WHITE PAPER: WHY ELITE ATHLETES NEED CUSTOM-FIT COMPRESSION

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Introduction

Despite being widely used by athletes at all levels, there is still considerable debate about how compression physiologically impacts the body, and its impact on athletic performance. This paper aims to provide the facts on sports compression by describing how pressure garments can augment physiological performance, and by how much. It also provides guidelines on how elite athletes should choose their compression garments.

Impact on Physiology

Considerable research has been conducted into the effects of pressure on the human body. The Aerospace industry, for example, has been intensely interested in this area for decades because of the range of pressures that pilots and astronauts are exposed to (and potentially exposed to) through their operating environments or their tight suits. The Medical industry has a long history of using compression garments as they are used extensively in the treatment of burns, lymphoedema, circulation insufficiencies etc. More recently the sports industry has used compression garments as a means to improve athletic performance and recovery.

Exposing localised regions of the body to different levels of pressure has been shown to have very significant impacts on the body, in both positive and negative ways. Mild compression has been shown to improve blood flow, allowing for the improved delivery of oxygen and nutrients to muscles, while flushing away metabolic waste products. Mild compression on the skin changes the pressure differential across the walls of the superficial blood vessels, ultimately causing them to expand (known as myogenic vasodilation). This effect can be further increased with greater levels of compression as it may cause the central venous pressure at the heart to rise, causing the blood vessels to relax further through a sympathetic nervous response.

Mild compression may improve physiology and performance via other mechanisms. The lymphatic system may be augmented, reducing swelling and oedema in muscles. The nerve cells may be triggered, causing in an increase in proprioceptive feedback and coordinative function. A mechanical support benefit may also be seen, as a reduction in muscle oscillation leads to a reduction in muscle fibre recruitment, energy cost and fatigue, resulting in an increase in movement economy. Other scientists have proposed improved thermal properties in the musculature may assist performance, and others refer to psychological impacts arising from compression. It has been theorised that compression garments may also aid performance by providing a passive torque about the joint as the elastic material around the outside of the joint is stretched, but beneficial effects have not been found by increasing the passive torque. Compression garments assist in the recovery of muscle function following exercise through reduction in the magnitude of exercise induced muscle damage. Compression garments have been shown to reduce levels of muscle swelling and creatine kinase (CK) (a marker of muscle damage) during the recovery period from exercise.

If too much compression is applied, intramuscular pressure receptors can be triggered which will lead to the overall constriction of vessels (vasoconstriction), or perhaps the collapse of the vasculature, and the impairment or loss of blood flow. Such occlusion may cause problems such as pain, loss of sensation, or compartment syndrome. It is known that several hours of 30 mmHg over-pressure in passive muscle constitute a compartment syndrome and therefore may risk tissue viability. Exercise improves tolerance by facilitating blood flow and venous return via action of skeletal muscle pumps, perhaps because occlusion of the superficial vessels may shunt blood flow into the deeper musculature where, during exercise, muscle pumps are more effective in the return of blood flow to the heart.

Sizing is Critical

The clear evidence across many industries is that compression can have a profoundly positive impact. Why then is there so much doubt over sports compression garments? The key issue is that off-the shelf compression garments are not accurate enough as they are not sized specifically to the athlete. Hill et. al. (2015) conducted a landmark UK study into compression by analysing the pressure regime of 3 major, well-known sports compression brands, fitted as per manufacturer recommendations. There was considerable variation in the size of the subjects within each garment size meaning that all subjects did not receive the same level of compression from the same sized garment. Secondly, there were differences in the compression level between the different brands. For one brand, subjects who were fitted to a medium sized garment had thigh and calf circumferences that ranged from 46.1 to 56.3 and 33.0 to 39.5 cm respectively, leading to compression that ranged from 4 to 16.7 mmHg at the quadriceps and from 10.3 to 25 mmHg at the calf. The compression garments did not meet minimum pressures necessary to elicit physiological response for the thigh in both the males and females in the study, nor for the calf in the females. It was also shown that some individuals may be receiving excessive compression.

To show that compression works, and that compression regime is critical, Wannop et. al. (2016) identified that sizing of the compression garment influenced performance in a countermovement jump task. Comparing four different sizes (from extra-small to large) to a control condition (loose shorts), the best results were recorded at the compression regime when wearing medium shorts. The majority had the worst results when wearing small shorts - just one size different - and they jumped lower than if they were wearing no compression at all.

A number of studies (including meta-studies, which aggregate the findings from multiple studies) show that compression garments worn during exercise have a negligible effect on performance, but the majority of studies do not measure or even report the compression regime, as they are just using off-the-shelf garments. Subjects are fitted to the garments based on measures of height and weight, meaning that athletes of different shapes and sizes are fitted to the same size garment, therefore the compression regime is not consistent for all athletes. Variable compression regimes means variable results.

More recent research is recommending that the only way to ensure correct fit is to create customised compression designed for the body shape and composition of the athlete (Brophy Williams et al 2020). A recent study comparing custom fit compression garments against standard sized garments, showed that the custom fit garments improved strength recovery and markers of muscle damage in Rugby players compared to standard sized garments (Brown et al., 2020).

In summary, compression must be accurate to provide genuine and consistent results, however the pressure from of off-the-shelf garments is too variable. Custom-fit garments are necessary to provide physiological benefit in sports, just as it is in other industries.

Graduated Compression Regimes

Graduated compression regimes are not necessary for all use cases. Compression graduation that starts highest at the feet is commonly targeted with an easing of compression up the leg intended to improve venous return back to the heart. If such a passive pressure regime can aid blood flow return to the heart, it may also hinder arterial inflow, reducing the overall effect. A graduated regime which is loosest at the ankle may increase blood pooling in the feet as arterial blood may move past the garment, but venous pressure is insufficient to return it. Graduated compression can be essential, however, in the drainage of passive fluids such as in oedema settings or lymph.

Two studies have found that off-the-shelf compression garments can have pressure in the reverse direction when worn to manufacturers recommendations, and this is definitely undesirable. Both studies found that the calf compression was approximately twice that of the ankle, and Rimaud et al (2010) found the garments resulted in raised lactate levels. Compression regimes must be carefully controlled.

Performance Benefits

Studies which have a rigorous measurement or assessment of compression imposed on the body have shown significantly positive effects on repeat sprint performance, strength and power, and also endurance performance.

Compression has been shown to enhance performance during repeat-sprint tasks. Cycling repeat sprint performance was improved by 5.3%, concomitant with an increase in muscle blood flow (Broatch et al 2018) when compression garments were worn. Upper body strength performance was improved by ~5% (concentric and eccentric) when upper body compression garments were worn (Lambert and Dongas 2006). Improvements in countermovement jump performance were also reported when correct fitting compression shorts were worn compared to loose fitting shorts or poorly fitting compression shorts (Wannup et al., 2016).

Wearing compression garments has also been shown to improve performance during endurance tasks. Driller and Halson (2013) reported an improvement in mean cycling power of 1.3% when lower body compression garments were worn during a 30 minute cycling test. The magnitude of these performance benefits (>1%) have been deemed practically worthwhile and could be included in practice to improve performance.

In addition, it has been shown that wearing compression garments during running can reduce muscle displacement and soft tissue vibrations which has important implications for reducing the risk of injury (Broatch et al., 2020).

Recovery Benefits

There is strong evidence from multiple meta-analyses for the use of compression to be worn for the recovery of muscle function, and to reduce exercise induced muscle damage and soreness. The reduction in muscle swelling has been considered the key mechanism in which compression assists the recovery process. Meta-analyses show that compression significantly reduced perception of muscle soreness compared to control ($p < 0.05$). Importantly, compression garments can also be used to enhance the recovery of muscle power and endurance performance.

Our feedback from professional teams is that Cape recovery garments improve recovery rate by 20%. This is shown in the literature, as wearing compression garments during the acute recovery period between two exercise bouts has been shown to enhance performance. Driller and Halson (2013b) showed that compression garments improved recovery and subsequent performance when worn for 60 minutes between two 30 minute cycling trials. Similarly, in a study with trained runners, wearing compression socks in the recovery period between two 5km run time trials improved recovery and subsequent performance. Repeat sprint performance was also improved when compression garments were worn during the 30 minute recovery period between two running trials (Argus et al., 2013). Therefore wearing compression garments in the short term recovery period between trials, may be beneficial for athletes who have a short turnaround between events (eg heats and finals).

Travel Benefits

Compression also benefits elite athletes in minimising the impact of extensive in-season travel. Deep vein thrombosis, pulmonary embolism and venous thromboembolism are circulatory conditions where blood clots are formed in the lower limbs due to pooling of blood. The full consequence of the condition is fatality, as the clot formed in the lower limbs dislodges within the vein and enters the lung.

People that travel long durations, hospital patients or those standing for extended periods are exposed to extended immobility and are at a risk of developing DVT, and/or experience associated symptoms such as swollen or painful calves or thighs. The effect of compression garments to increase blood flow during immobilised settings has been well documented. While the risk of developing DVT while travelling is low, studies have shown compression reduces the incidence of symptomless deep vein thrombosis by 90%, reduced superficial vein thrombosis by 54%, and reduced swelling/oedema by 47%.

Busy competition schedules mean that many elite athletes are required to travel extensively. Compression garments are greatly beneficial for elite athletes to minimise the risk of DVT and also minimise the effects of travel on performance.

In regards to performance, travel to a competition may impair performance at the event itself, whereas return travel may impair recovery and also negatively affect training in the days following. Therefore, adopting strategies to minimise the effect of travel can enhance both athlete performance and recovery.

It has been shown that wearing compression garments on a 6-hour flight can attenuate the decrement in performance associated with travel, therefore maximising performance at competition (Kraemer et al., 2016). A similar study with elite volleyball athletes showed that compression garments worn during long haul air travel, maintained exercise performance and reduced lower limb swelling (Broatch et al., 2019). Improved subjective ratings of alertness, fatigue, muscle soreness, and overall health, were also observed, suggesting that compression garments are beneficial in minimising the physiological stressors imposed by long-haul travel.

Choosing Compression Apparel

The key requirement for elite athletes seeking physiological benefit from compression is that garments must be custom-fit to ensure the correct amount of pressure is applied. Secondly, the correct regime must be chosen for the application eg performance, recovery, travel or rehabilitation. Tighter compression is often perceived to be better, but it is not. Some professional athletes use a rule of thumb to purchase garments two sizes smaller, however this can result in applying pressure that is too high (this has been shown to be worse than no compression) and/or exacerbating a reverse gradient.

The cuffs of retail compression apparel are also regularly formed with a folded hem. Such manufacturing doubles the strength of the material at the edge, causing a much tighter circumference of localised pressure and a potential tourniquet effect. Garments which utilise softer elastic cuffs that are designed to ease the compression transition at each end of the garment are desirable.

Conclusion

Accurate compression has been found to bring significant physiological benefits to athletes by enhancing performance, optimising recovery and reducing travel risks. The sizes of off-the-shelf compression garments, however, are not capable of sufficient precision to bring consistent and genuine advantage. Medical-grade, custom-fit compression garments, imparting specific compression regimes, is necessary to realise benefit, and is therefore recommended for athletes to perform at elite capability.

About the Author

James Waldie, PhD

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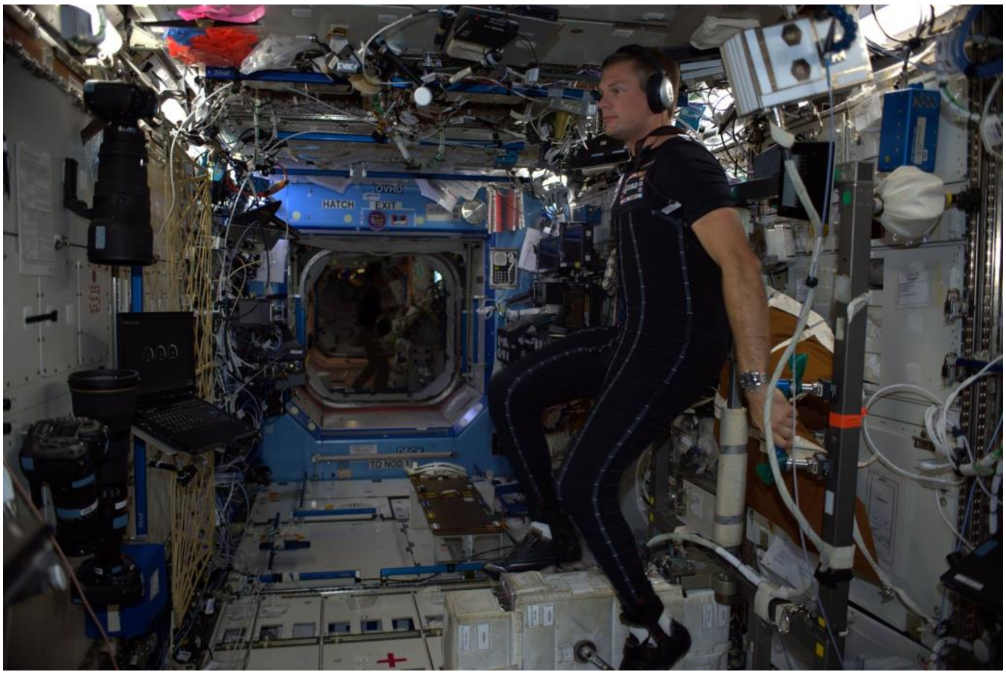
Dr James Waldie has been developing advanced compression garments for almost 2 decades. As a graduate Aerospace Engineer in 1999, James designed a skintight garment to impose G-loading on astronauts. This suit (called the Gravity Loading Countermeasure Skinsuit) would restore normal loading on the bones, and reduce skeletal atrophy on long duration missions. He was accepted as a Research Scholar at the University of California in San Diego at Masters level, working under Prof Alan Hargens (NASA Distinguished Service Medal), testing the physiological effects of compression, and measuring the pressure regimes of NASA elastic spacesuit garments on the body. He continued his studies and earned a PhD from RMIT, working on advanced skinsuits and Bioastronautics.

He was subsequently selected as a Postdoctoral Fellow at the Department of Aeronautics and Astronautics at the Massachusetts Institute of Technology (MIT), working principally on his Skinsuit design, but also consulting to NASA Johnson Space Centre to aid in studies of astronaut fingernail damage due to pressure from the spacewalking (EVA) gloves. Dr Waldie patented the Skinsuit with his MIT Professor Dava Newman (now retired NASA Deputy Director). As an Adjunct Professor at RMIT, Dr Waldie served as a Principal Investigator with the European Space Agency (ESA) on the Skinsuit programme, which deployed a Skinsuit to the ISS for a 2 week mission in October 2015, and for 6 months in 2017.

Dr Waldie saw the disparity in compression technology used in other industries compared to the sports industry, and so co-founded Cape Bionics in 2016 to brings the world's most advanced tailor-made compression technology using his experience – and that from the aerospace and medical industries in general - to aid elite athletes.

Dr Waldie testing the physiological effects of an advanced compression glove for NASA in a hypobaric chamber in 2000.

Andreas Mogensen wearing the Waldie Skinsuit on the International Space Station in 2015 (copyright European Space Agency)



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