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DO COMPRESSION GARMENTS STOCKINGS PLAY AN ACTUAL ROLE IN ENHANCING RUNNING PERFORMANCE?

Lucas-Cuevas, A.G.; García-Pérez, J.A.

RESUMEN

Physical activity is a practice performed by a large number of people all over the world. Physical exercise in general and running in particular have been associated with numerous physiological, psychological and social benefits for all range of ages. When analysing the biomechanics of running, stride length and stride frequency are the main technical parameters to look at when increases in speed are aimed. Apart from technique modifications, athletes use different ergogenic aids to enhance their sport performance. One of the most popular ones is the use of graduated compressive garments (GCS), which were initially used for clinical reasons improving blow and lymph flow in patients with venous deficiencies. Within the sport ambit, GCS have been showed to enhance performance by increasing skeletal muscle pump, clearance of lactate, maintaining leg power after exercise and improving running economy; and to promote a better and quicker recovery by decreasing muscle inflammation, muscle oscillation and delayed onset muscle soreness. Further anecdotal benefits such as increase of comfort and proprioception have also been attributed to GCS. However, most of the studies were carried out with middle-trained athletes and without a placebo garment. Therefore, the validity of the results obtained can be questioned and their effect on well-trained athletes remains unclear. Finally, there is a scarcity of studies relating GCS to the biomechanical parameters of the running cycle. Further studies may find it interesting to look into the effects that wearing GCS may have on stride length, stride frequency, and running gait mechanics.

COMUNICACIÓN VIRTUAL

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Introduction

Nowadays, the practice of physical activity is related to many benefits for the human health. Regular physical activity reduces the risk of premature mortality and of coronary heart disease, hypertension, colon cancer, obesity, Parkinson disease and diabetes mellitus (Pate et al., 1995; Thacker et al., 2008). An increasingly widespread form of physical activity is running, whose popularity and practice worldwide is still growing (Buist et al., 2007). If competitive running is excluded, there are many possible motivations for participating in "recreational" running. These include cardiovascular fitness, "burning calories" to maintain body physique, enhancing bone and muscle strength, and the promotion of a general feeling of health or youth (Milgrom et al., 2003). Moreover, with the increase in life expectancy, there has also been an increase in the number of elderly people engaged to this type of physical activity (Fukuchi & Duarte, 2008).

Although running positively contributes to health, there is also the possibility of a running-related injury, mainly caused by damage to joints or overuse injuries in the lower extremity (Buist et al., 2007; Fukuchi & Duarte, 2008), which has been associated to lack of running experience, previous injury, running to compete and excessive weekly running distance (Van Mechelen, 1992). Several strategies to prevent runners from getting injured involve proper training programme, massaging, cold water immersion therapy, and active recovery (Jakeman et al., 2010).

However, there is a recent trend of using special clothing with specific compressive qualities, which have been shown to enhanced performance and recovery after exercise (Noonan et al., 1999). Therefore, the use of these garments as an external ergogenic aid to improve results in running is becoming more and more common. Subsequently, the aim of this paper is to investigate the existing literature related to the effects that compressive garments may have on the running performance and recovery and provide a more depth insight into the role that these aids can play in enhancing running performance.

Graduated Compression Stockings

Graduated compression stockings (GCS) are garments that create compressive pressure around body estructures (muscle, bone and connective tissue) that is tightest at the most distal segment and gradually decays (with even pressure) up to the most proximal segment (Lawrence et al., 1980) (Figure 1).

Figure 1. Graduate Compression Stockings (GCS) correctly fitted over the legs, flush under the knee, and smooth to avoid bunching (Ali et al., 2011).

GCS were originally developed in a clinical environment to treat deep vein thrombosis (DVT) (Byrne, 2001) and venous insufficiencies (Stanton et al., 1949; Van Geest et al., 2003), as well as swelling from lymph deficiencies and acute inflammation (Jonker et al., 2001). These compression garments were mainly prescribed to patients to enhance blood and lymph flow from the lower extremities back to the heart (Ali et al., 2011). Within the clinical community, studies have shown that the optimum compression level for DVT patients is 20 mmHg at the ankle dissipating to 10 mmHg at the calf (Lawrence et al., 1980).

Investigations into the mechanisms that alleviated venous deficiencies found that GCS are effective because they apply static external compression to limb tissues and decrease the cross-sectional area of the venous system, which increases the linear velocity of blood flowing through veins (Lawrence et al., 1980). As a consequence, blood and lymph pooling at the skin and muscles is reduced, ensuring that circulation continues to return blood to the heart and assists clearance at damaged tissue, interstitial spaces and muscle (Kraemer et al., 2000; Mayberry et al., 1991).

GCS in Sports

Athletes keep searching for ergogenic aids that can enhance their performance during competition and training in order to improve their personal marks and gain an advantage over their opponents (Applegate & Grivetti, 1997). Throughout sport history, coaches and athletes have been aiming to perform better by using every aid permitted, trying to push the human physical capacity beyond their possible limits so as to reach success when facing a sportive challenge.

Nowadays, one aid that is becoming more and more popular is the graduated compression stockings (GCS), which is a form of mechanical ergogenic aid. Competitive runners have worn these GCS during races to enhance their potential to run faster. Despite the scarcity of scientific research, world records have been set wearing GCS for 20 km (Lornah Kiplagat, 1:02:57, October 14, 2007, Udine, Italy) and treadmill marathon performance (Michael Wardian, 2:23:58, December 11, 2004, Arlington, TX, USA). Although these results were undoubtedly the combination of exceptional athletic talent and comprehensive training, the runners'

choice to wear GCS indicates these athletes place considerable faith in their performance effects (Ali et al., 2011).

Sports clothing companies have offered for sale different types of GCS to the general population and athletes as having a number of performance and recovery benefits. In support of anecdotal claims made by athletes and manufacturers, research suggests that there may be some performance benefits from using GCS.

A study carried out by Kraemer et al. (2000) showed that workers standing and walking for long periods had their leg fatigue alleviated by wearing GCS. Regarding sport, athletes wearing GCS experienced performance enhancements such as better power maintenance over repeated jumps in voleyball (Kraemer et al., 1998, 1996), improvements in maximal jump height in track and field athletes (Doan et al., 2003) and better performance and reduced lactate concentration in cycling (Chatard et al., 2004).

The related rationale suggests that these aids may enhance sport performance by helping the skeletal muscle pump (Kraemer et al. 2000), increase deep venous velocity, reduce lactate concentration (Berry & McMurray, 1987; Chatard et al., 2004), and decrease blood pooling in the calf veins (Sigel et al. 1975). However, most of the aforementioned studies did not use a control test in their protocol. Regarding this issue, Doan et al. (2003) suggested that a possible explanation for this change in performance may be also due to the participants' perception that wearing compression garments would improve their performance, thus highlighting the importance of including a placebo control in the study methodology to determine whether GCS do influence sport performance.

It is important to take into account that competitive sports usually require high levels of cardiovascular fitness, implying long periods of standing, running, accelerations, turns and jumps leading to high impact forces from repeated contact with the ground. Moreover, events and training sessions in high-performance sports take place very often with short recovery periods (hours to days). For this reason, the use of GCS may enhance the maintenance of performance by reducing fatigue negative effects from one event or training session to the next, helping the athletes to achieve better results.

Besides the performance benefits already mentioned, the popularity of GCS spreads beyond their physical effects. General opinion states that these garments look and feel good. Responses from participants wearing GCS (18-22 mmHg) and ankle-length socks (control) indicated that athletes felt GCS were tighter but more comfortable (Ali et al., 2007), thus inferring that GCS not only may improve sport results but made athletes feel more comfortable when performing.

GCS in Running

Running performance is determined by a person's ability to complete a measured distance in the shortest possible time. Together with aerobic power (VO_2) at anaerobic threshold and run speed at VO_{2max}, running economy (RE) is considered an important factor determining success in endurance running (Conley et al., 1980; Costill et al., 1970; Noakes, 1988). It is important to take into account that in athletes with similar VO_{2max} values, running economy has been considered an integral determinant of running performance since

the best athletes are the most economical rather than those that possess the greatest running speed at VO_{2max} (Conley et al., 1980; Noakes, 1988).

Therefore, enhance running economy through the use of different aids may be an interesting issue for athletes aiming to improve their running performance. Technical innovations in clothing are one possible intervention that may influence running economy at a given intensity and alleviate stresses during aerobic exercise. In this line of work, wearing compression garments has been shown to decrease muscle fatigue by applying pressure that dynamically supports moving the muscle fibers in their contraction direction, therefore provoking decreased muscle oscillations (Bringard et al., 2006), which may additionally diminish the electrical activity in the skeletal muscles and facilitate lower energy expenditure at a given submaximal speed (Nigg et al., 2001). These improvements were associated to improved aerobic efficiency, attributed once more to the increased compression over the leg, what might have increased the biomechanical support of the muscle tissue and the muscle-tendon unit, leading to a higher mechanical efficiency resulting in less metabolic costs at given workloads.

Moreover, recreational runners wearing GCS showed a decrease in leg delayed onset muscle soreness (DOMS) after 24h, especially in the hip flexors, hamstrings and gastrocnemius muscle groups (Ali et al., 2007). Despite the reduction in muscle soreness and pain, a tendency to run faster was also found, what is a conflicting result considering that running faster implies higher intensity, therefore causing greater muscle damage. Ali and colleagues (2007) finally speculated that GCS may alleviate swelling and inflammation by applying compressive pressure around the biological tissues involved in the movement, thereby minimizing mechanical trauma caused by exercise and helping to enhance post-exercise recovery.

On the other hand, it is unclear whether some of the previous benefits of using GCS would occur when used by well-trained athletes. Several studies have not found venous flow (Sciacca et al. (1991) and performance (Sperlich et al., 2010) improvements for athletes training at least 5h/day. Taking these studies into consideration, we can reach three different conclusions when sport performance improvements are not found: 1) since GCS have been proved to enhance the recovery process, therefore the experimental exercise tests may have not been intense enough to promote muscle damage in the athlete's system; 2) the physiological adaptations produced by long periods of training may be efficient enough to cope with the cardiovascular stress produced by the physical exercise, thereby making the GCS beneficial effects not significant for athletes with such level of training; and 3) only athletes experiencing some kind of cardiovascular disorder may gain some benefits from wearing GCS (Sciacca et al., 1991; Bringard et al., 2006).

Future directions

Finally, there is a scarcity of literature regarding whether GCS may influence the biomechanics of the running technique. For any given running speed, it is generally known that metabolic efficiency is optimized through one specific combination of stride length and stride frequency (Hausswith et al., 2009). Moreover, alterations in stride length and frequency may have an effect on running economy, as these factors have been identified as integral to running economy (Noakes, 1988). To our knowledge, only one paper (Chatard,

1998) has studied the effect that GCS may have over running technique. This study found that compression tights improved the stride length of runners (lower stride length), which resulted in better performance. However, other studies have concluded that better distance running performance is related to larger stride length (Cavanagh & Kram, 1989; Saito et al., 1974). The simple process of shortening or lengthening the stride has an important effect on all the active musculature since each muscle is forced to work on a slightly different region of its force-velocity curve and, as a consequence, changes in efficiency can be anticipated (Hausswith et al., 2009).

Another possible effect of the GCS on the running biomechanics technique may be enhancing gastrocnemius and soleus efficacy and recovery. These muscle groups play a major role in running economy because they are responsible for the ankle extension. During the driving phase of the running gait, the propulsion force is produced by pushing down and backwards, as a result of the combination of hip, knee and ankle extension (Martin & Coe, 1998). Moreover, in the supporting phase at the moment the foot lands (moment the foot contacts the ground), the leg anticipates this contact by stretching eccentrically the extension muscle groups of the leg (Hay, 1993). This phase is considered crucial because the longer the foot is contacting the ground, the greater the loss of force will be and therefore the lower the running economy (Bravo et al., 1998). As a result, shorter contact times throughout the run are associated with better running performance (Leskinen et al., 2009).

In relation to these muscle groups, GCS have been reported to better maintain the maximal voluntary contraction of the triceps surae and reduce intramuscular pH (Miyamoto et al., 2011), responsible for impair muscle contractile properties such as isometric force and shortening velocity (Rassier and Herzog, 2002; in Miyamoto et al,. 2011). Taking into consideration these findings along with all the evidence presented before, GCS seem to enhance muscle performance and recovery. Bringing these results specifically to the triceps surae, the improvement in this muscle group efficiency may influence the mechanics of the running gait and subsequently the running economy of distance runners.

Basing on some studies previously presented that provides evidence of GCS enhancing triceps surae performance, one possible result of using these aids may be the maintenance of the proper running cycle relation (stride length-stride frequency) over time. When the runner starts to suffer fatigue, the athlete tends to change their running cycle (stride length) as a defensive response to muscle strain (Edwards et al., 2009). A possible effect of the GCS on the running mechanics may be the maintenance of the running cycle gait over time by enhancing the triceps surae workout. Therefore, the future approach of these hypotheses can be of interest and may help clarify the real role GCS plays as a sport aid enhancing running performance.

Conclusion

Running is a worldwide activity performed by a huge number of people with a widespread of physical, psychological and social benefits, although wrong behaviour (overtraining, previous injuries, wrong training programme, etc.) can lead to injury.

The technique in running is cyclic, which means that it repeats constantly over the same pattern, allowing little improvements in the technique have a great effect on the final outcome. Besides technique

improvements, athletes make use of ergogenic aids in order to achieve better results in competition such a special clothing that are said to enhance in some way the sport performance.

Wearing graduated compression stockings is a form of ergogenic aid that was firstly used to effectively treat venous deficiencies. These garments were shown to improve blood and lymph flow by compressing locally over the biological tissues. Regarding their application within sports, there is a controversy around whether GCS really provide benefits to sport performance. Improving blood flow, skeletal muscle pump action and clearance of lactate by one part; reducing muscle oscillation, muscle soreness, muscle inflammation and 24h DOMS by other; and maintaining leg power after exercise and improving running economy at last, have been noted to be influenced at some level by GCS. However, the majority of the studies did not use a placebo garment and therefore the validity of these results can be questioned. Furthermore, the participants were untrained to moderately trained athletes which does not clarify whether GCS can improve performance in well-trained athletes.

As a result of this study, future research can benefit from the aspects reviewed throughout this paper. Whether GCS enhance performance and recovery for athletes (both amateur and well-trained) is not conclusive. However, it seems they affect the performance in some way. Although researchers have been trying to study the GCS influence on sport performance by physiological components on the running, little research has been done taking into account the biomechanical parameters of the running technique such as the stride length, stride frequency and the running gait parameters (maintenance of optimal running cycle) over time. Therefore, it is recommended that future research look into the effects of GCS on the different phases of the running technique in order to find out whether the actual running technique is modified.

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