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The effect of calf neuromuscular electrical stimulation and intermittent pneumatic compression on thigh microcirculation

Shayan Bahadori *, Tikki Immins, Thomas W. Wainwright

Orthopaedic Research Institute, Bournemouth University, 6th Floor Executive Business Centre, 89 Holdenhurst Road, Bournemouth BH8 8EB, UK

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ABSTRACT

Objective: This study compares the effectiveness of a neuromuscular electrical stimulation (NMES) device and an intermittent pneumatic compression (IPC) device on enhancing microcirculatory blood flow in the thigh of healthy individuals, when stimulation is carried out peripherally at the calf.

Materials and methods: Blood microcirculation of ten healthy individuals was recorded using laser speckle contrast imaging (LSCI) technique. A region of interest (ROI) was marked on each participant thigh. The mean flux within the ROI was calculated at four states: rest, NMES device with visible muscle actuation (VMA), NMES device with no visible muscle actuation (NVMA) and IPC device.

Results: Both NMES and IPC devices increased blood flow in the thigh when stimulation was carried out peripherally at the calf. The NMES device increased mean blood perfusion from baseline by 399.8% at the VMA state and 150.6% at the NVMA state, IPC device increased the mean blood perfusion by 117.3% from baseline.

Conclusion: The NMES device at VMA state increased microcirculation by more than a factor of 3 in contrast to the IPC device. Even at the NVMA state, the NMES device increased blood flow by 23% more than the IPC device. Given the association between increased microcirculation and reduced oedema, NMES may be a more effective modality than IPC at reducing oedema, therefore further research is needed to explore this.

1. Introduction

Neuromuscular electrical stimulation (NMES) devices and intermittent pneumatic compression (IPC) devices have been shown to be effective in improving blood flow (Tucker et al., 2010, Currier et al., 1986, Kaplan et al., 2002). They are often used post-surgery to prevent deep vein thrombosis (DVT) (Goldhaber and Morrison, 2002), in procedures such as total hip replacement (Doran and White, 1976); and have been found to reduce oedema in the thigh of total hip replacement patients post-surgery (Faghri et al., 1997).

The geko™ is an NMES device (Firstkind Ltd., High Wycombe, UK. http://www.gekodevices.com/en-uk/) and the VenaPro an IPC system (DJO Global, Centerville, US. http://www.djoglobal.com/products/venaflow/venapro). Both are used to increase blood flow circulation. The geko™ is a small, self-adhesive, disposable device, which is battery-powered and applied posterior to the fibula head over the common peroneal nerve. It has seven stimulation modes and a frequency rate of 1 Hz, with a maximum charge of 20 μC per pulse. The VenaPro consists of a calf cuff that holds an electronically controlled pump. This pump delivers air to the calf cuff, applying 50 mm Hg once per minute, so that the calf experiences graduated and asymmetric compression. It is rechargeable and designed for single patient use (Summers et al., 2015).

A previous study on the geko™ device found that it performed better in increasing both venous and arterial blood flow by around 30%, when compared to two IPC devices (Jawad et al., 2014), without the discomfort which can be associated with traditional NMES technology.

Laser speckle contrast imaging (LSCI) (moorFLPI Full-Field, Devon, United Kingdom) has become an increasingly popular equipment for measuring microcirculatory blood flow (Draijer et al., 2009; Wu et al., 2015) as it offers a high spatial and temporal resolution (Roustit and Cracowski, 2013). Using LSCI, this study compares the effectiveness of an NMES device and an IPC device on enhancing microcirculatory blood flow in the thigh of healthy individuals, when stimulation is carried out peripherally at the calf.

2. Materials and methods

2.1. Study population

Ten healthy participants consented to take part in the study. Participants were excluded from taking part if they had taken low-molecular-

Abbreviations: ARTm, artefact movement; AOS, adhesive opaque surfaces; BMI, body mass index; CBF, cutaneous blood flow; DVT, deep vein thrombosis; IFU, indication for use; IPC, intermittent pneumatic compression; LMWH, low-molecular-weight heparin; LSCI, laser speckle contrast imaging; $LS_{(SK)}$, laser speckle skin signal; LSPU, laser speckle perfusion unit; NMES, neuromuscular electrical stimulation; NVMA, no visible muscle activation; ROI, region of interest; VMA, visible muscle activation.

* Corresponding author.
E-mail addresses: sbahadori@bournemouth.ac.uk (S. Bahadori), timmins@bournemouth.ac.uk (T. Immins), twainwright@bournemouth.ac.uk (T.W. Wainwright).

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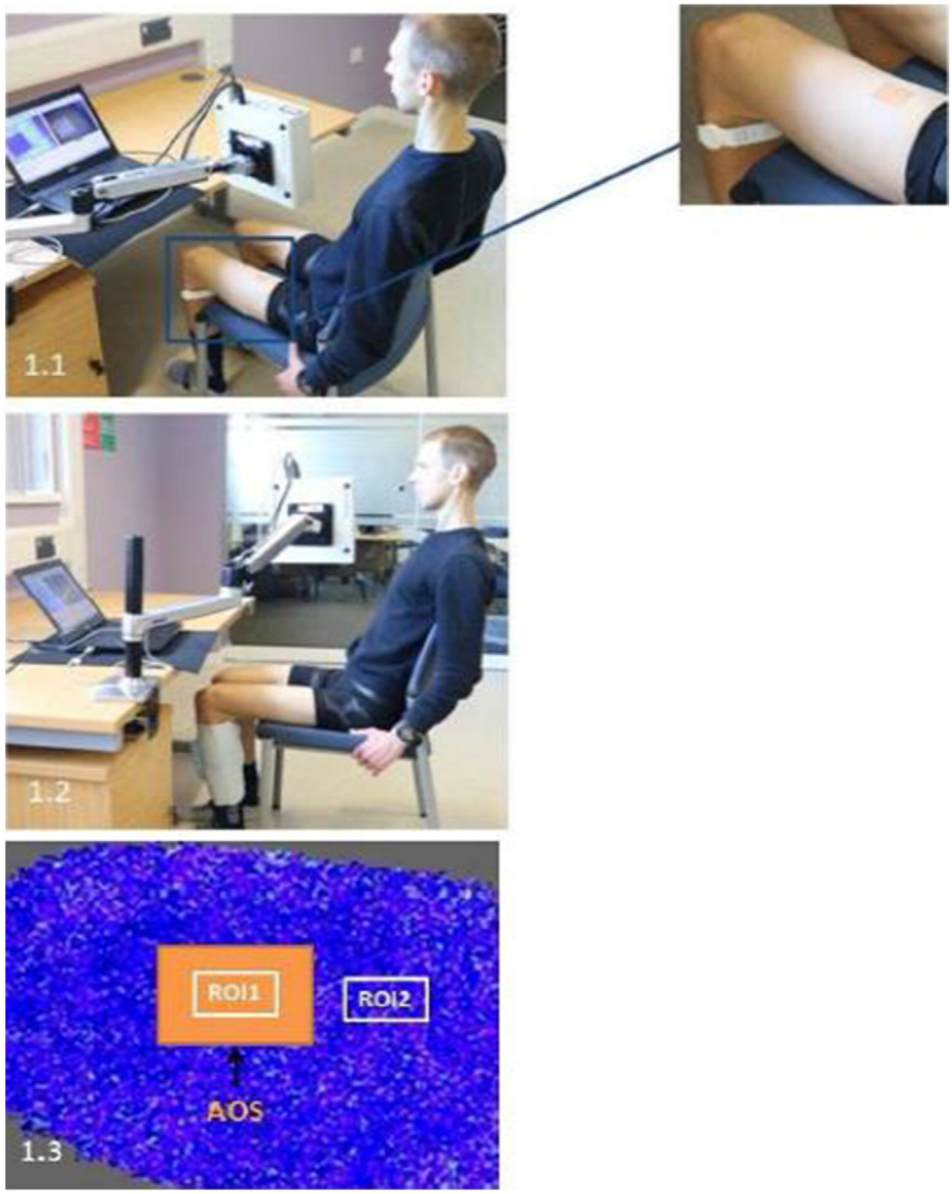

Fig. 1. Set up of LSCI for analysis of effects of NMES and IPC devices on an area of the anterior thigh. 1.1) NMES device placed just below the level of the knee simulating the common peroneal nerve behind the knee, which in turn, activates the calf and foot muscle pumps of the lower leg. 1.2) IPC cuff wrapped around the calf and secured using the Velcro. Wrap was secure, but not restrictively tight. 1.3) LSCI image recorded with graphical representation of the ROI 1, ROI 2 and AOS on an area of the thigh.

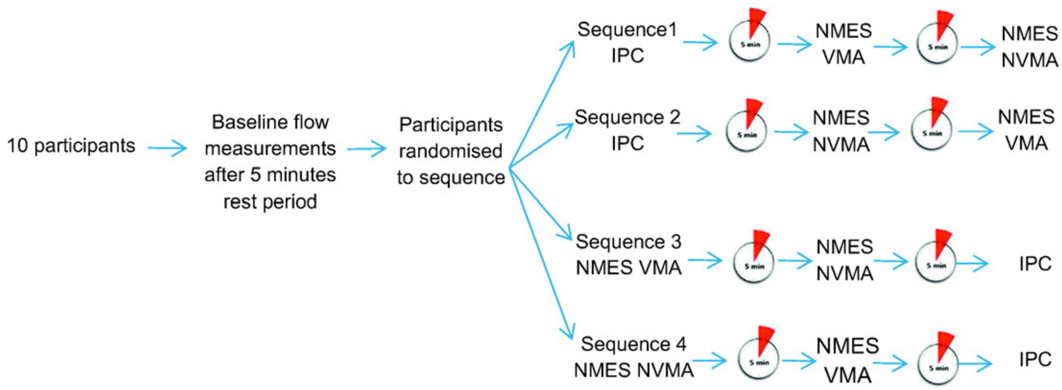

Fig. 2. Sequences of assessment using Sealed Envelope Randomization method with 5 min washout in between each test.