom, 1979).

Compression garments have been used to create optimal temperature, and has been suggested by manufactures that achievement of a greater blood flow and wicking properties (removal of moisture away from the skin) of garments it will help achieve such temperatures. Doan *et al* (2003) found that during a 5 cycle test the compression garments helped to reduce warm up time to the optimal muscle temperature. Properties of compression garment fabrics aid cooling of the body through the promotion of sweat evaporation (Gavin, 2003) However, other studies which have been performed in this area have shown that there has been no improvement or support for the thermoregulation system (Bringard *et al.*, 2006).

**1.3 Muscle Oscillation and Proprioception**

Muscle or joint proprioception is the ability to perceive joint movement and position in space, which is transmitted rapidly through neural pathways. Improving the speed and detail of the information received by afferent receptors (in the skin, muscle ligament and joint capsule) has the potential to improve the economy of movement (Perlau *et al.*, 1995). Compression garments support rapidly adapting superficial receptors in the skin and the underlying musculature receptors. These adapt to new stimuli such as the compression garment and generate a greater muscle proprioception (Perlau *et al.*, 1995).
Similarly a reduced muscle oscillation can help provide a more economical performance as a greater muscle stability will supply a greater muscular contraction. The supportive qualities of compression garments may allow for a reduced muscle oscillation and greater running economy (Bringard et al., 2006; Kemmler et al., 2009). The assisted merits may also allow for a reduction in muscular injury such as hyperextension (Kujala et al., 1997).

1.4 Impact on Venous Return and Regional Blood Flow

Improved venous blood flow to the heart has shown that will provide a greater cardiac filling, allowing for a superior expelled volume of blood. This is demonstrated in the Frank-Starling law, which has been contributed to a positive effect upon performance (Lambert 2005; Ali et al., 2006). Current studies have stated that the local forces created by the compression garments can functionally support the action of the skeletal muscle and improve the venous return (Bringard et al., 2006; Scanlan et al., 2008). This has been contradicted by a previous study which suggested that with incorrect compression it can have the reverse effect and restrict such improvement (Berry et al., 1987).

In any case, even with such venous blood flow enhancement it has been suggested that oxygen utilization cannot be greatly improved. The muscle only has a limited inherited ability to extract oxygen from the blood flow and this may not be the mechanism which provides such improvements in performance (Sirna et al., 1998; Grassi 2005).

1.5 Blood Lactate Clearance

The clearance of lactate from the muscle may assist in delaying the onset of fatigue and could translate to an improvement increase in (endurance) performance. The lactate is subsequently transported to the organs and either converted back to glucose or oxidised (Chatard et al.,
Once again the increased compression provided by the garment may assist in the clearance of the lactate.

1.6 Heart rate

Heart rate can increase to 220 bpm during high intensity exercise and rest at 30 bpm when resting. Heart rate is able to depict the intensity the athlete is working at as it is proportional to the work load and oxygen consumption. It can also increase linearly with the rate of perceived exertion to validate the athlete’s feelings. Heart rate can also be employed to measure venous return as it is related to stroke volume and cardiac output.

1.7 Rate of perceived exertion (RPE)

The rate of perceived exertion focuses on how hard an intensity the athletes believes they are currently working at. It is a psycho physiologic approach which uses a numerical scale, with assisted wording and pictures, from 6 – 20. The rational for using RPE is to identify if the participant feels the work is harder or easier with or without the compression garments.
CHAPTER II
REVIEW OF LITERATURE
2.0 REVIEW OF LITERATURE

2.1 Determinates Running Economy

Running economy is the steady state oxygen consumption (kg/ml/min) at a given running intensity. Research suggests that in order to reach a steady state the athlete must exercise for a minimum of 3 minutes at a set intensity (Morgan, 1989). It can also be governed by the lack of blood lactate accumulation or the respiratory exchange ratio (RER) of less than 1.00. However these factors are limited by their methodological constraints. Oxygen levels must be taken during a steady state to assess the true value of an athlete’s VO₂ requirements for that particular intensity. This is attributable to the slow increase in oxygen uptake at the initiation of exercise from the oxygen transportation systems inability to work responsively (Astrand & Rohahl, 1977).

VO₂ max has been defined by Bassett & Howley (2000) as, the maximal volume of oxygen that is drawn in and utilized during intense exercise. It has shown to be a good determinant of an athlete’s performance during endurance events; however in recent studies it has been noted that economy of the performance may be a better indicator (Daniels, 1985). In a comparison of athletes it has been demonstrated that it may not be the athlete with a higher VO₂ max who has the greater ability to produce better performance results (McArdle et al, 2001). An athlete with a higher sub maximal VO₂ at a given intensity is considered to be less economical than one with a lower VO₂ max.

In the research conducted there have been several possible mechanisms which may have an effect on specifically running economy (Morgan et al., 1989). These variables appear to be associated with: gender, age, body composition, body temperature, running technique, fatigue, genetic makeup (percentage of type I muscle fibres) and training. The limited
research conducted on running economy and compression garments has found that compression garments may assist in some of the variables.

Current research has found that in terms of endurance training in sub-maximal exercise the VO$_2$ slow component is a critical aspect (Bearden et al., 2004). After two to three minutes of heavy sub-maximal exercise a delayed response in oxygen uptake transpires and continues to rise above the set energy requirement and therefore increases the energy requirement (Bringard et al., 2006). Several studies have shown that compression garments can aid in the prevention of such a severe increase in VO$_2$ above the expected energy requirement (Agu et al., 2004; Bringard et al., 2006; Scanlan et al., 2008). Many of these studies have suggested that the mechanism for such improvement is attributed to greater oxygen utilization created by improved blood circulation (Bringard et al., 2006).

2.2 Body Temperature

Body temperature during exercise can have an imposing effect upon athletic performance. The human body employs thermoregulation to control body temperature to an ideal temperature to maintain effective working order, in both hot and cold conditions. It is the hypothalamus, located in the brain, which acts as a thermostat (usually set at 37°C ± 1°C) to activate responses when there is either a build up or loss of heat (Charkoudian, 2003).

Exercise which is undertaken in the heat causes great stress for the thermoregulatory system resulting from both metabolic heat production and environmental heat. The thermoregulatory system instigates an increase in blood flow to the skin and a rise in body temperature to dissipate heat from the core temperature. There have been suggestions that a high core and muscle temperatures may be causes of fatigue during prolonged exercise (González-Alonso et al., 1999). The grow in temperature effects the metabolism of glucose causing the rate at which it reacts to increase (Hargreaves et al., 1996). In a study performed by Papadopoulos et
al. (1998) it was observed that the lactate threshold is obtained at an earlier stage and VO₂ max is much lower at higher room temperatures, possibly caused by the depletion of energy sources more rapidly. In the bodies attempt to cool itself through sweating, blood volume decreases also influencing a decline in cardiac functions and an increase in heart rate to maintain oxygen delivery to the working muscles. These physiological responses in an extreme can pose serious issues for the athlete’s endurance performance and health.

Similarly, the thermoregulatory systems becomes under pressure in cold conditions. Even though the body can tolerate a drop in temperature of 5°C more than an increase, the body still struggles to perform at peak performance whilst under such stresses. The body responds when cold by redirecting blood flow from the colder areas of the body to preserve core temperature, and induces muscular activity such as shivering to warm the muscles. Cold muscles can have a detrimental effect on performance as they are more likely to become injured than a warm muscle (Kujala et al., 1997). Muscles with an optimal temperature (suggested as 38.5°C by Astrand and Rodahl, 1977) will also produce faster contractions, a greater economy of movement due to lowered viscous resistance within active muscles, and superior oxygen delivery and utilization because haemoglobin releases oxygen more easily at higher temperatures. This was proven in a study performed by Berk and Ekbloom (1979) where they found that during short, power related activities, performance improved when muscle temperature was enhanced above normal temperature.

Athletes have looked towards the use of compression garments, especially Skins™, to help promote a more efficient thermoregulatory system and encourage an optimal temperature during exercise. The manufacture states that their enhancement of the circulatory systems allows for a greater blood flow to the muscles, warming muscles quickly. Also the wicking properties and large surface area of the fabric allows for evaporative cooling, sustaining ultimate body temperature throughout exercise. Although this theory may have been provided
by the manufacture, some existing literature does support these claims that compression garments improve thermoregulation through more economical blood redistribution (Kajala et al., 1997; Charkoudian, 2003; Doan et al., 2003). In a 5 minute cycling test with 1.5 W · kg⁻¹ of body weight resistance, it was observed that warm up time to optimal muscle temperature, whilst using lycra type compression garments, decreased substantially and therefore enhancing muscle performance (Doan et al., 2003). However as this study was based on short bouts of exercise, Doan et al. (2003) remarked that in activities which are of long durations, muscle temperature may reach above the optimal level. Further studies into muscle temperature have shown that increases in temperature will most likely diminish the chances of muscular injuries (Kujala et al., 1997). However, other studies which have used body temperature as measurable determinant have found no difference in temperature and performance with athletes who have used compression garments (Bringard et al., 2006). They found that even with the improved sweat evaporation and skin coverage supplied by the compression garments thermoregulation was not improved.

Gavin (2003) established that the type of fabric used has an impact on the effectiveness of thermoregulation. Many compression garments use a synthetic material that is able to both insulate and dissipate heat. As evaporation of sweat from skin is critical to the cooling of the body it is essential that the compression garment provides minimal opposition to evaporation. It has been reported that synthetic garments allow for a greater sweat production, but retains insignificant amounts (Gavin, 2003). This illustrates that the wicking of the clothing fabric may have an effect of thermoregulation.
2.3 Muscle Oscillation and Proprioception

It has been suggested that muscle oscillation and proprioception has an effect on the efficiency of human movement (Perlau et al., 1995; Kreamer et al., 1996; Doan et al., 2003; Bringard et al., 2006; Kemmler et al., 2009). Muscle or joint proprioception is the ability to perceive joint movement and position in space, which is transmitted rapidly through neural pathways. Improving the speed and detail of the information received by afferent receptors (in the skin, muscle ligament and joint capsule) will improve the economy of movement. Perlau et al. (1995) observed an increase in proprioception in the uninjured knee when wearing compressed elastic bandages. They speculated that the bandages had limited effect on the major position sense receptors, such as the golgi tendon organ stretch receptor as they lie too deep. However, they surmised that the receptors that would be involved are the rapidly adapting superficial receptors in the skin and the underlying musculature receptors. These receptors have a greater reaction to new stimuli (like the movement of the bandage of the skin), whereas deeper receptors are much slower to adapting to responses. This was demonstrated in the results as the group with previously lower proprioception had a greater improvement than those with good proprioception, suggesting inherited proprioception cannot be greatly affected by compression garments.

The study conducted by Perlau et al. (1995) was limited as the protocol used was an open chain passive motion test, which is very limited in terms of sporting performance. This was rectified by Kreamer et al. (1996) where they used the influence of compression garments on vertical jump height. This study established that vertical jump height was improved through the use of compression garments over a period of jumps. Kreamer et al. (1996) suggested that although the mechanisms for the improvement remain speculative, proprioception and muscle oscillation are the possible causes for the improvement. The identifiable aspect from their
study was that compression garments had the greatest mean power output over 10 vertical jumps, suggesting that compression garments can support the prevention of fatigue.

In more recent studies conducted on overall athletic performance (Doan et al, 2003) and running performance (Bringard et al., 2006; Kemmler et al., 2009) there has been similar mechanisms theorized for enhanced performance. However, their suggestions were more prioritised on the reduction in muscle oscillation combated by supportive qualities of the compression garments. They proposed that whilst muscles are particularly stable, the compression garments provided greater stability for the active muscles and applied pressure in such ways that they supported the muscle fibres in their contraction direction. This enables the muscles to work with greater efficiency and produces a greater power output, resulting in improved endurance running performance. These positive effects will also provide the athlete with increased comfort as it will help prevent muscular injuries such as hyperextension (Kujala et al., 1997).

### 2.4 Impact on Venous Return and Regional Blood Flow

A number of studies have stated that increased venous blood flow and transportation can certainly be a consequence from the application of compression garments (Mayberry et al., 1991; Watanuki et al., 1994; Benko et al., 1999; Kraemer et al., 2000; Agu et al., 2004; Bringard et al., 2006; Bringard et al., 2006; Ali et al., 2006; Scanlan et al., 2008; Kemmler et al., 2009), with one particular study suggesting that venous return was impeded through graduated compression garments (Berry et al., 1987). The result of this may have been conflicting due to improper fitting of the garments. Such studies have identified that the increased blood flow may have a positive effect on oxygen transportation and utilization along with greater blood lactate clearance from the exercising muscle. However the
mechanisms involved in the improvement in blood transportation and to as whether it creates a direct improvement in performance is yet to be fully understood.

The improved venous blood flow to the heart has been suggested to increase both ventricular filling and preload during the diastolic phase. This will consequently supply a greater ventricular contraction created by the increase in the cardiac muscle through stretching. This will enable the heart to eject the additional venous return and thereby raise the stroke volume and the cardiac output identified in the Frank – Starling Law (Katch et al., 2001). Previous studies have recommended that these physiological improvements may have a positive effect on performance (Lambert 2005; Ali et al., 2006). This enhancement in venous return has been related to the compression from garments supporting the skeletal muscle pumps in the extremities (Bringard et al., 2006; Scanlan et al., 2008). For the cardiac filling pressure, stroke volume and cardiac output the skeletal muscle pumps needs to be effective in the expulsion and translocation of peripheral venous blood volume into the heart. Medical studies conducted have shown that in every day actives (Agu et al., 2004) and when in standing and supine positions (Watanuki et al., 1994; Kraemer et al., 2000; Agu et al., 2004; Bringard et al., 2006) the improvement in venous return has been related to the more efficient skeletal muscle pumps. These studies however were conducted on participants who have circulatory diseases, and results from participants who have normal circulatory conditions, did not show such improvements wearing compression garments (Watanuki et al., 1994). Within the studies focused on athletic exercise using compression garments this mechanism has shown that it may not be the primary function that has an influence upon improved performance. This was highlighted in several studies which suggested that during tests associated with VO$_2$ max, which is dependent on oxygen delivery and utilization, there was only a small influence; however they experienced increases in other performer (Scanlan et al., 2008; Kemmler et al., 2009). Kemmler et al. (2009) contributed this to O$_2$ kinetics and other pathways which may
contribute to a better performance. However others have contributed this failure to influence VO$_2$ max to the muscles inability to utilise increased oxygen capacity (Sirna et al., 1998; Grassi 2005). They reported that even with increased levels of O$_2$ to the working muscle it could not be extracted and therefore would not provide such benefits.

2.5 Blood Lactate Clearance

Although there is little improvement in VO$_2$ max through improved venous blood flow it has been reported that it does have an influence upon blood lactate clearance (Berry et al., 1987; Chatard et al., 2004; Bringard et al., 2006; Scanlan et al., 2008). The previous studies noted that there was a faster clearance of blood lactate after completion of exercise, and suggested that this physiological benefit was related to the improved blood circulation. Berry et al (1987) recorded lower levels of blood lactate volumes throughout 60 minutes of samples with the first 15 minutes being significantly lower. This greater blood lactate clearance from the working muscles to the peripheral muscles and organs will allow for oxidation or gluconeogenesis (Chatard et al., 2004). This will help to sustain aerobic metabolism and assist in delay of fatigue. This mechanism may be the cause of such slight performance improvements over endurance and high intensity exercise. However, according to Berry et al. (1987) the explanation to as why there are lower levels of blood lactate may be attributable to an inverse gradient created by the compression garment retaining the lactate within the muscular bed. They ascribed this to the stability of the plasma volume levels, which would not create the blood lactate levels which were provided. If this remains to be the case then these symptoms would have a negative impact upon an athlete’s performance and recovery. A suggestion provided to eliminate such problems is the correct fitting of the compression
garments. Generating the ideal compression on the muscle to assist with blood circulation may be the critical implication of wearing compression garments.

2.6 Heart Rate

Heart rate is a good predictor of the amount of work the participant has performed. The heart rate is influenced by the activity of the sympathetic and parasympathetic nerves of the autonomic nervous system, centred in the brain (Clegg, 2000). At the onset of exercise, noradrenalin and adrenalin is released from the sympathetic nerves and adrenal glands which increases heart rate. This shows a proportional and linear increase in heart rate and VO₂ during exercise intensity increases. Heart rate reaches its maximal values at a similar intensity as VO₂, suggesting that the athlete has accomplish their aerobic capacity. Heart rate can also used as a surrogate measure of the venous return. This is due to the increased venous blood flow enhancing the stroke volume and end diastolic volume, allowing for a decrease in heart rate whilst maintaining cardiac output. Although this is a crude method of measurement it can be a significant indicator to help provide further evidence towards venous circulation (Ali et al., 2006). A lower heart whilst wearing whole body compression garments could suggest that compression is aiding the skeletal muscle pump and ultimately, support blood lactate clearance, oxygen transportation and utilizaton.

2.7 Rate of Perceived Exertion (RPE) - The Borg Scale

The rate of perceived exertion focuses on how hard an intensity the athletes believes they are currently working at. It is a psycho physiologic approach which uses a numerical scale, with assisted wording and pictures, from 6 – 20 (Appendix D). It can be used in conjunction with oxygen consumption, heart rate, and blood lactate volumes to provide indication of the exercise intensity. Studies conducted have shown that the Borg scale has high correlation of 0.80 – 0.90 with the physiological variables (Borg 1982). With the use of compression
garments only one study has employed the rate of perceived exertion as a psychophysiological measure. Ali et al (2006) focused on perceived exertion and soreness after completion of exercise and recovery. After two shuttle runs with a one hour recovery between they found that there was no significant difference between the utilisation of compression garments and without. However as these recordings were taken after the events rather than during, the perception of the intensity can be altered. Along with this, the participants were asked to continue with the exercise until exhaustion, which would suggest that whatever the effect of the compression garments the participants would always feel the same perception of exertion.
CHAPTER III
METHODOLOGY
3.0 METHODOLOGY

3.1 Reliability

The reliability of the test and tester must be scrutinised before any testing can begin, or any conclusions or comparisons can be made. The precision and consistency of the results is one of the foremost important considerations of any study carried out involving measurements. The central errors which occur most regularly derive from the tester, the protocol, the participants, and the instruments involved. For the study to have any credibility and validity these errors must be removed.

3.2 Pilot Study

A pilot study was implemented in order for the tester to become accustomed to the protocols and equipment, and to carry out tests to confirm that all the equipment required was in working order to ensure reliable data. One male undergraduate Sports Coaching student (age 21, height 174.7cm, and weight 69.3 kg) volunteered for the pilot studies. The participant was given information regarding the testing procedures and provided informed consent (see Appendix C). The subject then completed a VO₂ max test till exhaustion, following the same procedure as in the study proper. The participant then also completed the sub maximal test on the subsequent day, once again following the procedure stated in the study proper.
3.3 Study Proper

3.3.1 Participants

\((n = 8)\) Male athletes (Mean ± SD) age: 21 ± 0.9 (yr); height: 179.7 ± 3.5 (cm) body mass: 80.6 ± 8.2 (kg); VO2max: 53.9 ± 3.5 (kg/ml/min) volunteered to participate in the current study. The participants were recruited from the University of Wales Institute, Cardiff’s (UWIC) sports teams. Each participant was given detailed information of the procedures concerned with the study and provided written consent of their involvement. The participants were passed through a screening for any medical conditions that may hinder or halt their participation from the study. All of these procedures were approved by the UWIC’s ethics committee.

3.3.2 Compression Garments

The compression garments used were unisex long tights and long sleeve CROM (complete range of motion) tops (Sport Skins Classic, Skins™, Campbelltown, New South Wales, Australia). The compression garments are made from 76% Nylon and Meryl Microfibre, and 24% Roica Spandex (Scanlan et al, 2008 pg 426). Each compression garment was specifically made to fit the participant using a chest measurement for the long sleeve CROM top and a mathematical calculation for the long tights. The compression top fitted the participant from the waist up to the neck and the arms running down top the wrist. The Lower body compression garments ran from the waist to the ankle allowing only for the feet, hands and head to be free from the garment. The participant used their own footwear which comprised of various makes of running shoe.

A control condition was supplied using UWIC School of sport athletic clothing consisting of loose fitting shorts and t-shirt (Erreà™, Ross-on-Wye, Herefordshire, England).
3.3.3 Testing

All testing was performed in the Exercise Physiology and Kinanthropometry Laboratory at The University of Wales, Institute Cardiff. The room temperature and the barometric pressures were recorded when entering the room.

3.4 VO₂ Max Assessment

Initially, participants completed VO₂ max tests to exhaustion to assess their maximal oxygen uptake (Vo2max).

3.4.1 Warm Up

For the participants to become primed for the exercise and have an understanding of the treadmill and equipment used in the testing, they completed a 5 minute warm up. They chose the speed and gradient at which this would be performed at and then concluded with a number of stretches until they were happy to start the test.

3.4.2 Protocol

When considering the protocol of a VO₂ max test the speed, gradient and/or both can be increased. This protocol involved a variant of stages, beginning at 7 kph with 1% gradient for 5 minutes which was then increased to 9kph at 3% gradient. Thereafter the speed was increased by one kilometre an hour after every minute. (Katch et al, 2001). The duration of the test was determined using the criteria suggested by Howley and colleagues (1995), which consist of the attainment of two of the following:

- Plateau in VO₂ despite increase in workload
- Respiratory exchange ratio (RER) score ≥ 1.15
- Peak HR – attaining 95% of age predicted maximum in running tests
- Rating of Perceived Exertion (RPE) – Provide a score of ≥ 18 or voluntary exhaustion

The participants received continual motivation throughout the testing and were encouraged to remain in the test for as long as possible. The participants were also given a high level of communication regarding the changes of speed and gradient throughout the test. When the participant could continue no further they would place their hands and feet onto the sides of the treadmill, which would then terminate the testing.

After termination of the test the participants performed a cool down at a speed of their choice with a 0% grade to allow for recovery.

3.5 Sub-Maximal Tests

The participants also completed two sub-maximal tests on different occasions to identify the effects of WBCG on running economy. Each participant would complete a test comprised of 2 stages of 5 minutes at 50 and 80% of the participants $V_{0_2}\text{max}$, which was determined by the previous maximal tests. This test was completed twice as it was required to be performed with and without skins. To maintain validity within the testing, the participants were split into two groups of four. This was in order for the testing with and without the skins could be alternated.

Expired gas analysis was taken breath by breath and the heart rate and RPE in the last 5 seconds of each minute. The results of the tests were compared against each other to discover whether wearing WBCG has a greater economical benefit than not.
3.6 Physiological Measures

3.6.1 Expired Gas Collection

The expired gas was continually recorded throughout the incremental VO₂ max test, and was also collected during the sub-maximal tests. Participants were instructed on how to use the mouth piece prior to the testing to eliminate any issues with the breath-by-breath analysis of the expired gas. The expired gas collection and analysis was performed using Oxycon - Pro® system. This system has been shown to provide valid and accurate data during both high and low intensity exercise (Rietjens et al., 2001). The data recorded included;

- Minute ventilation (VE)
- Volume of oxygen consumed (VO₂)
- Volume of carbon dioxide produced (VCO₂)
- Respiratory exchange ratio (RER)
- Volume of oxygen per kilogram (VO₂kg)

3.6.2 Heart Rate

Heart rate (HR) was recorded constantly throughout the maximal tests and during the sub-maximal tests it was taken in the final 5 seconds of each minute. HR was monitored using a Polar RS400™ and data was analysed using Polar ProTrainer 5™ software.

3.6.3 The Borg Rate of Perceived Exertion (RPE)

The RPE will be collected after every 3 minutes during the VO₂ max test and every minute during the sub-maximal tests. The participants were shown and given understanding of the Borg RPE scale’s number and diagrams, in order for them to identify their perceived feeling of exhaustion during the exercise.
3.7 Statistical Procedures

Means and standard deviations (X ± SD) were calculated for all descriptive and physiological data and, all statistical analysis calculations were conducted using the computer software package SPSS 17 (Chicago, IL). Initially the group means were used to assess if there were any identifiable differences in performance from the application of skins. Paired sample t-tests were then conducted to determine any significant differences (P = >0.05) between physiological measures.
CHAPTER IV
RESULTS
4.0 RESULTS

4.1 Participants

Eight male participants completed the study. Table 1 demonstrates the mean height, weight and age of the participants.

<table>
<thead>
<tr>
<th>Table 1. Subjects characteristics (Mean ± SD)</th>
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<tr>
<td>Height (cm)</td>
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<td>179.7 ± 3.5</td>
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</tbody>
</table>

4.2 VO₂ Max Assessment

The table below is a summary of the participants’ performance during the VO₂ max assessment tests. The data was then further used in the sub-maximal protocols.

<table>
<thead>
<tr>
<th>Table 2. The physiological and sub-maximal calculations from the VO₂ max assessment</th>
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<tr>
<td>Participants</td>
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<tr>
<td>----------------</td>
</tr>
<tr>
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<td>Participant 8</td>
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</table>
4.3 Sub – Maximal Tests

4.3.1 Oxygen Consumption and the VO₂ Slow component

Figure 1. shows the mean VO₂ (kg/ml/min) consumption at both 50% and 80% intensities for the control and whole body compression garments (WBCG) groups. The current results exhibit no significant difference (P > 0.05) between the control group and the WBCG on both intensities.

Figure 1. The mean VO₂ (kg/ml/min) consumption (± SD) at 50% and 80% for both the control and WBCG. No significant difference (P > 0.05) was recorded between the control and WBCG.
Figure 2. illustrates the mean values (±SD) of the VO₂ slow component (ml/min) at both 50 and 80% intensities for the control and WBCG groups. The current results exhibit no significant difference (P>0.05) between the control group and the WBCG on both intensities, however there is a slight difference between the two groups.

**Figure 2.** The mean values (±SD) of the VO₂ slow component (The difference between the second and end minute values of each intensity). No significant difference (P>0.05) was recorded.
4.3.2 Heart Rate

Figure 3 illustrates each participant’s heart rate (bpm) between the control and the WBCG at the 50\% maximal intensity. A significant difference was recorded ($P = 0.028$) between the groups and demonstrates an improvement in heart rate. Figure 4 displays similar results for heart rate at 80\% intensity, with a significant difference also being recorded ($P = 0.02$).

Figure 3. The mean heart rates (± SD) at 50\% intensity of the control and WBCG groups. A significant difference of 0.028 was found.
Figure 4. The mean heart rates (± SD) at 80% intensity of the control and WBCG groups. A significant difference of 0.02 was found.
4.3.3 Rate of Perceived Exertion

Figure 5 illustrates the rate of perceived exertion at both 50% and 80% intensities for the control and WBCG. A significant difference was recorded between the groups and implies that the participants believed the test to be easier when completing it in WBCG.

Figure 5. The mean RPE ratings (± SD) at 50% and 80% for both the control and WBCG. A significant P value below 0.05 was recorded.
CHAPTER V
DISCUSSION
5.0 DISCUSSION

The purpose of the present investigation was to examine the effects of whole body compression garments on running economy. Currently there is very little research within running economy and WBCG, and data supplied is inconsistent. The results of the current study suggest that there is no statistically significant effect of WBCG on running economy performance. The results do suggest that they have a significant effect on heart rate and rate of perceived exertion however, neither suggests an association with improvement in running economy performance.

5.1 Heart Rate

The results obtained regarding the heart rate show a positive significant difference (P>0.05) between the control group and the WBCG, at both 50 and 80% intensities. All of the participants exhibited a detrimental decrease in heart rate when wearing WGCG, which may subsequently enhance physiological aspects, such as blood transportation and oxygen utilization (Lambert, 2005; Ali et al., 2006), and clearance of deoxygenated blood and waste products. (Moffat, 2002). Previous studies have suggested that more efficient removal of waste products such as lactate and hydrogen ions (H⁺) from the working muscle will allow for greater oxidation and gluconeogenesis (Chatard et al., 2004). Therefore, the circulatory benefits may help to sustain aerobic metabolism and assist in the delay of fatigue. This enhancement in venous return has been related to the compression from the garments supporting the skeletal muscle pumps (Bringard et al., 2006; Scanlan et al., 2008). For the cardiac filling pressure, stroke volume and cardiac output the skeletal muscle pumps needs to be effective in the expulsion and translocation of peripheral venous blood volume into the heart. Medical studies conducted have shown that in every day actives (Agu et al., 2004) and when in standing and supine positions (Watanuki et al., 1994; Kraemer et al., 2000; Agu et
al., 2004; Bringard et al., 2006) the improvement in venous return has been related to the more efficient skeletal muscle pumps. These studies however were conducted on participants who have circulatory diseases, and results from participants who have normal circulatory conditions, did not show such improvements wearing compression garments (Watanuki et al., 1994). However a study conducted in regard to running performance showed evidence of a similar nature to the current study. Ali et al (2006) illustrated lower heart rates during 10km run when using graduated compression stockings. The findings from previous studies and the current study demonstrate that compression garments do have a positive influence to heart rate and blood circulation. Berry et al., (1987) also noted that compression stockings have a positive performance indicator regarding increased femoral blood flow. Conversely, Berry et al., (1987) documented that blood lactate levels may have been reduced as the compression garments where reducing the diffusion of lactate from the muscular bed and the muscle was retaining the lactate. These results were attributed to either increased hydrostatic pressure or an inverse gradient produced from an improper fit of the compression garments. This is in agreement with what Lewis et al., (1976) suggested in response to blood pooling. This may suggest that the compression garments used in the current study were fitted correctly. However, further studies in more controlled settings with more sophisticated techniques are needed to gain a more detailed and a definite finding.

Further evidence in support of the current studies findings towards lower heart rate may lie in thermoregulation. It has been stated that specific compression garments have an affect upon body temperature (Doan et al., 2003). In a study performed by Papadopoulos et al. (1998) it was observed that the lactate threshold is obtained at an earlier stage and VO₂ max is much lower at higher room temperatures, possibly caused by the depletion of energy sources more rapidly. In the bodies attempt to cool itself through sweating, blood volume decreases also influencing a decline in cardiac functions and an increase in heart rate to maintain oxygen
delivery to the working muscles. This may demonstrate that the use of WBCG may have an influential impact upon thermoregulation, as the results of the current study show a decrease in heart rate whilst wearing WBCG. However, other studies which have used body temperature as measurable determinant, have found no difference in temperature and performance with athletes who have used compression garments (Bringard et al., 2006). They noted that even with the improved sweat evaporation and skin coverage supplied by the compression garments thermoregulation was not improved. As the current study did not measure body temperature this suggestion can not be used a direct hypothesis for the noted improved heart rate. Once again, further studies which employ more refined methods may provide an absolute answer.

5.2 Oxygen Consumption and the VO₂ Slow Component

No significant data was recorded in relation to oxygen consumption (P>0.05). A common analysis of the data also found no differences in mean oxygen uptake during either group (control or WBCG). In some circumstances the performance of individual athletes decreased when wearing WBCG and the mean average shows a greater consumption when wearing WBCG. These results seem to contrast those discovered by Lambert (2005), who noted an increase in aerobic capacity whilst wearing WBCG. Lambert (2005) ascribed these findings to greater oxygen transportation and utilization at the working muscle, created by increased venous blood flow. The results displayed in the current study seem to match those recorded by Scanlan et al., (2008) where they found a significant difference between heart rate, but found no difference between oxygen consumption. However it has been suggested that even with increase oxygen transportation, through more efficient blood distribution, oxygen utilization will not necessarily increase linearly (Grassi, 2005). It was noted that the facility to extract and exploit oxygen at the working muscle is limited and any additional oxygen
delivered would not be utilized (Grassi, 2005). Therefore, although WBCG may induce increased venous return and cardiac output, it has no effect upon VO_2.

There have been suggestions towards other factors which may have an influence upon running economy relating to compression garments. This may explain the slight differences in the VO_2 slow component recordings. The data did not show a significant difference between the control and the WBCG at either intensity however there are slight divergences between the two. A reduction in the slow component can be observed when wearing WBCG at both intensities (especially 80% of VO_2 max), which may allow for athletes to work at the same intensity or higher for longer periods before fatigue occurs. This reduction in the slow component through the application of compression garments has been detected in other studies (Bringard et al., 2006; Scanlan et al., 2008). These studies have hypothesised the enhancement in the slow component to an increased ability to delay the onset of fatigue. A possible mechanism which may have a positive affect has been suggested to be greater efficiency in biomechanical movement (Kreamer et al. 1996; Chatard, 1998; Bringard et al., 2006). Kreamer et al. (1996) identified that vertical jump height was improved through the use of compression garments over a period of jumps. They suggested that although the mechanisms for the improvement remain exploratory, proprioception and muscle oscillation are the possible causes for the improvement. The identifiable aspect from their study was that compression garments had the greatest mean power output over 10 vertical jumps, suggesting that compression garments can support the prevention of fatigue. Within running performance, Bringard et al., (2006) prioritised the improved performance to reduced longitudinal and anterior muscle oscillation resulting from the supportive qualities of the compression garments. They proposed that whilst muscles are particularly stable, the compression garments provided greater stability for the active muscles and applied pressure in such ways that they supported the muscle fibres in their contractual direction. This enables
the muscles to work with greater efficiency and produces a greater power output, resulting in improved endurance running performance.

A reduction in the slow component may also be related to removal of lactate from the working muscle. Bearden et al., 2004 noted that there is a close relationship between lactate increases and the slow component, suggesting that the removal of lactate may support the reduction in the slow component. As suggested earlier that compression garments may aid in the removal of waste products, this may also correlate into a reduction in the slow component.

5.3 Rate of Perceived Exertion

The results achieved in the rate of perceived exertion (RPE) show a significant difference (P > 0.05) between the control group and the WBCG, at both 50 and 80% intensities. All participants believed that the sub-maximal testing to be easier when wearing the WBCG. The current results are a contrast to those recorded by Ali et al., (2006) who found no significant difference in RPE with the use of compression garments. However the recording where taken after the completion of the test, rather than during which may alter the perceived feelings of the athlete. Although, there may not be a direct improvement in performance resulting from the application of WBCG, the perceived feeling that they help performance may actually improve performance. If an athlete believes that they run for longer or faster while using compression garments they generally will. These perceived feeling however may only last if the product is marketed with the belief that they do improve performance.
5.4 Limitations

5.4.1 Compression Garment Fitting

With the absence of any significant data resorting from oxygen consumption and the slow component in the WBCG group, there can be many suggestions that method had limitations. Firstly the compression supplied by the WBCG may have been incorrect to produce some of the hypotheses mechanisms relating to improved performance. The WBCG were fitted using height (cm), weight (kg) and chest size (cm) rather than individual body dimensions, and may have exerted inadequate and mixed pressure across the athletes. Insufficient pressure which is supplied by WBCG may have an adverse effect upon the suggested mechanism for improved performance and has been demonstrated in previous studies (Lewis et al., 1976; Berry et al., 1987). This may have also caused the differences in reduced heart rate between the participants. Different compression between athletes may have caused different results.

5.4.2 Athlete Recruitment

A second limitation of the study may have been the recruitment of team sport athletes. When focusing upon running economy it may have been more advisable to recruit elite mid and long distance runners whose technique is biomechanically efficient. Also elite endurance runners’ cardiovascular fitness will be of peak performance and therefore the testing will be of more relation to their dominant energy system. This may have transpired into the oxygen consumption and slow component results and provided more positive data towards the application of WBCG. However as the study was cross reference, the results should show an improvement whether the athletes are elite distance runners or recreation team sport athletes.
5.4.3 Athlete Compliance

A further limitation of the study may be the participant compliance with diet and training, as this could not be controlled. Participants were asked to follow dietary recommendations for a 24hr period before testing, however as the participants involved where recruited from the University of Wales, Institute Cardiff’s sports teams it is very difficult to control and regulate there diet. The use of substances such as caffeine and alcohol has been found to limit endurance performance (O’Brien and Lyons, 2000).

5.4.4 Participant Sample Size

The WBCG that were used within the current study are expensive it was not appropriate or financially viable to recruit to large number of participants for the study. A larger sample size may produce a greater generalised understanding of the effects of the application of compression garments.

5.4.5 Indirect Methods

Apart from the breath by breath analysis the methods used to collect data can be classed as indirect. To collect more detailed and clinical data more sophisticated methods are needed. In order to understand the influence that compression garments have on body temperature a gastrointestinal radio pill could be used; however this method is expensive and intrusive. To gain a greater understanding on the volume of blood lactate blood sample could have been taken and analyzed. Further improvements could be made to measure the muscle oxygenation to gain a greater understanding of the oxygen utilization. This can be measure using a continuous wave near infra-red spectroscopy (NIRS) device.
5.5 Potential Improvements and Future Recommendations to the Study

The outcome of the current study relating the effect of WBCG on physiological and performance indicators has opened up several recommendations for future examination. These relate to the compression garments themselves, the athletes used within the study and the methods used to measure physiological constraints.

5.5.1 The Compression Garments

There are several recommendations for further investigation regarding the compression garments.

5.5.1.1 Compression from the Compression Garment

Firstly, the essential level of compression which is necessary to produce the reported physiological and performance improvements, needs to be defined. Further investigation is needed to supply specific values at which these benefits are observed. This would then allow for the correct fitting of the compression garments to be fulfilled.

5.5.1.2 Compression Garment Fitting

Secondly, the fitting of the WBCG was based on broad measurements. The WBCG were fitted using height (cm), weight (kg) and chest size (cm) rather than individual body dimensions, and may have exerted inadequate and mixed pressure across the athletes. Insufficient pressure which is supplied by WBCG may have an adverse effect upon the suggested mechanism for improved performance and has been demonstrated in previous studies (Lewis et al., 1976; Berry et al., 1987). To remove the possibility of incorrect fitting the compression garments could be specially constructed to athlete’s individual body dimensions and segments.
5.5.1.3 Make and Type of Compression Garment

The make of the compression garment supplied for the current study were unisex long tights and long sleeve CROM (complete range of motion) tops (Sport Skins Classic, Skins™, Campbelltown, New South Wales, Australia). However there are several different ranges within Skins™ themselves and other makes that produce compression garments. Comparisons between the different makes and types of compression garments may provide an outcome of which one produces the best results.

5.5.2 Athlete Recruitment

The athletes recruited in the current study were recreational team sports athletes who train on a weekly basis. To produce more detailed data it is recommended that elite athletes are used, specifically middle to long distance runners. Elite endurance runners have a technique which is biomechanically efficient and a cardiovascular system which is of peak performance. The type of testing will suit their dominant energy system. This may have transpired into the oxygen consumption and slow component results and provided more positive data towards the application of WBCG. However, as a lot of recreational athletes and elite team sports athletes are currently wearing compression garments it could be suggested, that a range of athletes over multiple tests are recruited.

5.5.3 Methods of Measuring

The methods of measurement in the current study could be classed as indirect and produce assumed values. To collect more detailed data it maybe suggested that further areas and more sophisticated techniques should be used. The collection of body temperature using a gastrointestinal radio pill could be implemented as it is suggested that compression garments have an effect on thermoregulation (Doan et al., 2003). This will provide evidence of how the
core body temperature changes when wearing compression garments. Another indicator which could be measured is the blood lactate volume. Many studies have suggested that blood lactate levels are lowered when wearing compression garments clearance (Berry et al., 1987; Chatard et al., 2004; Bringard et al., 2006; Scanlan et al., 2008). A further indicator which may supply evidence in support in the application of compression garments is muscle oxygenation. This can be measured using continuous wave near infra-red spectroscopy (NIRS) device. Existing literature has suggested that it is not necessarily oxygen utilization that is increased with the application of compression garments but muscle oxygenation (Scanlan et al., 2008). Other literature has suggested that blood circulation is improved when using compression garments (Mayberry et al., 1991; Watanuki et al., 1994; Benko et al., 1999; Kraemer et al., 2000; Agu et al., 2004; Bringard et al., 2006; Bringard et al., 2006; Ali et al., 2006; Scanlan et al., 2008; Kemmler et al., 2009). Therefore regional blood flow could be inspected at the working muscle during exercise.
CHAPTER VI
CONCLUSION
6.0 CONCLUSION

The observations from the present study indicate that there is no significant difference in running economy when wearing WBCG at both 50% and 80% of VO₂ max. The results achieved regarding oxygen consumption show no variation and can be termed irrelevant in the application of WBCG. Although there was no significant difference recorded in the VO₂ slow component, there was a noticeable distinction in its reduction and may suggest that improved muscle oxygenation is being achieved. This may be in association with the enhanced venous return and regional blood flow which is demonstrated in the decreased heart rate levels (P>0.05). The improved blood circulation may also have an affect upon the removal of waste products and deoxygenated blood respectfully. If this is the case then WBCG may have supply an improvement in aerobic metabolism and delay the onset of fatigue. However the use of heart rate as an indicator for is a crude assumption and may not truly relate to improved regional blood flow. Another aspect which may have a case for the suggested slight improvement of the slow component is that the WBCG enhance muscle oscillation and proprioception. The improvement of the two mechanisms may support in increasing the biomechanical efficiency of the athletes running and essentially reduce the required VO₂ for the exercise intensity.
A further significant difference was found in the rate of perceived exertion between the control group and the WBCG. All participants found that the exercise was easier when wearing the WBCG. This could have been due to either a lowered body temperature or just the previous perceptions that the athletes had about the WBCG. If athletes continue to believe that compression garments do have an influence over performance they will generally improve their own performance inadvertently.

While the majority of literature does support the data found within this study, there are many others that have conflicting suggestions. For this reason further study needs to be conducted around this area using more sophisticated technology and methods to identify the improved mechanisms supplied by the application of compression garments, if there indeed any. Future recommendations for studies in this area so investigate several aspects of the compression garment, such as compression and fit, as well as regional blood flow within the working muscle at exercise.
CHAPTER VII

REFERENCES
7.0 REFERENCES


APPENDICES
APPENDIX A - Subject Data
## Subject Data

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APPENDIX B - Informed Consent
Title of Project: Influence if compression garments on performance

Background

This project is an attempt to understand the effectiveness of compression garments such as Skins™ on exercise performance. It has been commissioned and will also be carried out by Cardiff School of Sport at the University of Wales Institute, Cardiff.

In today’s sporting environment it is critical that there is every opportunity for peak performance. Sport is continually evolving along with its scientific involvement, providing new ways in which performance can be developed.

The wearing of compression garments (CG) during both training and competition has become increasing popular in both recreational and elite athletes (Wallace et al. 2005). Factors such as style, comfort, reduction in chaffing between limbs when exercising and anecdotal reports of their enhanced performance effecting from their use have all contributed to their increasing popularity.

Your participation in the research project

Why you have been asked

You have been invited to take part in the programme because a wide variety of UWIC Sports club standard athletes are required in order to generate a view of how compression garments can influence performance of a sporting nation.

What would happen if you agreed to join the study?

If you agree for your child to join the study, there are two main things that will happen.

1. You have your physical measurements taken such as height, weight, chest size and blood pressure.
2. You will then take place in a VO2 max test. A VO2max protocol is an exhaustive test and requires participants to exercise at progressively increasing exercise intensities until volitional exhaustion.
3. After the VO2 max test, you will then participate in 2 sub-maximal tests. The tests will be 10 minutes long, with 2 stages of 5 minutes at 50 and 80% of your VO2 max. One test will be run without the use of compression garments and the other with, to discover the influence compression garments have on running economy and the physiological responses.

Are there any risks?

We do not think there are any significant risks to you from taking part in the evaluation study. However, due to the exhaustive nature of the VO2 max it is suggested that you do not volunteer if you have any health problems.
Your rights

Joining the programme does not mean that you give up any legal rights. In the very unlikely event of something going wrong during the evaluation, UWIC fully indemnifies its staff, and participants are covered by its insurance.

What happens to the results of the study?

All measurements and data that are taken will be stored securely in locked filing cabinets at UWIC. They will be coded so that we can remove names, but we need to keep a record of the codes to compare each participant’s measurements / scores. We will present this information together for all of the participants, but there will be no description that would identify individuals.

We will present a report to the supplier of the compression garments to provide scientific backing to their product. However, all names will be unidentifiable.

Are there any benefits from taking part?

There are no stated benefits to taking part in the study.

What happens next?

With this letter you’ll find there is another form to complete. The second sheet is a different form for you to complete to confirm that you are willing to take part.

How we protect your privacy:

As you can see, everyone working on the study will respect your privacy. We have taken very careful steps to make sure that you cannot be identified from any of the information that we have about you.

All the information about you and you will be stored securely away from the consent and assent forms. At the end of the study we will destroy the information we have gathered about you. We will only keep the consent and assent forms with your name and address. We keep these for ten years because we are required to do so by UWIC.

Further information

If you have any questions about the research or how we intend to conduct the study, please contact us.

Dr Paul Smith

✉️ psmith@uwic.ac.uk
APPENDIX D – The Whole Body Compression Garments (Skins™)
Appendix D – The Whole Body Compression Garments (Skins™)
APPENDIX E – The Borg Scale of Rate of Perceived Exertion
### Rating of Perceived Exertion (RPE)

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</tr>
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<td>Light</td>
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<td>Hard (heavy)</td>
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Taken from: http://www.sport-fitness-advisor.com/images/heart_rate_training_rpe.jpg