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Effects of Compression Garments on Lower Limb Muscle Activation via Electromyography Analysis during Running

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Abstract: Sports compression garments are common-selected sportswear to improve athletic performance and reduce sports injury, since they consist of elastic textile that exerts compression and pressure onto the muscle[1]. Muscle activation is of interest to sports compression garment manufacturers who seek to enhance sports performance through gradient compression garment design. However, there are few scientific investigations to explore this effect of muscle activation to evaluate the performance of sports compression garments during sport activity. In this paper, a systematic experimental protocol was presented to improve the quality of evaluation test under a standardized running test. Then muscle activation with and without wearing sport compression garments to highlight the changes caused by compression garment was investigated. The electromyography (EMG) signal was collected and processed by the proposed method to represent the muscle activation combined with gait analysis of running. As a result, the average muscle activation of gait cycle for the major muscles such as rectus femoris (RF) and gastrocnemius medialis (GM) revealed that they needed to exert more muscle force without wearing garment at certain periods for mid-stand and pre-swing phase within gait cycle. These lower muscle activation levels prolonged activity duration[7-9] reduced fatigue[10] and presented low risk for sport injury. Such an evaluation study therefore would scientifically prove the effect of compression garment and provide information on muscle activation and the ergonomic efficacy of gradient compression garment design.

Key words: compression garments; muscle activation; electromyography (EMG)
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Introduction

Sport compression garment is commonly selected sportswear to improve athletic performance and reduce sports injury[1] which consists of elastic textile that exerts compression and pressure onto muscles to relieve muscle stiffness and fatigue during sports[9-12]. It is common for professional athletes customizing their form-fit garments to identify and optimize the right amount of compression pressing according to body area. In order to pursue diverse compression for improved sports performance by enhanced venous return and oxygenation for working muscles[3] it is therefore not surprised that the evaluation of the compression garment becomes a current research focus. Specific details on anatomy and biomechanics of the compression garments are assessed[13] which assist with selection of fabrics and design of garment for existing performance compression garments currently available and recognize specific prototype modifications and the details to implement for future product.

Wang and Zhang[17] developed an illustrative method to indicate the pressure magnitude of elastic fabric by using INSTRON tensile tester to measure the stress[18,19] strain and compression. Moisture management[17] air permeability[1] and contact angle of textile were also tested to control body temperature and sweat[20] which prevented chafing and rashes during sports. Those results via materials tests are effectively focusing on the textile itself. Meanwhile systematic methodologies are desired to evaluate the product according to the customer feedback. Perception feedback are frequently gathered by surveys and questionnaire to designate the comfort and fit with applied test protocols. Those oral descriptions are valuable but there are subjective information lacking the experimental measurement. Liu et al.[7,8] have conducted a series of researches on psycho-physiological responses through heart rate (HR) blood pressure (BP) respiratory consumption and energy expenditure to evaluate the effect when wearing form-fitted wear in intensive exercise. At the same time, biomechanics feedback of human also draw researchers’ attentions[21,22] however, there is limited scientific work to explore on this area. Especially with development of design of the muscle stabilization garment reduction in muscle oscillation that may contribute to optimizing neurotransmission is proposed. It is believable that detection of the underlying regulation of muscle activation may lead to a better understanding of athletic performance.

Electromyography (EMG)[7,8] is a substantial component often used for the assessment of muscle activation[7-9]. Besides[23] by association with new technology EMG data collection and analysis becomes more convenient compared with that decade ago. Although muscle activation can be detected to evaluate the effects of compression garments[10-12] few scientific analysis investigation of specific changes in muscle activation was affected by the compression garment. As highlighted[10] that was quite challenging to design a systemic methodology for sports compression garment based on laboratory testing but it is worth to explore. Since muscle strength[11] fatigue[12] and EMG activations are very sensitive to external conditions[12] experimental framework is not easy to develop[13]. Meanwhile[10] pilot studies explore the identification on an appropriate range of fabrics that is the most suitable for muscle stabilization[17]. As reported that muscle activation decreased when wearing compression garments on the lower limbs[10] the alternations of muscle activations were detected during the sports activities between wearing or without wearing the compression garment[17]. To further determine the effects of lower limb muscle activation and find effective solutions by developing an innovative performance for the running suit gait analysis of running needs to be carried out with synchronized EMG analysis.

In this paper, a systematic experimental protocol is presented to improve the quality of evaluation test under a standardized running test. Then we investigate muscle activation with and without wearing sport compression garments during the designated running procedures. Participants are recruited and results are analyzed to assess whether less muscle activation with wearing garment has...
advantages during the running combined with the concurrent movement of wearer. Particular gait analysis combined with EMG data processing makes the evaluation meaningfully reveal with running activity. Scientific analysis of subjects are conducted to determine if particular changes in muscle activation effect reveal the performance of compression garments. The test results will further enable informed decisions for the design and construction of garments.

1 Experimental

1.1 Participants

Eight volunteering participants were recruited from local university and randomly selected. Experimental procedure are informed without the purpose of the study to avoid biasing the data.

1.2 Protocol

EMG was used to capture the muscle activation of participants. The EMG data were collected by 1 000 Hz with a wireless Delsys EMG system. Surface electrodes were attached to the major muscles of participants’ lower limb. While collecting EMG single with synchronized video recording subjects were running on a floor-mat while recording footprint. The locations of electrode placement were thigh and shank as shown in Fig. 1. The portable pressure mat walkway embedded with pressure-activated sensors provided measurement of temporal and spatial parameters such as running speed cadence step/stride length moment when heels contact the ground.

The participants commenced walking prior to and after the run trial to count the accelerations and decelerations during running. In order to standardize the running process the normalized mean running velocity is around 7 - 8 m/s. Participants conducted pre-trials to familiarize the experimental setup and settle down around the desired running speed. Then 10 formal trials were repetitively conducted with their preferable arm swing. Five of those trials were selected for data analysis. Participants were running with regular pants and two kinds of lower limb compression garments to repeat the running process. The products were currently available on market and sponsored by an anonymous apparel company. Type 1 compression garment and Type 2 compression garment were named to distinguish. Type 1 compression garment indicated the cropped trousers as illustrated in Fig. 1 and Type 2 compression garment were long trousers sharing the same materials with Type 1 compression garment.

The EMG signal was synchronized with footfall information. Time markers inserted every time when the right heel contact on the ground were highlighted. At the same time the footfall information including heel contact and toe off of both sides were recorded by pressure mat. So we offset right heel contact of EMG recording to footfall information. As a result time markers were inserted into EMG signal when heel contact and toe off occurred and was captured by pressure mat.

1.3 Data analysis

The signals are full-wave-rectified to produce positive values only smoothed using a 0.5 ms travelling window and then passed through a digital low-pass Butterworth Filter with a cut-off frequency of 4 Hz as commonly used in processing EMG raw data to filter the low frequency disturbance during the data collection. After every gait cycle starting from right heel contacting ground is picked up the average muscle patterns are obtained and compared.

In order to standardize the running process the mean normalized running velocity was around 7 - 8 m/s. The EMG signal was processed by the proposed method to represent the muscle activation. The effect of wearing compression garment via muscle activity evaluation was presented then.

2 Results and Discussion

Previous research mentioned the decreased tendency when wearing garment appeared which should be also highlighted in this paper. The overall effect of EMG data are presented. Then detailed analysis with connections to running cycle are investigated. The specific effect of garment are provided as a pilot study to guide the further design of compression garment.

2.1 General comparisons

The representative muscle activation for the major muscle GM is shown in Fig. 2. Results of three average running trials are compared. Comparisons are carried out with random-selected participant as a case study on without wear compression garment wearing Type 1 compression garment and wearing Type 2 compression garment. The decrease of muscle activation has been revealed throughout the entire running trial.

As shown in Fig. 2 GM impulsed a peak activation once a running cycle which provided the propulsion muscle power to push forward during pre-swing phase of the leg. It also exerted continuously within the whole running cycle to stabilize lower limb and foot. This muscle acted as a major functional group to conduct running. Without wearing elastic garment the EMG data seems more active with higher spike compared with wearing one. Noisy disturbance appears throughout the entire activation pattern. While wearing compression garment seems restrict and refines the active focus on certain phase within cycle. As the data turn out to be more tidy and neates it is believed that the garment constrains muscle activation so the activation tendency appears more compactly. Although relationship between muscle activation and muscle power that indicates the sports performance is not proved clearly less muscle activation enlarges the time before fatigue is convincing. Therefore wearing garment assist performance is clearly revealed.
2.2 Average muscle activation

In order to investigate the change of muscle activity\[s\] various methods are applied such as rectification\[s\] root mean square (RMS)\[s\] and high pass/band pass filters to process raw data to obtaining “envelop” shape of EMG data and comparing for the overall muscle activation pattern tendency. From overall muscle activation pattern tendency\[s\] the significant decreasing muscle activity is presented in the major muscles during running at similar speed. More effects are shown on RF than GM as shown in Fig. 3. RF pulls lower limb flexion to swing limb forward and also stabilizes thigh during stance phase within running cycle. Two activation peaks appear within one cycle. Holding activation during mid-stance phase to keep leg straight exerting large activation as shown when without wearing garment. As illustrated in Fig. 3 (a)\[s\] the RF muscle power is reduced greatly from 80 μV to 20 μV after wearing the garments during the mid-stance phase. This activation drops when wearing compression garments which indicates compression garment helps hold leg straight during stance phase. Instead of using muscle power to hold the posture\[s\] extra garments contribute to this function during running. So less energy is consumed with wearing garment which increases the efficiency of running. Long running or marathon could show this advantage more obviously. Another peak of RF muscle activation is similarly expressed\[s\] which works as pulling limb back in extension during swing leg back. There is no obvious difference during this phase\[s\] and more efforts are needed when wearing the garment. It is might be the compression garment which limits the swing of limb. Slightly more force is exerted to overcome constrain pressed on the limbs. In Fig. 3(a)\[s\] time marker of mid-stance (around 10% progression of whole gait cycle) is articulated by a dotted line and the corresponding mid-stance moment is captured from the video clip.

As illustrated in Fig. 3 (b)\[s\] GM muscle activation peak is reduced from 240 μV to 150 μV after wearing the garment during the pre-swing phase. As mentioned in Fig. 2 GM impulsa peak activation once a running cycle at the pre-swing phase which provides the propulsion muscle power to push forward lower limb. The spike of muscle activation during this propulsion is declined when compression garment is worn compared with that without it. Less activation volume might lead to less muscle activity within certain time\[s\] which it is constructive to sports duration. The activation phase has a little change which specifies that the compression garments do not alter the functional period. Only activation volume is diminished. Time marker of pre-swing (around 70% –80% progression of whole gait cycle) is articulated by a dotted line and the corresponding pre-swing moment is captured from the video clip. Garment-related muscle activation changes of Type 1 and Type 2 compression garments are similar. Type 1 compression garment is slightly effective to diminish the muscle activation volume. The knitting pattern of Type 1 compression garment might be emphasized specifically for this running speed. The oscillation of muscle activation after heel contact on the right side is also weakened at the beginning of running cycle when wearing garments. Researchers declared the additional muscle oscillation caused by hitting on the ground introduced unwanted energy waste\[s\]. So the decreased tendency during
mid-stance: around 10% of gait cycle

pre-swing: around 70%-80% of gait cycle

3 Conclusions

Muscle activation can be of interest to sports compression garment manufacturers who seek to enhance sports performance through gradient compression garment design. Researchers have also claimed that muscle force exerted for a limb’s motion and stability may be wasted on stability on muscle oscillation while compression garment may prevent it during sports activities which may enhance athletic performance. Hence it is necessary to determine if a link exists between muscle activity and the performance of sports compression garments during dynamic activities. Such an evaluation study would scientifically prove the hypothesis and proved information on muscle activation and the efficacy of gradient compression garment development.

As shown in this paper, EMG data illustrate decreased activation tendency and less noisy oscillation overall. Furthermore, the average muscle activation pattern analysis highlights major muscles contributed to running need to exert more muscle activation without wearing garment during their functional period. Particularly, RF performs declined muscle activation during the mid-stance phase and GM performs less muscle activation during the pre-swing phase. Those foremost functions are spikes showing in the average muscle activation pattern. Compression garment stabilizes the shank by contribution on holding the lower limb straight during the mid-stance and helps on the flexion of limb which might have advantage during the physical exercises. More muscle force is needed to overcome constraining force on the limbs during swinging limbs with wearing garment. Future studies would further investigate the statistical analysis based on the conclusion of representative case. As similar performances of two types of garments are shown in this study, selection of suitable garment may rely on other factors such as comport and thickness.

References


