THE EFFECT OF DIFFERENT EXTERNAL ELASTIC COMPRESSION ON MUSCLE STRENGTH, FATIGUE, EMG AND MMG ACTIVITY

Yu Liu, Wei-jie Fu, and Xiao-jie Xiong

School of Kinesiology, Shanghai University of Sport, Shanghai, China

The purpose of this study was to quantify the effects of three different compression conditions on (a) performance of muscle strength/power and fatigue in lower extremity, and (b) the responses of electromyography (EMG) and mechanomyography (MMG) of rectus femoris (RF) under repeated concentric muscle actions. All subjects (N=12) performed maximal voluntary contractions (MVC) and consecutive, maximal isokinetic knee extension movements at 60°/s & 300°/s velocities with three different compression conditions. The results indicated that local elastic compression of lower extremity, while not significant in improving isokinetic strength in short period, may have a positive effect on fatigue by helping maintain long-term force production through altering muscle activity in high-velocity of locomotion.

KEY WORDS: different compression, strength, fatigue, electromyography, mechanomyography.

INTRODUCTION: In high-intensive competitions or leisure sports, the use of compressive garments (e.g., tights, pants, and suits) has become increasingly widespread with the need to reduce muscle injury and maintain muscle function (Trennell et al., 2006; Wallace et al., 2006). Commercially available compression garments have been proposed to provide positive effects on athletes (Houghton et al., 2007). Mechanisms to explain the improved performance included changes in blood flow, improvement on muscle function and the damping of soft tissue vibrations (Herzog, 1993; Kraemer et al., 2001a; Coze and Nigg, 2008). Recently, there have been many publications demonstrating the benefits of compressive garments, however, there are still a quantity of studies from which the results do not support the positive effects claimed by some apparel manufacturers (Duffield and Portus, 2007; Sato et al., 2008). Moreover, far fewer rigorous scientific studies have been conducted to make a detailed investigation into the performance and muscle function under different compression conditions.

In addition, surface electromyography (sEMG) and mechanomyography (MMG) have been widely used to obtain biological information of muscle activities in sport science research field (Tarata, 2003). Specifically, the MMG amplitude is considered to reflect motor unit recruitment, whereas the EMG amplitude reflects both motor unit recruitment and firing rate (Beck et al., 2005; Orizio 1992). Thus, simultaneous measures of EMG and MMG provide additional insight with regard to the motor control strategies utilized by the electromechanical function of active skeletal muscle during a concentric fatiguing task.
Therefore the purpose of this study was to quantify the effects of three different compression conditions on (a) performance of muscle strength/power and fatigue in lower extremity, and (b) the responses of electromyography (EMG) and mechanomyography (MMG) of rectus femoris (RF) under repeated concentric muscle actions.

METHODS: Subjects: Twelve male students specialized in sport were recruited for this experiment (age: 21.2±1.4, mass: 67.1±6.4 kg, height: 1.78±0.05 m). All the participants were with 4-5 years of experience in track and field specializing in sprint or jump events and had no previous musculoskeletal injuries of the lower extremity half a year before this study.

Elastic Compression: Testing utilized adjustable compressive wrap which made of 43% polyamide, 42% cotton, 10% elastodiene, 5% elastane, and its tension was obtained by the force-length curve. The three conditions of testing were: medium loads, high loads and control condition (no compression). The covered area was from thigh to just above knee.

Isokinetic Strength Testing: Prior to the isokinetic testing, the strength of maximal isometric voluntary contraction (MVC) of the quadriceps was measured at 60° angles of knee flexion.

Isokinetic testing consisted of 1 set of 25 consecutive, maximal isokinetic knee extension movements at two selected velocities (60°/s and 300°/s) on a calibrated Contrex Isokinetic System (CMV AG Corp. Switzerland) for each condition.

Muscle Activity Procedures: The amplitude of EMG (Biovision, Wehrhaim, Germany) and MMG (a biaxial accelerometer, Biovision, Germany; bandwidth of DC–1000 Hz) of the rectus femoris (RF) under wearing different compression elastic textile were acquired with Dasylab 8.0 software both at a sampling frequency of 1000Hz. Furthermore, in order to observe isokinetic knee extension movements synchronously, an inclinometer was positioned with its values recorded along with EMG and MMG signals at the same time through a Biovision data acquisition system.

Signal Processing and Statistical Analyses: Date analysis for muscle activity was performed with custom programs written with Dasylab 8.0 software. The EMG and MMG amplitude (RMS) were calculated over the middle third of each repetition based on a total range of motion of 90° (approximately a 30°range of motion; 0.5s for 60°/s and 0.1s for 300°/s) (Ebersole et al., 2006). The EMG signals were bandpass filtered from 10 to 700 Hz, while the MMG signals were filtered with a pass band of 10–100 Hz prior to signal analysis.

The main variables discussed in this study for force production were peak torque, peak power and average power for the 1^{st} five repetitions of knee extension, for fatigue performance were total work and decaying ratio of torque (k), and for muscle activity were EMG and MMG root mean square amplitude (rmsEMG/rmsMMG) of the rectus femoris for each of 1^{st} five repetitions and total 25 repetitions. One-way ANOVAs were used for the analysis of different compression conditions using SPSS 13 (SPSS Inc., Chicago, IL). The significant level was set at α=0.05.

RESULTS AND DISCUSSION: Torque and Power: The isokinetic results for force production (peak torque, peak power and average power) were shown in Table 1 (N=11). No significant differences were found among control, medium and high external elastic compression conditions at MVC and other two angular velocities.

Table 1: Force production of knee extensors at MVC and two angular velocities. Values are mean *(SD)*

Knee Extension	MVC			60°/s			300°/s		
	Control	Medium	High	Control	Medium	High	Control	Medium	High
Peak Torque(Nm)	223.0 *(36.7)*	212.8 *(34.7)*	213.6 *(34.8)*	175.7 *(30.3)*	179.1 *(35.0)*	174.4 *(23.2)*	140.0 *(29.9)*	140.6 *(22.4)*	130.7 *(28.7)*
Peak Power(W)				182.7 *(31.6)*	186.7 *(37.5)*	181.6 *(25.1)*	616.0 *(88.0)*	614.4 *(88.9)*	590.5 *(98.4)*
Ave. Power(W) for 1st five repetitions				107.4 *(14.3)*	110.2 *(20.0)*	103.7 *(18.0)*	233.9 *(36.2)*	238.3 *(26.8)*	231.1 *(46.8)*

Fatigue Performance: No significant differences were found between elastic compression and control condition in total work and decaying ratio of torque k (Figure 1 and 2). However, it is worth noting that trends toward declined work and ascended k were observed in high loads compression at two angular velocities. That is to say, compared control condition with high loads, the total work of the latter one decreased approximately 4% both at 60°/s and 300°/s.

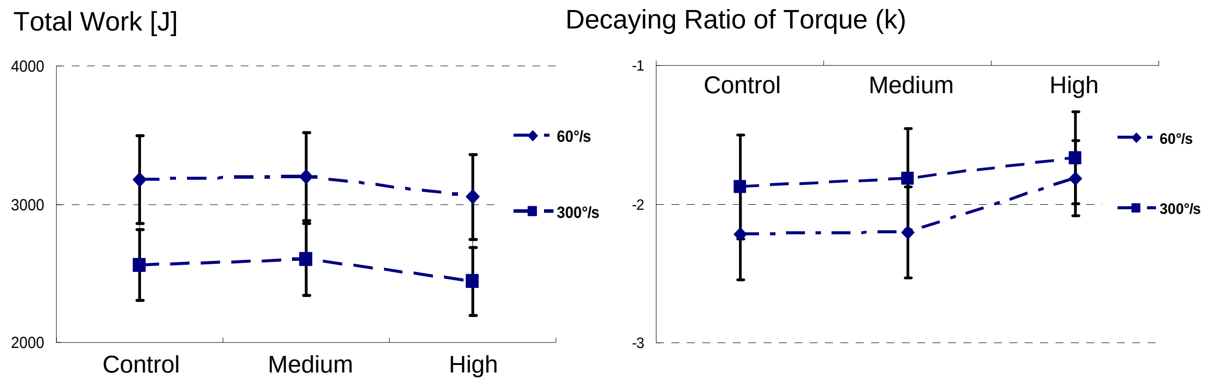

Figure 1 and 2: Influence of elastic compression conditions on total work and decay ratio of torque (k) at two angular velocities

EMG and MMG Amplitude: The amplitude (RMS) of EMG and MMG of RF under three different loads for MVC and the 1st five repetitions of two angular velocities was presented in Table 2 (N=12). No significant differences were found at MVC and 60°/s, but at 300°/s, the medium loads compression condition showed 21.5% and 37.9% increase in EMG and MMG ($p<0.05$) respectively when compared to the control condition.

Table 2: The RMS of EMG and MMG for the RF under three loads at MVC and 1st five repetitions

	MVC			60°/s			300°/s		
	Control	**Medium**	**High**	**Control**	**Medium**	**High**	**Control**	**Medium**	**High**
EMG	0.59±*0.3*	0.53±*0.2*	0.60±*0.4*	0.48±*0.3*	0.45±*0.2*	0.43±*0.2*	0.65±*0.2*	**0.79±*0.3****	0.56±*0.2*
MMG	0.29±*0.1*	0.24±*0.1*	0.29±*0.1*	0.46±*0.1*	0.33±*0.1*	0.35±*0.1*	0.66±*0.3*	**0.91±*0.3*#**	0.79±*0.4*

* and # indicate a significant difference compared with control condition, $p<0.05$.

Results above indicated that if the compression and velocity of locomotion could not reach a certain range, the effect of external elastic compression for short-term force production may not be as distinct as we considered before. Meanwhile, compared with no or high compression in local area, medium loads might have a better ability of recruiting additional motor units, especially for fast twitch fibers (Beck et al., 2005), in helping improve short-term performance. This may to a certain extent provide indirect evidence of enhancing proprioception after using the compression (Kraemer et al., 1996).

For total 25 repetitions, there was an significant gradual decrease ($p<0.01$) in rmsEMG with its elastic compression enhanced (from zero to high loads) both at 60°/s and 300°/s, whereas no significant differences were found in rmsMMG (Figure 4 and 5).

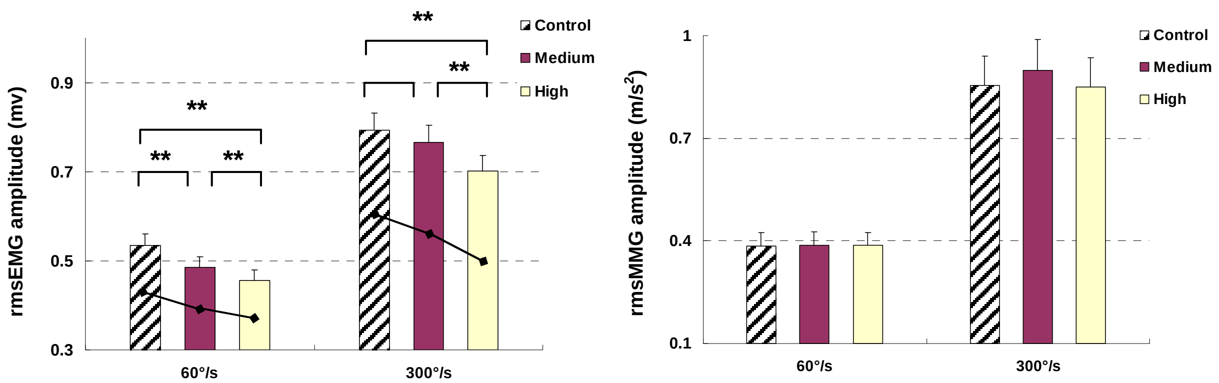

Figure 4 and 5: Influence of elastic compression conditions on the amplitude of EMG and MMG at two angular velocities for total 25 repetitions (p<0.01).**

Definitely, from EMG amplitude, elastic compression has an effect on muscle activity in isokinetic knee extension movements. These findings are similar to recent investigations reporting compression apparel decreased muscle pre-activation during running (Coza & Nigg, 2008). Considering with the results of declined work and ascended k showed above, it implies that these changes may have a positive effect on fatigue and performance. From rmsMMG, the effect in reducing muscle oscillation was insensitive to the changes in compression. This could be partly due to the pattern of muscle force production and the deficient range of motion which was not as extensive as running or jumping. However, this speculation requires further investigation.

CONCLUSION: The results of this study indicated that local elastic compression of lower extremity, while not significant in improving isokinetic strength in short period, may have a positive effect on fatigue performance by helping maintain long-term power output. Moreover, the amplitude (RMS) of EMG and MMG suggested that appropriate external elastic compression may be beneficial to recruiting additional motor units of rectus femoris in high-velocity of locomotion for short-term force production and have a positive effect on muscle activity in isokinetic knee extension movements for fatigue and performance. However, further work should focus on frequency-domain responses (e.g. mean power frequency) for more definite fatigue performance and optimal loads (press or compression) for different muscles to comprehend the benefits and mechanisms underlying the use of compression garments in athletes and healthy populations.

REFERENCES

Beck, T.W. et al. (2005). Mechanomyographic amplitude and frequency responses during dynamic muscle actions: a comprehensive review. *BioMedical Engineering OnLine*, 4, 1-27.

Coza, A., Nigg, B.M. (2008). *Compression apparel effects on soft tissue vibrations*, The 4th North American Congress on Biomechanics, University of Michigan, Ann Arbor, MI, USA.

Cramer, J.T. et al. (2002). Power output, mechanomyographic, and electromyographic responses to maximal, concentric, isokinetic muscle actions in men and women. *Journal of Strength and Conditioning Research*, 16, 399-408.

Duffield, R., Portus, M. (2007). Comparison of three types of full-body compression garments on throwing and repeat-sprint performance in cricket players. *British Journal of Sports Medicine*, 41, 409-414; discussion 414.

Ebersole, K.T. et al. (2000). The effects of leg angular velocity on mean power frequency and amplitude of the mechanomyographic signal. *Electromyography and Clinical Neurophysiology*, 40, 49-55.

Herzog, J.A. (1993). Deep vein thrombosis in the rehabilitation client: diagnostic tools, prevention, and treatment modalities. *Rehabilitation Nursing*, 18, 8-11.

Houghton, L.A. et al. (2009). Effects of wearing compression garments on thermoregulation during simulated team sport activity in temperate environmental conditions. *Journal of Science and Medicine in Sport*, 12, 303-309.

Kraemer, W.J. et al. (1996). Influence of compression garments on vertical jump performance in NCAA Division I volleyball players. *Journal of Strength and Conditioning Research*, 10, 180-183.

Orizio, C. (1992). Sound myogram and EMG cross-spectrum during exhausting isometric contractions in humans. *Journal of Electromyography and Kinesiology*, 2, 141-149.

Sato, K. et al. (2008). *The effect of compression tights and duration of testing on continuous jumping mechanical power*, ISBS Conference 2008, Seoul, Korea.

Tarata, M.T. (2003). Mechanomyography versus electromyography, in monitoring the muscular fatigue. *BioMedical Engineering OnLine*, 2, 3.

Trenell, M.I. et al. (2006). Compression garments and recovery from eccentric exercise. *Journal of Sports Science and Medicine*, 5, 106-114.

Wallace, L. et al. (2006). Compression garments: Do they influence athletic performance and recovery. *Sports Coach*, 28, 38-39.