EMG in People with Different Heel Height Condition

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1. Introduction

It has been reported that a prevalence proportion of foot problems in women were associated with wearing high-heeled shoes [1]. Women's walking pattern and the biomechanical behavior of the foot could be altered significantly by raising the heel height [2, 3]. Biomechanical studies showed that walking in high-heeled shoes may alter lower-extremity joint function [4], raise the peak pressure in the forefoot [5], and alter the load distribution on the media foot region [6]. Some of these biomechanical changes can be detrimental to the foot structure, such as increasing the metabolic cost of gait, accelerate on of muscle fatigue [7], high inner stress level of metatarsal bones [8]. In Latin dancing, partners perform tightly choreographed routines in which they must project energy and passion. The pair's appearance, including costuming and shoes, is important to the success of the routine. A detailed biomechanical study of different types of human movement such as walking, dancing, etc. would help to improve the understanding of the biomechanics and provide important data for design optimization to reduce the adverse effects associated with high heeled shoes.

The detailed diagnosis and correction of pathologic states of human mobility is mainly limited by an incomplete knowledge of the musculoskeletal system and the detailed and quantitative description of the activity of the individual muscles in the synergistic patterns which combine to produce different human movement. Commonly used techniques which employ myolectric, force plate and kinematic gait pattern acquisition only provide a representation of the external manifestations of the underlying muscle physiology. At present, there is no exist research equipment to study the actions of the involved muscles non-invasively. A model of the musculoskeletal system could, in principle, given kinematic data and with assumptions to mitigate muscle redundancy, predict individual muscle behavior. Surface electromyography (SEMG), has been used in both research and clinical applications for non-invasive neuromuscular assessment in several different fields such as sport science, neurophysiology and rehabilitation. Different variables, related to different aims, can be monitored: muscle activation intervals are useful to evaluate motor coordination and treatment efficacy [9]; myoelectrical manifestations of fatigue [10] can be used to assess EMG signal modifications in pathologies such as exercise [11], back pain [12] and neurological diseases [13]. Previous EMG study in high heel gait found out the low back EMG increased significantly while walking with high-heeled shoes, which successfully explained the reason why high heel wearers always complained of lumber back pain [14]. But there is very limited study of the high-heeled state of muscle activity in a high intensity movement such as dancing. Female dancers have to wear high-heeled shoes during routine exercise and competitions, while passively raised heel could greatly increased the foot injury probability [5]. The objective of this study is to investigate the lower limb muscles' surface SEMG activity during Latin dancing with different heel height shoes.

2. Methods

The study involved 10 professional female dancers to participate in the biomechanical tests and data collection. The mean age of the subjects was 22.8years (S.D. 2.3 years), the mean weight of the subjects was 49.5kg (S.D. 5.2 kg), and the mean height of the subject was 163.6cm (S.D. 2.5 cm). Each participant has more than five years' dancing history. The subjects' feet/lower limb was clinically checked to ensure that there was no recent injury phenomenon or medical conditions that may affect their performances. The shoes used in this study have a similar structure apart from the heel height. Typical dancing conditions included four shoes with a heel height of 1.0cm, 4.5cm, 7.5cm and 10cm, designated as flat, low heel, medium high heel and high heel shoes, respectively.

Fig. 1. The structure of typical dancing shoes.

Typical dancing shoes are made of leather, women's Latin dance shoes are lightweight, flexible and have suede soles, which provide the right blend of grip and slide while moving across the floor (Fig.1). In the study, shoes of different heel heights (1.0cm, 4.5cm, 7.5cm and 10cm) were randomly assigned to the participants. Each participant walked 5 minutes before the test in order to habituate to each heel height shoes, and took a 20-min rest in-between dance to prevent body fatigue. All the subjects were required to perform a similar warm up exercise before the test, and the Latin basic motion *visk* step (basic crossing step, Fig.2) was selected as experiment motion, concomitance with the dancing music.

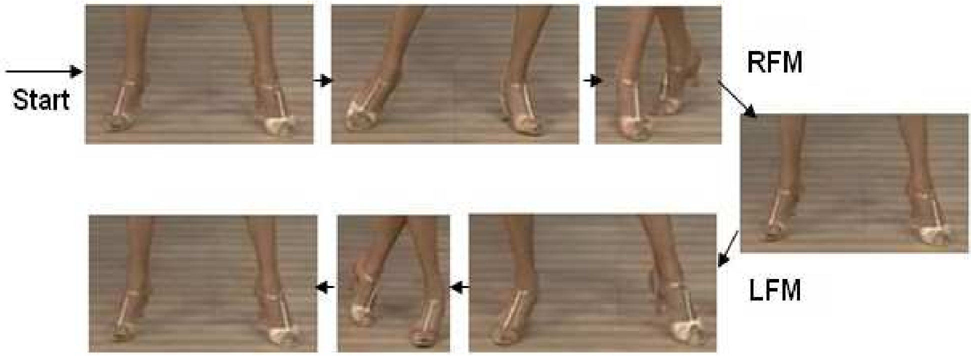

Fig. 2. Illustration of *visk* (crossing) step in the latin dancing: RFM (right foot move); LFM (left foot move).

SEMG activities of the tibialis anterior (TA), medial and lateral sides of gastrocnemius (MG and LG), soleus (SO) and biceps femoris (BF) were obtained using self-adhesive pairs of disposable Ag/AgCl surface electrode pairs with an electrode diameter of 10mm and an inter-electrode spacing of 20mm. Low impedance at the skin-electrode interface was obtained by skin preparation procedure of shaving, light abrasion and cleaning. For electrode placement, the SENIAM [15] recommendations for SEMG were followed (Fig.3). Furthermore, the electrode placement was confirmed by palpations of muscle bulk during brief maximal isometric contraction. The raw SEMG signal was recorded at the sampling rate of 1000Hz using a device (ME6000, Mega Electronics, Finland). The average EMG (aEMG) for the five muscles were calculated which using the rectified signal with a 512ms window, and used for further analysis.

Statistical data analysis was conducted with the statistical software package SPSS (version 13.0). Analysis of variance was employed to study the effects of heel height, and Turkey's HSD test was used for post hoc comparison. The level of significance was set at the 5% level.

3. Results

Fig.4 illustrated the comparison of aEMG data in five lower limb muscles during dancing under different heel height. It was clearly shown that all the muscles aEMG values except BF were significantly increased in heightened heel shoes comparing to wearing the flat heel height dancing ($p<0.05$). The largest increasing value of aEMG between flat and low heel height was appeared in LG, which was up to 36%. Differences were not found in LG, MG and SO among low, medium and high heel height.

Meanwhile, it was interesting to find that the aEMG value was quite close between the low and medium heel height in LG. Also, in BF the muscle activity was not changed a lot between the medium and high heel height. Although the mean value of aEMG data increased from low to high heel height, the significant difference only appeared at TA in which the high heel height was larger than the value in both low and medium heel height.

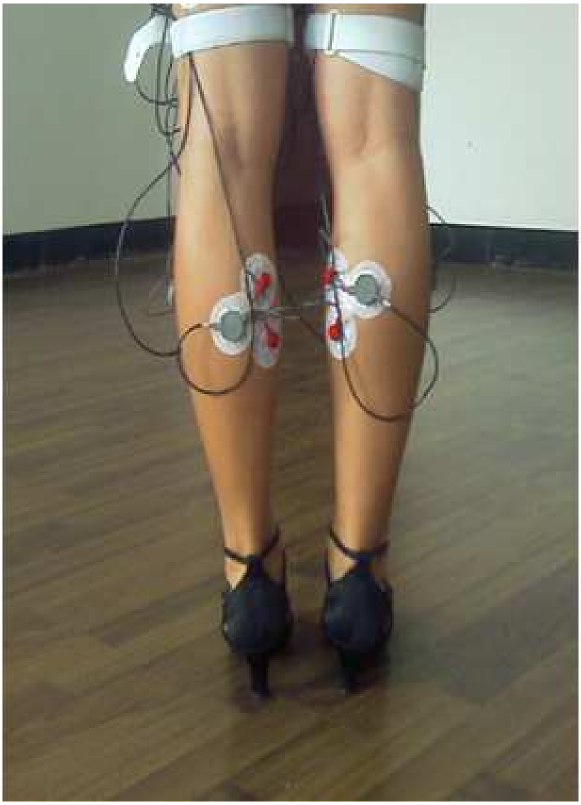

Fig. 3. Electrode placement methods.

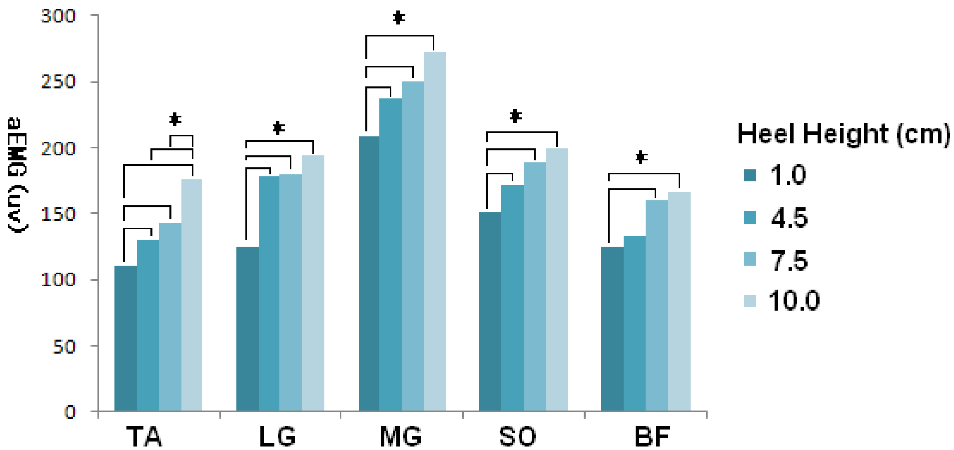

Fig. 4. Comparison of aEMG data in five muscles of lower limb during different heel heights dancing (Significant change *p<0.05).

Another interesting finding in these dancing testing subjects, in which 70% are found have a certain extent deformation in the first metatarsal-phalangeal joint (Fig.5, should to further think about the muscles activity to cause joint deformation.

Fig. 5. The certain extent deformation in the first metatarsal-phalangeal joint of the testing subject.

4. Discussion

The results of this study showed that increasing heel height caused increases in SEMG activity in lower limb muscles during dancing. Although previous studies in high heel gait reported similar trend [16, 17], to the authors' knowledge, no studies of heeled dancing movement have evaluated at lower limb muscles activity. It's interesting to find the SEMG activity of the TA was seemed as the most vulnerable part to the heel height increasing. While the heel height increased to 10cm, the aEMG data of TA significantly higher than both 4.5cm and 7.5cm heel height. Due to the function of TA was to adjust dorsiflexion of the foot, acting as a stabilizer of the ankle, this implies that dancing with high heel shoes would consume more energy to control the balance. The trend of activity of LG increased more versus that of MG in heel height increased from flat to low. This different response of the two sides of the gastrocnemius under different heel height was close to one other study conducted by Gefen et al. [18]. The increased muscle acitivity would apparently cause higher loads on the shoe's front part and accelerate its damage or worn out that correlates well with failure analysis of dancing shoes after a long time of training (Fig. 6).

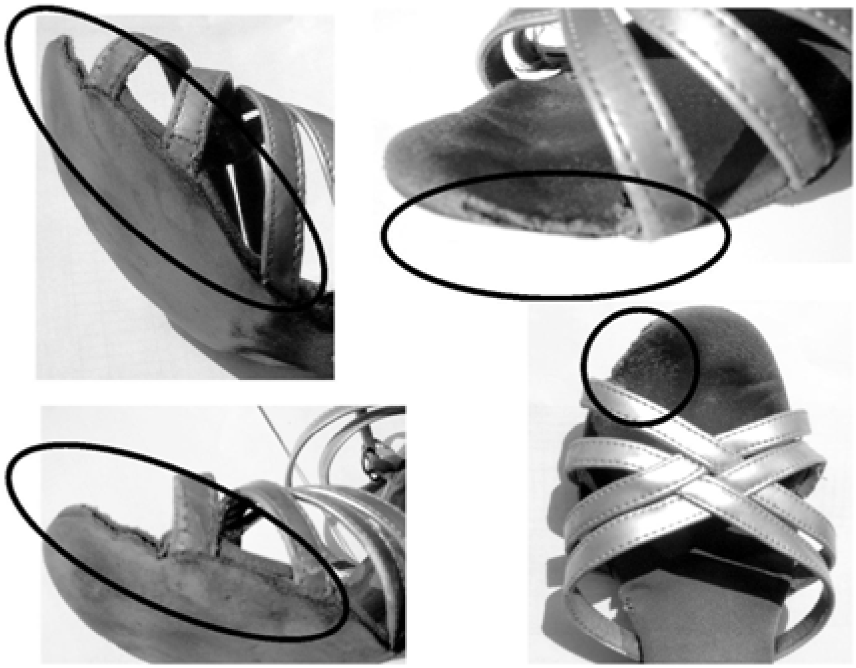

Fig. 6. Damage part in shoe's front part after a long time of training.

There are limitations to the current study, which could be developed further. The lack of kinematic and kinetic data means that confounding variables may be present. In addition, all participants who took part in this study were experienced high heel wearers. Muscle response to heel height may difference between regular and non-regular wearers of high-heeled shoes.

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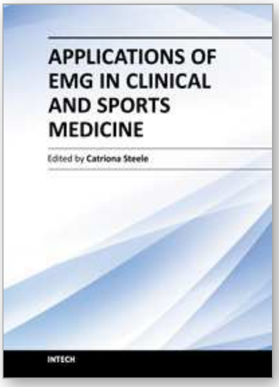

Applications of EMG in Clinical and Sports Medicine
Edited by Dr. Catriona Steele

ISBN 978-953-307-798-7
Hard cover, 396 pages
Publisher InTech
Published online 11, January, 2012
Published in print edition January, 2012

This second of two volumes on EMG (Electromyography) covers a wide range of clinical applications, as a complement to the methods discussed in volume 1. Topics range from gait and vibration analysis, through posture and falls prevention, to biofeedback in the treatment of neurologic swallowing impairment. The volume includes sections on back care, sports and performance medicine, gynecology/urology and orofacial function. Authors describe the procedures for their experimental studies with detailed and clear illustrations and references to the literature. The limitations of SEMG measures and methods for careful analysis are discussed. This broad compilation of articles discussing the use of EMG in both clinical and research applications demonstrates the utility of the method as a tool in a wide variety of disciplines and clinical fields.