Research Article

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Preventative Aspects of Muscle Displacement in the Running Athlete

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ABSTRACT

In respect to human movement, especially at high intensities, the body is subjected to vibratory phenomena that can have an influence in the aspects of prevention and performance. This is mainly due to the fact that the human body is endowed with good elasticity along with a good capacity for elastic reuse, unlike the hard and inelastic surfaces and structures with which it often comes in contact with. The impact or the meeting between two different structures from the point of view of both the elasticity and the ability to deform determines the vibrations that are transmitted on the more elastic structures in the form of waves with amplitude and frequency, forcing the latter to find a way to dampen them with the aim of reducing the "noise" in the system. An example of this is the runner who, by running on a more rigid surface, can experience vibrational forces up to 4-5 times his or her body weight, starting in the lower extremities, at each landing phase, and consequently increasing exponentially in those structures that are close to the contact areas. A negative consequence from this type of running can be seen visually with the discoloration in the calf musculature and is suggested that the increase of vibrations during impact with ground may be one of the causes of retrocalcaneal exostosis, or Haglund Syndrome.

Haglund's deformity is an abnormality of the bone and soft tissues of the foot. An enlargement of the bony section of the heel [where the Achilles tendon is inserted] triggers this condition. The etiology is unknown, but other suggested causes than increase in vibrations during impact with the ground is a tight Achilles tendon, and or an accentuated arch of the foot. According to the latest research, women are more affected than men, and more often than not it is bilateral. Haglund syndrome is diagnosed with ultrasound and radiographic examination, pain on palpation, redness in the heel area, joint stiffness in the ankle. Treatment of Hanglund syndrome is often conservative, surgery is often not the best route. The use of specific orthoses, physiotherapy, a correct biomechanical evaluation can prevent this syndrome. This syndrome, as with other injuries incurred by runners due to increase vibrations during impact is the focus on this study.

Eleven runners were tested on treadmills at submaximal speed, with footage taken on the calves at high speed [1000 frames per second] and their movements analysed during the landing or impact phase on the ground. The comparison was made between two graduated compression stockings, with one compression stocking having two silkscreened strips of silicone on the calf to stabilize the muscle. The latter socks data pointed to a 0.3 cm improvement in terms of calf movement reduction with the runners analysed [1,2].

Introduction

The use of graduated compression stockings or compression garments have developed significantly in recent years among endurance athletes and, in particular, among runners. Along with the benefits of recovery, compression stockings are also widely used for injury prevention. There are recent studies highlighting the importance of wearing compression clothing in runners [3]. Several studies also report the presence of various injuries among marathon participants, mostly related to overload, and or overuse, with the breakdown of various structures of the body due to the repeated trauma [4-7].

The study of the aetiology of injuries reports various aspects related to the onset of the same, as described in the articles cited above. Issues with overuse, overload, poor biomechanics, frequency and duration of training, foot morphology, use of inappropriate footwear and consequences of the the ground reaction forces that is determined in the landing phase are just a few examples. All these can increase the formation of vibrations, of which are being transmitted from the foot through the Achilles tendon, creating a vibrational phenomenon on the entire muscle compartment connected to it, producing muscle displacement, tendon inflammation, with tendinopathy and injuries to the calf muscles [8,9].

Some studies have even gone so far as to say that it would seem that a vibrational increase in the Achilles tendon can lead to a reduction in motor reaction times, this biomechanically would make sense as we know that the first muscle to be affected by the vibrations themselves is the gastrocnemius. From the anatomical and physiological point of view, the gastrocnemius is rich in fast motor fibres, and would presumably be involved in the damping of vibrational stimuli with consequent loss of speed in reactive movements, and here is where compression stockings can play an integral part in not only assisting performance, but also decreasing the risk of injury. If we think of all sports where the effectiveness of action is linked to the ability to react quickly thus making the action unpredictable, [for example football, basketball, American football, rugby, and even in sports such as tennis] we realise what the value is, from a performance point of view, to reduce the movement of the calf thus keeping the athlete's reactive abilities unaltered and hence his unpredictability for the opponents [10].

Bilateral vibrations of the Achilles tendon, in the absence of vision, play a significant role in postural orientation. It is well known that the vibrations applied to the Achilles tendon induce a backward movement of the body in standing subjects and an illusory inclination of the body forward in restrained subjects. The vibrations stimulate the neuromuscular spindles in the calf muscles. Neuromuscular spindles alert the brain that the body is moving forward, so that the central nervous system compensates for this movement by moving the body backward [11].

So, if the vibrations affecting the Achilles tendon can alter an athlete's static and dynamic posture, proprioception and reaction times, then stabilizing the calf becomes a very important preventive factor and is linked with more than just performance [12-15]. One of the factors generating the vibrations is the landing phase during running and therefore the contact of the foot with the ground. This force, called Ground Reaction Force [GRF], generates in turn, as a result of Newton's third law of dynamics, forces and vibrations directed towards the athlete's body, creating vibrational waves that will affect the Achilles tendon [16]. In the landing phase of the biomechanics of running, we can develop up to six times our body weight, so the forces imply are very important [17,18]. According to the studies cited, we can receive vibrations in the landing phase ranging from 2 to over 20 hertz, depending on the type of structure we are running or walking on.

For those who are less familiar with the hertz scale, we can say that 20 hertz of stress correspond to having as many as 20 vibrational waves per second on the muscle. This aspect helps us to understand how traumatic a phenomenon of this kind can be affecting the muscle tendon structures. These are characterized by different viscoelastic behaviors. The tendon that has the task of transmitting the forces generated by muscle contraction to the joints is much less elastic and extensible than the muscle itself. The muscle composed of a greater number of components [the muscle fibers that form the motor units], aided by muscle architectures ranging from the pinnate muscle to the biceps to the fusiform up to muscles with strong aponeurotic components, is able to dampen differently and more effectively vibrations [19-21].

Biewener in his book "Mechanical Behavior and Biological Function Collagen" helps us to remember the characteristics and viscoelastic possibilities in favor of the tendon that make it similar to a spring and therefore very suitable for storing energy both in the form of traction due to muscle contraction and of another nature such as that potential elastic [plyometry] or vibrational. It states: "The non-linear viscoelasticity of tendons and ligaments, for which much of their mechanical behavior reflects the properties of their collagen I fibrils, is well suited to absorbing and returning energy associated with the transmission of tensile forces across joints of the body. The high resilience of tendon means that it can serve as an effective biological spring. At the same time, the flexibility of tendons and ligaments allows them to accommodate a wide range of joint movement [or, in the case of ligaments, to restrict movement within a certain range]" [22]. Understandably, vibrations with an important wavelength and amplitude can produce such stresses on the tendon as to become potentially damaging. In fact, these stresses combined with the loads due to body weight and speed during the landing phase that affect the Achilles tendon, can cause injuries [23].

Material and Methods

We tested 11 semi-professional female runners at sub-maximal speed on a cushioned treadmill. After an optimal warm-up, the sample runners donned control socks and ran for about three minutes. At the end of this test, after an adequate recovery, we repeated the test with the new Run up socks. A marker was placed on both types of socks and on both limbs at the anatomical center of the calf. The data relating to the movement of the calf was detected during the landing phase in the moment of foot / ground contact when the ground reaction force determines the vibrations on the limb. The markers were followed by a video played at 1000 frames per second. And processed with a video analysis software [Biomovie] capable of recording the movements of the marker both on the vertical and horizontal planes. It is also able, by exploiting the pixels of the video, to process the movement area of the marker itself, differentiating the data between right and left limb and between control sock and Run up sock (Figure 1) The Run-up socks compared to the control socks differ in a silkscreened silicone system on the back of the tibia, on the calf, with a kinesiotape effect. This should ensure stabilization of the calf more than a traditional compression sock without additional screen printing [control sock]. The stabilization of the calf takes place in traditional stockings through greater compression. We wanted to understand by comparing the two types of compression stockings how much calf stabilization the silk-screen printing could provide.

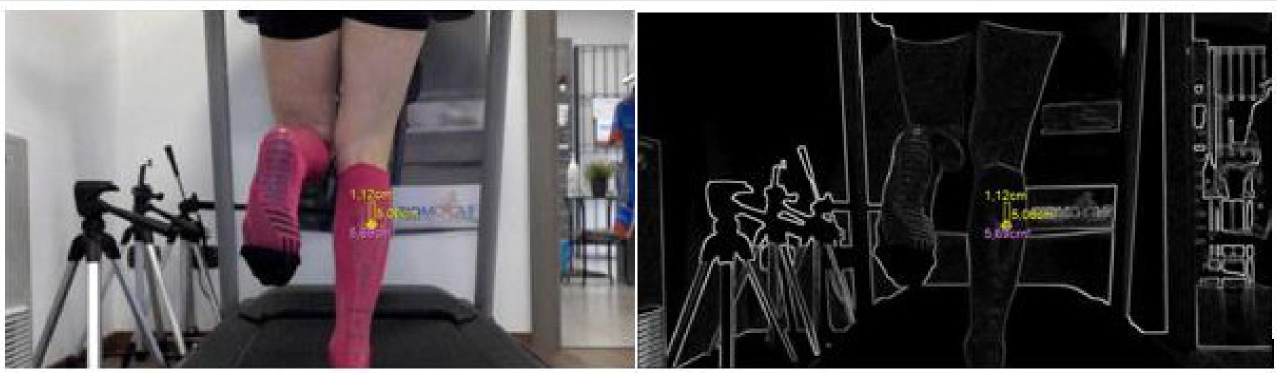

Figure 1: Alternative filter for the analysis.

Figure 2: The Run-up sock.

The Run-up sock (Figure 2) has a right and a left side and must be worn with care, paying attention that the rear screen printing is placed centrally and therefore passes through the heel. The bad positioning of the sock invalidates the effectiveness of the stabilization system. We therefore spent some time training the runners to wear the device correctly. The size of the sock must be chosen carefully through a table designed to allow total vertical coverage of the tibia, the sock must be pulled up vertically up to the maximum, in the upper part of the sock there is an anti-slip system in contact with the skin to prevent slipping at the bottom of the sock itself. The correct tensioning of the silk-screened system posterior to the tibia guarantees optimal stabilization of the underlying musculature, thus could also preventing injuries to the soleus.

As a video analysis program, we chose the Biomovie program, able to offer different video filters that could guarantee us an optimal marker tracking. In Biomovie there is a program tool where it is possible to indicate the size of the point, even a few millimeters, to be followed. This guarantees light movements that can be expressed in millimeters, therefore highly precise. This was also possible thanks to the quality of the video recorded by our video camera. The more pixels the video contains, the higher the quality and accuracy of the marker motion analysis. Biomovie can identify the single pixel and be able to track it by measuring its movement.

The decision fell on the filter with a black background and white outlines because it is the most contrasted and indicated to perfectly follow the pixel chosen for the evaluation. The video camera used is

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the Sony RX10 mark III. The Sony Cyber-shot DSC-RX10 III is Sony's flagship compact digital camera, built around a 1"-type stacked CMOS sensor which produces 20MP stills as well as 4K/UHD video. The RX10 III features a solid video specification, offering 4K video from 1.7X oversampled, full pixel readout without binning. The RX10 III offers the high frame rate 'HFR' videos modes that capture footage at up to 960 fps and then play it back as 1080/24p (Figure 3).

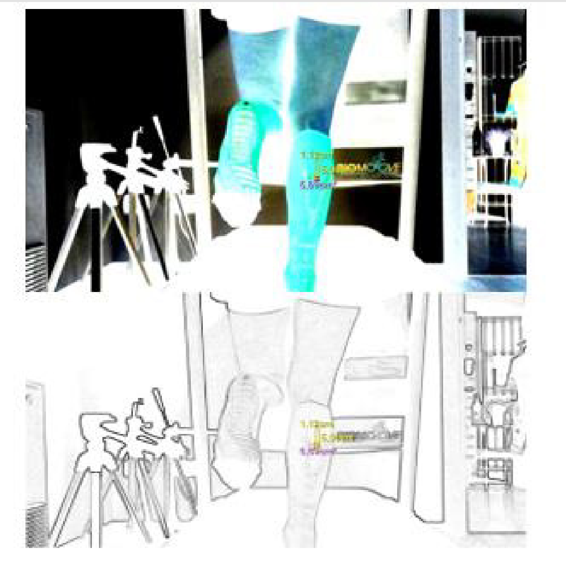


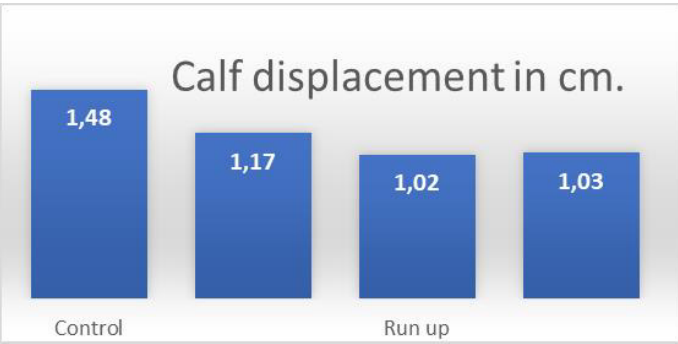
Figure 3: Alternative filter for the analysis.

Result

Table 1: Differences between Control and Run Up.

Control		Socks	Run Up	Socks
Average cm.	Left	Right	Left	Right
	1,48	1,17	1,02	1,03

Table 2: Calf displacement (cm) and total.



After analyzing the average of the data of all the subjects by dividing the data between left and right limbs, we also made the average of the two limbs, thus obtaining a single data that identifies the differences in oscillation and vibration of the calf during the landing phase at the moment of the foot contact with the ground. At this biomechanical phase the impact forces of the subject, which according to the running speed can reach the value of five times its own weight, due to the effect of the constraining force to the ground or ground reaction force produce counter forces [based on Newton's 3rd law] which can also develop in the form of vibrations, displacing the calf and causing the Achilles tendon to vibrate (Tables 1-5).

Table 3: Calf displacement (cm) and total.

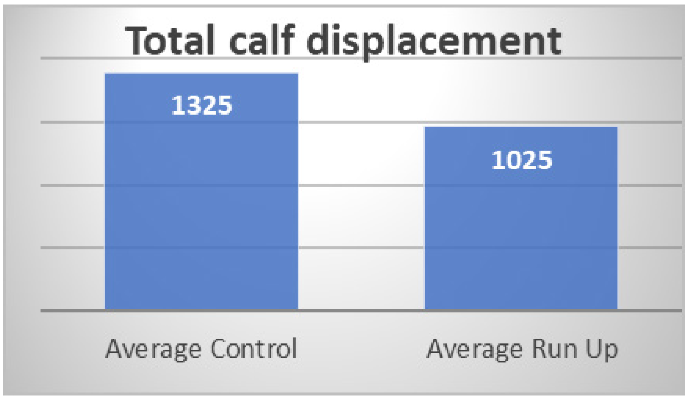


Table 4: The least squares line.

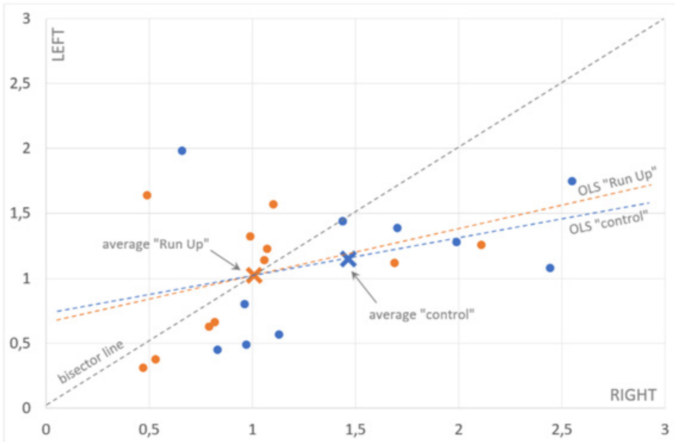


Table 5: Correlation, Covariance, SD (left and right).

Control	Run Up	
0,350992	0,395127	Correlation
0,106092	0,083315	Covariance
0,612259	0,482785	Standard deviation left
0,493684	0,43675	Standard deviation right

The data give us some interesting indications. A decrease in calf movement appears evident with the Run up, while a balance of calf movement between the two hemisomes is also noted. In the control sock it is noted that the dominant limb prevalent among the testers, the right, is more stable than the contralateral. In Run Up sock this aspect disappears with obvious benefits for the reduction of muscle overloads on a part of the body. The average of the left side, control sock, plus the right side is 1.325 cm of movement. The average of the left side, Run Up fit, plus the right side is 1.025 cm. The result is a decrease in calf movement of 0.3 cm or better a 23% reduction in movement recorded with the control sock.

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It is not considered particularly important to test the significance of the data, because they are the result of advanced technical research and therefore extremely reliable. We considered it important to examine the improvement already noted by relating the two limbs. In a regime of perfect body symmetry and movement the oscillations should be very similar and converge towards an identical value. Consequently, the detections of the two right and left limbs lie on the bisector of a bivariate graph. In reality, the least squares line relative to the control data shows an imbalance in relation to the right limb [the linear correlation indices calculated show a positive correlation both for control and for Run Up; remember that the correlation oscillates between -1 and + 1, with 0 representing the mismatch]. The least squares line relative to Run Up shows an improvement in the symmetry between the limbs. Above all, the fact is highlighted that the average of the values lies precisely on the bisector. Covariance values are also an advantage of the Run Up sock, indicating more stability in data variations [4-5].

Discussion

The evident reduction in calf dislocation with the use of silicone screen printing, leads us to think that we can hypothesize that the benefits described in the introduction is attainable. The reduction of vibrations and displacement on the muscle-tendon structures reduce overload, thus inducing less compensatory muscle activations aimed at stabilizing muscles and tendons with consequent reduction of fatigue. Furthermore, the reduction of vibrations could significantly reduce injuries to the muscles of the triceps sural area such as the soleus. There are also studies that suggest an improvement in the EMG signal in the absence of vibrations in the lower limbs [24-29].

Conclusion

The graduated compression sock certainly brings many metabolic benefits to athletes, both in post-training and competition recovery, in terms of better blood circulation for an improvement in venous return with the reduction of metabolic acidity conditions with the increase of O2 available for the cellular respiration to the production of ATP [30]. The new screen-printing application seems to improve all the mechanical parameters of the lower and posterior lodge muscle of the leg. This stabilization improves both the athlete's performance parameters and the aspects related to injury prevention. The use of a garment with this technology in competition and even in training brings significant benefits to the athlete, and in this particular study, the running athlete. In fact, it could reduce reaction times, stabilize posture, improve balance and reduce overloads while protecting the athlete from injuries. Further studies in this regard are needed [31-36].

Conflict of Interest

None.

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