Effect of Compression Bandages on Muscle's Behavior

Abdelhamid R. R. Aboalasaad 1, Brigita S. Kolčavová 1, and Gözde G. Berk 2

1 Technical University of Liberec, Faculty of Textiles, Department of Technologies and Structures, Studentská 1402/2 461 17 Liberec 1, Czechia

2 Istanbul Technical University, Faculty of Textile Technologies and Design, Fashion Design Department, Inonu Cad. No.65 Gümüşsuyu Beyoğlu, Istanbul, Turkey

Corresponding author: eabdo6@gmail.com

Abstract: This study aims to explore the relationship between compression bandage (CB) and muscles' performance. Hand wrist, mid-calf, and ankle muscles are subjected to electrical voltage test with and without wearing CB. Electromyography (EMG) analysis is a substantial component often used for the assessment of muscles activity. Flexor Carpi (FC), Medial Gastrocnemius (MG), and Soleus (SO) muscles are selected to represent wrist, mid-calf, and ankle muscles respectively. The standardized activities protocol used to test FC muscles are (flexion-extension and squeezing a soft roll), while the activities for MG and SO muscles are (flexion-extension and while walking). The obtained data are analyzed using Mega-win and Mat-lab software. Wearing CB was associated with significantly lower muscle activation and higher median frequency for MG and SO muscles during different actions. These results suggest that using CB can improve muscles function, which might enhance walking performance and reduce muscles fatigue.

Key words—Compression bandages, Electromyography, Mega-win software, Muscle performance.

1. INTRODUCTION

1.1. Compression bandages

Compression bandages (CBs) consist of elastic textile that exert pressure onto muscles. Bandages can provide the required optimal environment by controlling moisture and compression levels for wound healing. These medical elastic textile structures can improve athletic performance and reduce sports injury, which exerts compression and pressure onto muscles to relieve muscle stiffness and fatigue during sports [1-6]. In clinical practice, CBs are applied in the form of overlapping layers which results in multiple layers of fabric that overlay a particular point of the surface of the limb [7]. CB which applied with spiral 50% overlap technique will overlay the leg with two layers of bandage, CB applied with 33% overlap will result in three layers of bandage and CB applied with the Fig.-of-eight technique with 50% overlap will result in four layers bandaging [7, 8]. Wei-Chun Hsu et al selected eight healthy male recreational runners to perform 40 min. treadmill running trials, one with compression garment (CG), and the other with control garment made of normal cloth. The rating of perceived exertion (RPE) and the surface EMG test of 5 lower extremity muscles including gluteus maximus (GM), rectus femoris (RF), semitendinosus (ST), tibialis anterior (TA), and gastrocnemius (GAS) were measured during the running trial. Participants wearing CG had lower muscle activation in GAS, ST, and RF muscles, despite no additional benefit to lactate clearance or RPE [9].

1.2. Detection and analysis of muscles activation

Electromyography is the subject which deals with the detection, analysis and utilization of electrical signals emanating from skeletal muscles. The electric signal produced during muscle activation, known as the myoelectric signal, is produced from small electrical currents generated by the exchange of ions across the muscle membranes and detected with the help of electrodes [10]. Many researchers have evaluated the effect of sports compression apparel using EMG, applied testing methods and mathematical modeling. However, there is a limited scientific work which has explored that wearing compression garments has a positive influence on muscle activation during running [11]. So that it was necessary in current study to discuss the enhancement of Medial Gastrocnemius (MG) and Soleus (S) muscles activation while wearing CB using eMotion wireless EMG system moreover describe muscle's performance of Flexor Carpi (FC) at different hand wrist actions.

2. EXPERIMENTAL WORK

A. Experimental Samples

Viscose/Polyamide bandages (VI-PA) and two types of Cotton CBs (as shown in “Fig. 1”) were used for hand and leg muscles testing respectively. The three bandages structures are plain weave. Yarn counts and densities are different depends on the construction and technology of the final product.
A) Bleached Cotton
Bandage
Warp set: 8 ends/cm
Weft set: 15 picks/cm
Warp count: 20x2 tex, 2x1200 turns/m, SS/Z, ZZ/S
Weft count: Cotton, 75 tex, OE.

B) Cotton/Polyamide/Polyurethane (CO-PA-PU)
Warp set: 11 ends/cm
Weft set: 18 picks/cm
Warp count: Cotton, 10x2 tex / Polyamide, 7.8 tex / Polyurethane, 42.5 tex
Weft count: Cotton, 36.9 tex

C) Viscose/Polyamide bandage (VI-PA)
Warp set: 12 ends/cm
Weft set: 14 picks/cm
Warp count: Viscose, 16.5 tex, open end (OE), Polyamide – 7.8 tex
Weft count: Viscose, 16.5 tex.

Fig. 1. Experimental Compression Bandages description.

B. Testing Methods

Viscose/Polyamide bandages were used to test the FC muscle voltage during different wrist actions (flexion-extension, squeezing a soft roll) with and without wearing CB (as shown in “Fig. 2”). VI-PA compression is adjusted and standardized to medium compression ranges 22±2 mmHg (through 70% bandage extension and 50% overlap). Bleached Cotton and CO-PA-PU bandages were used to test MG and SO muscles behavior during the standardized protocol actions (flexion-extension and while walking). The lower leg bandage pressure was adjusted to compression ranges 30±2 mmHg (by 100% bandage extension and 50% overlap) [12]. All these tests were carried out on 3 healthy men (age ranges 29–37 years) using eMotion wireless EMG system at different metronome beats (20, 30, and 40 beats/min). Surface electrodes were pasted on the mentioned muscles of the human skin as shown in “Fig. 2”, three trials for each activity [13]. In order to investigate the change of muscles activity, root mean square (RMS) is processed by exporting the filtered signals with band-pass filtering between 20–500 Hz using Matlab software.

Fig. 2. Emotion EMG system for Flexor Carpi, Medial Gastrocnemius and Soleus muscles [14], [15]

3. RESULTS AND DISCUSSION

“Fig. 3” illustrate the FC muscle voltage with and without wearing the VI-PA CB during the standardized action (flexion-extension), average muscle voltage was 85 and 93.33 µV respectively (i.e. wearing CB decreases muscle activation by a percent 8.92 % (as listed in Table I).

Fig. 3. Flexor Carpi muscle voltage with and without CB, (flexion-extension) action.

“Fig. 4” shows the FC muscle voltage with and without wearing the VI-PA CB during the action (squeezing a soft roll), the average EMG measured signal was 90.67 and 97.67 µV respectively (i.e. wearing CB enables lower muscle activation by a percent 7.17 %) as illustrated in (Table I). The obtained results in “Figs. 3 & 4” confirm that wearing CB enhances the Flexor Carpi Radials muscle performance while performing the
standardized activities. The frequency of flexion and extension are similar and therefore, the effect of CB focuses on a reduced muscle oscillation and improves muscle function and efficiency.

Fig. 4. Flexor Carpi muscle voltage with and without CB, (squeezing a soft roll) action.

3.1. EMG Test of Medial Gastrocnemius Muscle

Surface EMG signals were obtained from the MG and SO muscles by pre-amplified bipolar surface electrodes [16]. “Figs. 5 & 6” show MG muscle performance with and without wearing the CO-PA-PU CB during the standardized action (flexion-extension) and using the bleached Cotton bandage for walking action. Wearing CB enables a significant decrease in MG muscle activity during flexion-extension action by a percent 26.67% and 4.65% while walking (see Tables III and II respectively). This decrease may be due to the increase in the mean muscle fascicle length and the reduction in the mean muscle thickness and mean pennation angle [17]. Researchers have also claimed that muscle force being exerted for a limb's motion and stability may be wasted on muscle flexion-extension, while compression garment may prevent muscle vibrations during sports activities which can enhance athletic performance [11].

Fig. 5. MG muscle voltage with and without wearing CO-PA-PU bandage during (flexion-extension) action.

Fig. 6. MG muscle voltage with and without wearing bleached cotton bandage while walking action.

3.2. EMG Test of Soleus Muscle

“Figs. 7 & 8” show SO muscle behavior with and without wearing the CO-PA-PU and bleached Cotton CBs during the activities (flexion-extension and walking) respectively at same speed (using metronome beats 20, 30, and 40 beats/min). Wearing CB decreases SO muscle activity during flexion-extension action by a percent 21.88% and 34.13% while walking as summarized in (Tables III and II) respectively. These significant reductions in SO muscle activation clarify the enhancement of ankle muscle behavior wearing CB, because SO muscle is the main factor of controlling the walking performance while MG muscle is more effective for flexion-extension action.
3.3. EMG Mean Voltage for FC, MG, and SO Muscles

Emotion EMG system and Mega-win analysis were used to investigate the relationship between three types of CBs and muscles activation. EMG mean voltage for Flexor Carpi muscle (FC) during standardized activities (squeezing a soft roll and flexion-extension) are illustrated as shown in (Table I). Average FC muscle voltages with and without wearing the VI-PA CB were 90.67 and 97.67 μV respectively (i.e. wearing CB decreases muscle activation by a percent 7.17 % during squeezing a soft roll action). Moreover using CB decreases muscle activation by a percent 8.92 % during flexion-extension action.

| Case          | Metronome beats (BPM) | FC, squeezing soft roll action | FC, flexion-extension action |
|---------------|-----------------------|-------------------------------|------------------------------|
|               |                       | Mean voltage (µV)             | Standard deviation          | Mean voltage (µV) | Standard deviation |
| With bandage  | 20                    | 75                            | 101                         | 78               | 85                |
|               | 30                    | 81                            | 108                         | 84               | 86                |
|               | 40                    | 91.67                         | 111                         | 85               | 91.33             |
| Mean          |                       | 90.67                         | 111                         | 85               | 91.33             |
| Without bandage| 20                   | 76                            | 95                          | 81               | 93                |
|               | 30                    | 98                            | 121                         | 85               | 101               |
|               | 40                    | 119                           | 128                         | 114              | 134               |
| Mean          |                       | 97.67                         | 114.67                      | 93.33            | 109.33            |

EMG mean voltage for MG and SO muscles using the C-p-p and bleached cotton compression bandages during the standardized activities (flexion-extension and walking) at the same speed (using metronome beats 20, 30, and 40 beats/min) can be summarized and compared as listed below in (Tables II and III). Wearing bleached cotton CB while walking was associated with a decrease in average MG and SO muscles activation by a percent 2.91 and 18.18% respectively, whereas using C-p-p CB decreases MG and SO muscles activation by a percent 4.65 and 34.13% respectively. While wearing C-p-p CB during flexion-extension action decreases MG and SO muscles activation by a percent 26.67 and 21.88% respectively.

| Case          | Metronome beats (BPM) | Medial Gastrocnemius | Soleus Muscle |
|---------------|-----------------------|----------------------|---------------|
|               |                       | Mean voltage (µV)    | Standard deviation | Mean voltage (µV) | Standard deviation |
| With bandage  | 20                    | 76                   | 69              | 54              | 59                |
|               | 30                    | 80                   | 82              | 88              | 67                |
|               | 40                    | 110                  | 114             | 117             | 102               |
| Mean          |                       | 88.67                | 88.33           | 93              | 76                |
| Without bandage| 20                   | 77                   | 93              | 96              | 68                |
|               | 30                    | 94                   | 106             | 111             | 98                |
|               | 40                    | 103                  | 136             | 134             | 102               |
| Mean          |                       | 91.33                | 111.67          | 113.67          | 89.33             |
TABLE III
EMG MEAN VOLTAGE FOR LEG MUSCLES WHILE WALKING (BLEACHED COTTON BANDAGE)

| Activity Case       | Medial Gastrocnemius | Soleus Muscle |
|---------------------|-----------------------|---------------|
|                     | Mean voltage (µV)    | Standard deviation | Mean voltage (µV)    | Standard deviation |
| Flexion – extension | with bandage          | 22 ± 2        | 27 ± 5               | 32 ± 6              |
|                     | without               | 30 ± 6        | 32 ± 6               | 60 ± 7              |
| While walking       | with bandage          | 82 ± 7        | 83 ± 8               | 126 ± 11            |
|                     | without               | 86 ± 6        | 126 ± 11             | 112 ± 6             |

3.4. Data Analysis Using Matlab Software

The RMS value for each muscle’s activation is calculated using Matlab software to clarify and compare the differences between different standardized actions for hand and leg muscles as shown in (Tables IV to VI). RMS values of the FC muscle using the VI-PA bandage are illustrated in Table IV. Wearing VI-PA bandage was associated with lower muscle activation by a percent of 8.13 % for FC muscle during the standardized activity (squeezing a soft roll) and 7.10% during (flexion-extension action).

TABLE IV
RMS VALUES FOR FLEXOR CARPI MUSCLE SIGNALS

| Case       | Metronome beats (BPM) | FC, squeezing a soft roll | FC, flexion-extension |
|------------|-----------------------|---------------------------|-----------------------|
| With bandage | 20                   | 136.98                    | 132.36                |
|            | 30                   | 161.78                    | 147.70                |
|            | 40                   | 180.43                    | 164.72                |
|            | Mean                 | 159.73                    | 148.26                |
| Without bandage | 20                   | 132.10                    | 127.86                |
|            | 30                   | 189.11                    | 155.44                |
|            | 40                   | 200.40                    | 195.46                |
|            | Mean                 | 173.87                    | 159.59                |

Table V concludes the RMS values for the human leg muscles' signals using the bleached cotton bandage while walking. Wearing CB was associated with a reduction of muscle activation as assured by lower RMS values for MG and SO muscles as average value of the obtained results at metronome beats 20, 30, and 40 beats/min. Table VI summarizes the RMS values for the leg muscles signals using the CO-PA-PU bandage. Wearing C-p-p bandage decreases muscle activation as confirmed by lower RMS values by percentages of 21 and 13.42 % for MG and SO muscles respectively during flexion-extension action, and a percent reduction of RMS values as 6.03 and 22.31 % for MG and SO muscles while walking action. The enhancement of muscles’ performance wearing CB may be due to a small increase in intramuscular pressure and in conjunction with the proposed reduction in muscle vibration [18].

TABLE V
RMS VALUES FOR MG AND SO MUSCLES’ SIGNALS

| Case       | Metronome beats (BPM) | RMS value | RMS value   |
|------------|-----------------------|-----------|-------------|
| With bandage | 20                   | 147.85    | 145.81      |
|            | 30                   | 165.65    | 151.47      |
|            | 40                   | 183.88    | 237.15      |
|            | Mean                 | 165.79    | 178.14      |
| Without bandage | 20                   | 138.4     | 167.53      |
|            | 30                   | 181.33    | 205.74      |
|            | 40                   | 191.13    | 190.94      |
|            | Mean                 | 170.29    | 188.07      |

TABLE VI
RMS VALUES FOR MG AND SO MUSCLES’ SIGNALS WEARING (C-P-P BANDAGE)

| Activity Case       | RMS value | RMS value |
|---------------------|-----------|-----------|
| Flexion – extension | with bandage | 31.26 | 35.68 |
|                     | without   | 39.57 | 41.21 |
| While walking       | with bandage | 112.74 | 145.97 |
|                     | without   | 119.97 | 187.88 |

CONCLUSION

Using VI-PA CB reduced the average FC muscle activation by a percent 7.17 and 8.92 % during the standardized actions (squeezing a soft roll and flexion-extension) respectively. Wearing bleached Cotton CB enabled lower muscle activation and higher median frequency for MG and SO muscles by a percent of 4.65 and 34.13 % during walking action. Using CO-PA-PU CB was associated with significantly reduction of MG and SO muscles activation by a percent 26.67 and 21.88 % during flexion-extension action. The obtained RMS values
using Matlab software confirmed that wearing CB improved the performance of FC, MG, and SO muscles and could enhance muscles fatigue.

ACKNOWLEDGMENT
I wish to acknowledge assistance and encouragement of my colleagues (Sinem Kahveci and Shahrukh Shahbaz); specially during testing of my samples. This work is supported under Student Grant Scheme (SGS 21249) by Technical University of Liberec, Czech Republic.

REFERENCES
[1] W. Ping, L. Lei, Y. Mao-de, et al., “Effects of compression garments on lower limb muscle activation via electromyography analysis during running”, Journal of Donghua University, vol. 32, no.1, pp. 48-52, 2015
[2] N. Mityamoto, K. Hirata, N. Mitsukawa, et al., “Effect of pressure intensity of graduated elastic compression stocking on muscle fatigue following calf-raise exercise”, Journal of Electromyography and Kinesiology, vol. 21, pp. 249–254, 2011
[3] K. Goto, S. Mizuno, A. Mori, “Efficacy of wearing compression garments during post-exercise period after two repeated bouts of strenuous exercise: a randomized crossover design in healthy, active males. Sports Medicine, 2017.
[4] Martorelli S., Martorelli A., Pereira M., et al.: Graduated compression sleeves: effects on metabolic removal and neuromuscular performance. Journal of Strength and Conditioning Research 2015, vol. 29, 5.
[5] Jariyapunya N., Musslová B., Geršak J., et al.: The Influence of stretch fabric mechanical properties on clothing pressure. Vlákna a textil (Fibres and Textiles) 2017, Vol. 24, Issue 2, pp. 43-48.
[6] Fu W, Liu Y, Fang Y. (2013). Research advancements in humanoid compression garments in sports. International Journal of Advanced Robotic Systems. Volume 10(66), pp. 1-6. Available: www.intechopen.com
[7] Khaburi J., Dehghani-Sanij A.: The Effect of multi-layer bandage on the interface pressure applied by CBs. International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering 2017, 5, pp.1169-1174.
[8] Rimaud D., Convert R., Calmels P.: In vivo measurement of CB interface pressures: The first study. Annals of Physical and Rehabilitation Medicine 2014. Doi: 10.1016/j.rehab.2014.06.005
[9] Hsu W., Tseng L., Chen F., et al.: Effects of compression garments on surface EMG and physiological responses during and after distance running. Journal of Sport and Health Science 2017. Doi:10.1016/j.jshs.2017.01.001.
[10] Jamal M. (Intech 2012). Signal acquisition using surface emg and circuit design considerations for robotic prosthesis [Online]. Available: http://dx.doi.org/10.5772/52556.
[11] P. Wang, J. McLaren, K. F. Leong, et al., “A Pilot study: evaluations of compression garment performance via muscle activation test”. Procedia Engineering 2013, 60, pp. 361-366.
[12] A. Aboulasaid, K. Broadin, “Analysis and prediction of CBs tension,” in Conf. CEI, 2017. International Ph.D. Students Day, pp. 6-9.
[13] C. Gatti, J. C. Case, J. Langenderfer. (2008 February). Evaluation of three methods for determining EMG-muscle force parameter estimates for the shoulder muscles. Clin Biomech (Bristol, Avon). Volume 23(2), pp. 166–174.
[14] Gvs14. (Sep. 2012). Anterior Forearm Muscles [Online]. Available: https://anatomystudybuddy.wordpress.com/2012/09/20/flexor-carpi-radialis/
[15] Luqmam (May 02, 2017). Pearson Benjamin Cummings [Online]. Available: https://humananatomyly.com/gastrocnemius-muscle/
[16] Sell K., Ghigiarelli J., Kitsos J., et al.: Electromyographic analysis of abdominal and lower back muscle activation during abdominal exercises using an objective biofeedback device. JEJ online 2011, 14(5), pp. 54-65.
[17] James M. W., Meghan J. and Ana I. N.: The Effect of external compression on the mechanics of muscle contraction. Journal of Applied Biomechanics 2013 vol. 29, pp. 360-364
[18] R. Duffield, J. Cannon, M. King, “The effects of compression garments on recovery of muscle performance following high-intensity sprint and plyometric exercise”, Journal of Science and Medicine in Sport, pp. 136-140, 2010.