Journal of Biomechanics 46 (2013) 1088–1091

Contents lists available at SciVerse ScienceDirect

Journal of Biomechanics

journal homepage: www.elsevier.com/locate/jbiomech
www.JBiomech.com

Myoelectric stimulation on peroneal muscles with electrodes of the muscle belly size attached to the upper shank gives the best effect in resisting simulated ankle sprain motion

Daniel Tik-Pui Fong [a,b,*], Dan Wang [a], Vikki Wing-Shan Chu [a], Kai-Ming Chan [a,b]

[a] Department of Orthopaedics and Traumatology, Prince of Wales Hospital, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong, China
[b] The Hong Kong Jockey Club Sports Medicine and Health Sciences Centre, Faculty of Medicine, The Chinese University of Hong Kong, Hong Kong, China

ARTICLE INFO

Article history:
Accepted 20 January 2013

Keywords:
Biomechanics
Injury prevention
Prophylactic device
Biomedical engineering

ABSTRACT

Ankle sprain is a common sports related injury that may be caused by incorrect positioning of the foot prior to and at initial contact during landing from a jump or gait. Furthermore a delayed reaction of the peroneal muscle may also contribute to the injury mechanism. A recent study demonstrated that myoelectric stimulation of the peroneal muscles within 15 ms of a simulated inversion event would significantly resist an ankle spraining motion. This study further investigated its effect with three different electrode sizes and three different lateral shank attachment positions. Twelve male subjects with healthy ankles performed simulated ankle supination spraining motion on a pair of mechanical sprain simulators. A pair of electrodes of one of the three sizes (large, medium, small) was attached to one of the three positions (upper 1/4, middle, lower 1/4) along the lateral shank to deliver an electrical signal of 130 V for 0.5 s when the sprain simulator started. Ankle kinematics data were collected by a tri-axial gyroscope motion sensor and the peak inward heel tilting velocity was obtained to represent the effect in resisting the simulated ankle spraining motion. Repeated measures one-way analysis of variance was performed and showed a significant drop from 273.3 (control, no stimulation) to 215.8 deg/s (21%) when small electrodes were attached to the upper 1/4 position. Decrease was found in all other conditions but the drops (11–18%) were not statistically significant. The small electrodes used in this study fitted the width of the peroneal muscle belly at the upper 1/4 position, so the electrical current may have well flowed to the motor points of the muscles to initiate quick contraction.

1. Introduction

Ankle sprain is a common sports related injury that may be caused by incorrect positioning of the foot prior to and at initial contact during landing from a jump or gait. Furthermore a delayed reaction of the peroneal muscle may also contribute to the injury mechanism. (Fong et al., 2007, 2009). Recently, an intelligent sport shoe has been designed to prevent the injury by stimulating the peroneal muscles through the use of an external myoelectric stimulation to initial an antagonist muscular response to resist sudden ankle spraining motion (Fong et al., 2012). The design contains three parts: (1) sensing: a motion sensor attached to the heel to monitor the ankle motion. (2) Identification: when the ankle motion exceeds a threshold, the device actuates the correction. (3) Correction: myoelectric stimulation is delivered by a pair of electrodes to the peroneal muscle to initiate quick contraction. The first two steps have already been reported. Chan et al. (2010) demonstrated a method with one motion sensor at the calcaneus to identify 300 simulated sprain injury motions and 300 normal common sporting motions with an accuracy of 91.3%, while Chu et al. (2010) suggested an ankle inversion velocity of 300 deg/s to be the threshold for identifying hazardous ankle spraining motion after investigating such between simulated sprain injury motions and various common sporting motions.

For the correction, Fong (2012) reported that a myoelectric stimulation on the peroneal muscles within 15 ms would significantly resist a simulated ankle sprain injury motion. The method utilized a pair of electrodes of size 37 cm^2 attached on the upper shank. The effect of electrode size and stimulation position has not been investigated in Fong's study. Many studies reported the important of electrode size and stimulation position in neuromuscular electrical stimulation. For example, Alon et al. (1994) pointed out that the electrode size will affect stimulation efficiency. Excessively large electrodes are likely to decrease stimulation efficiency by wasting energy to stimulate undesired muscle groups. Moreover, larger electrodes cost more. Stimulation position is also a critical

* Corresponding author at: The Chinese University of Hong Kong, Department of Orthopaedics and Traumatology, Prince of Wales Hospital, Faculty of Medicine, Hong Kong , Hong Kong, China. Tel.: +852 2632 3535; fax: +852 2646 3020.
E-mail address: dfong@ort.cuhk.edu.hk (D.-P. Fong).

0021-9290/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jbiomech.2013.01.019

issue. Proper electrode positioning is necessary to maximize generated force and minimize discomfort (Gobbo et al., 2011).

This study investigated the effect of myoelectric stimulation on peroneal muscles with electrodes of three different sizes attached at three different lateral shank positions in resisting simulated ankle sprain motion.

2. Methods

2.1. Chose of electrode position

Peroneus muscle includes a group of three muscles, namely, peronues longus (PL), peroneus brevis (PB) and peroneus tertius (PT). PL has been well known as an ankle evertor, however, some studies reported that PB is a more effective evertor than PL (Otis et al., 2004; Pintore et al., 2001). Witvrouw et al. (2006) suggested the majority of the isokinetically measured eversion and dorsiflection strength of ankle is produced by PL, PB and tibialis anterior rather than PT. Moreover PT has a relatively small muscle belly width (average 9.1 mm) and may be absent in some persons (Sarrafian, 1993). Therefore, this study focused on PL and PB only. According to SENIAM recommendations, stimulating electrodes should be placed along a reference line between the tip of the head of the fibula to the tip of the lateral malleolus (Fig. 1a). Further, the location of the electrodes should be at 25% (upper 1/4 position) and 75% (lower 1/4 position) of the distance between these proximal and distal landmarks for the PL and PB, respectively. Lee et al. (2011) reported that the dense area of motor points of PL and PB was between 20–40% and 40–60% of the reference line, respectively. In order to test whether stimulation of both PL and PB is possible, the mid-point of the reference line (middle position) was chosen for stimulation also.

2.2. Chose of electrode size

The size of the electrodes used by Forrester and Petrofsky (2004) was 37 cm^2, however, such a large size may have stimulated other neighboring, but unwanted muscles. A smaller electrode size was chosen based on a cadaveric dissection. A cadaveric shank from a deceased 87-year-old Caucasian male was dissected to expose the peroneal muscles. The muscle belly was located at the upper 1/4 position and measured 4 cm (Fig. 1c), while the peroneal tendons were located at the middle and the lower 1/4 positions (Fig. 1b). This muscle belly width defined the diameter of the small circular electrode. We have tried to further reduce the electrode size by decreasing the diameter to 3 cm, however, the subject reported intolerable discomfort and pain and we could not proceed with the test. We also believe that any size smaller than the muscle belly width would give another practical problem to precisely locating the electrodes on the right position. Therefore, we suggested that 12.6 cm^2 size electrode should be the smallest electrode tested. One more size, the medium (18.5 cm^2), in between the largest and smallest size were also tested (Fig. 2).

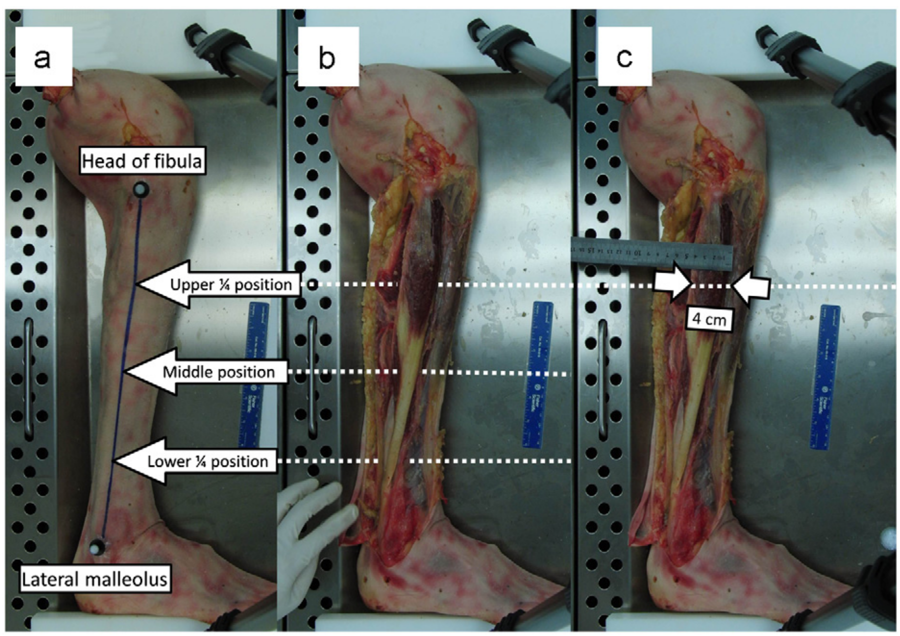

Fig. 1. (a) The upper 1/4, middle and lower 1/4 positions for electrode attachment in this study; (b) direct observation of the peroneal muscles showed that muscles fibers are mainly at the upper 1/4 position, while the tendons are at middle and lower 1/4 positions; (c) the widest width of the peroneal muscles measured 4 cm at upper 1/4 position.

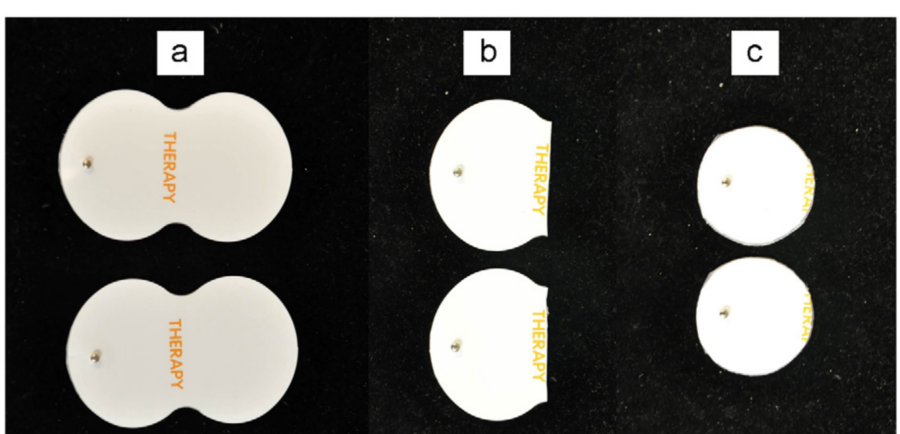

Fig. 2. Electrodes of different sizes used in this study: (a) large size, 37 cm^2; (b) medium size, 18.5 cm^2; (c) small size, 12.6 cm^2.