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WHY IS IT CRUCIAL TO USE PERSONALIZED OCCLUSION PRESSURES IN BLOOD FLOW RESTRICTION (BFR) REHABILITATION?

J.A. McEwen OC PhD PEng[1,2], J. Jeyasurya MASc PEng[2], J. Owens MPT[3,4]
[1]*Department of Orthopaedics and Electrical and Computer Engineering, University of British Columbia, Vancouver BC, Canada*
[2]*Western Clinical Engineering Ltd., Vancouver BC, Canada*
[3]*Owens Recovery Science, San Antonio Texas, USA*
[4]*San Antonio Military Medical Center, San Antonio Texas, USA*

INTRODUCTION

Blood Flow Restriction (BFR) applied to a limb during low intensity exercise has been shown to increase muscle size and strength across different age groups. However, a review of BFR rehabilitation literature shows that inconsistencies exist in methodology, equipment and in levels of restriction pressure used. For example Jessee et al. [1] summarized fifteen recently published BFR studies in the upper body and cuff pressures ranged widely. Some studies used a pressure applied with a tourniquet cuff at a level set as a percentage of personalized Limb Occlusion Pressure (LOP), other studies used a fixed cuff pressure applied with cuffs having a variety of sizes and shapes, and a few studies set pressure based on systolic blood pressure using old formulas that have been proven inaccurate, unreliable and largely discontinued in surgical tourniquet settings [2-4]. These inconsistencies in methodology and equipment have made it difficult to apply a safe and consistent BFR stimulus to patients, they prevent a controlled comparison of different BFR protocols, and thus they limit the identification and delivery of optimal patient outcomes.

This paper explains why it is crucial to use surgical-grade tourniquet technology with automatic LOP measurement capability, adapted to incorporate and deliver optimal protocols, for safe and effective application of BFR to consistently achieve optimal patient outcomes in rehabilitation.

LIMB OCCLUSION PRESSURE (LOP)

To overcome the above described inconsistencies, many studies [1-3,5] have recommended the use of personalized pressures based on LOP for BFR rehabilitation. LOP can be defined as the minimum pressure required, at a specific time in a specific tourniquet cuff applied to a specific patient's limb at a specific location, to stop the flow of arterial blood into the limb distal to the cuff. LOP is affected by variables including the patient's limb characteristics; characteristics of the selected tourniquet cuff, including shape, width, length, presence or absence of circumferential bladder and internal stiffener; the technique of application of the cuff to the limb; physiologic characteristics of the patient including blood pressure and limb temperature; and other clinical factors (for example, the extent of any elevation of the limb during LOP measurement and the extent of any limb movement during measurement) [4].

THE NEED FOR PERSONALIZED PRESSURES

A restriction pressure level set for each individual patient, based on a percentage of LOP measured at rest, and applied using a surgical-grade tourniquet cuff, enables those individual patients to receive a consistent BFR stimulus compared to other methods of setting the restriction pressure level [3]. Loenneke et al. [2,3] demonstrated that setting BFR pressure as a function of blood pressure or at a fixed pressure does not provide a consistent stimulus across patients because these

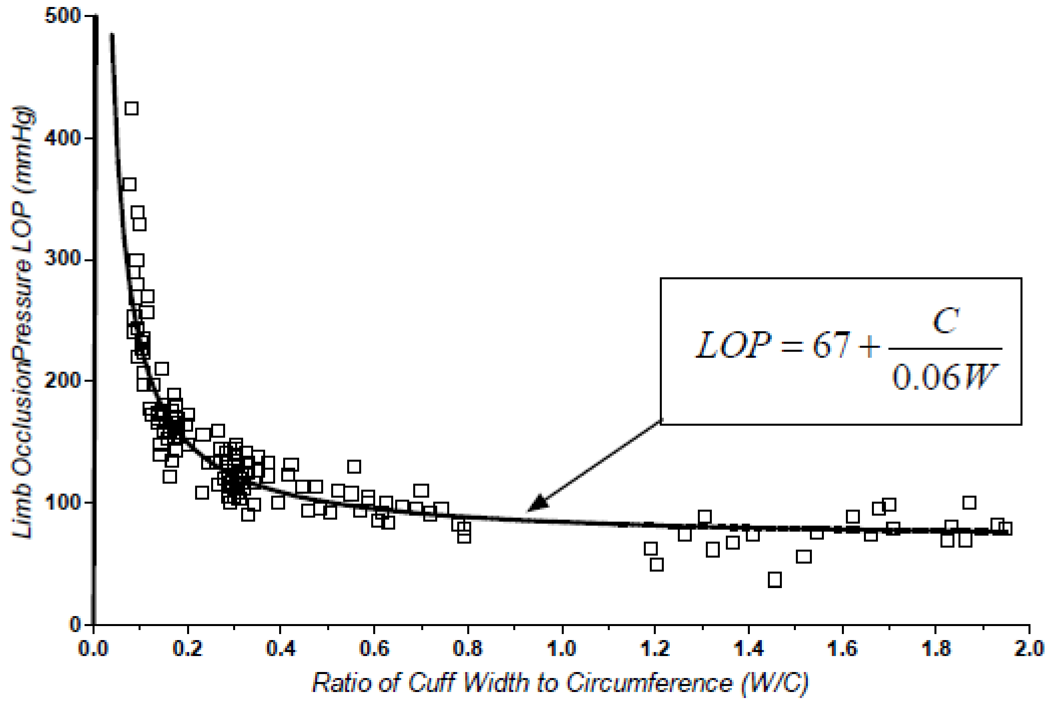

Figure 1: Limb Occlusion Pressure (LOP) versus the ratio of tourniquet cuff width to limb circumference. For any given limb circumference, the tourniquet pressure required to stop arterial bloodflow decreases as the width of the tourniquet cuff increases. Adapted from Graham et al. [10].

methods of setting pressure neglect important factors that affect LOP, including limb circumference and cuff width, Figure 1. This confirms what has been well established in the surgical tourniquet literature on LOP [4]. Fatela et al. [5] analyzed the effect of relative BFR pressure on the acute neuromuscular response to BFR resistance exercise and showed that muscular activation and neuromuscular fatigue varies as a function of relative blood flow restriction. Consequently, Fatela et al. [5] concluded that it is crucial to determine individual levels of vascular restriction, by quantifying the resting LOP, before engaging in BFR exercise and rehabilitation.

BENEFITS OF PERSONALIZED PRESSURES

There are three primary benefits of using personalized pressures based on a relative percentage of LOP, determined automatically on a resting patient by a surgical-grade tourniquet instrument, and applied safely and consistently by a surgical-grade tourniquet cuff, Figure 2. First, the use of such tourniquet instruments and cuffs are based on decades of experience in surgical settings, and assures the safe, accurate, and reliable application of pressure to a patient's limb [4]. Setting and regulating the pressure as a predetermined percentage of the LOP can help avoid adverse events that may result from inadvertently applying pressures that result in complete arterial occlusion [1]. Second, the application of a consistent level of restriction pressure limits variability in BFR intensity for individual patients, since muscular activation, as well as neuromuscular fatigue, varies as a function of relative BFR intensity [5]. Third, accurately applying a consistent level of restriction pressure enables the outcomes and results of a full range of BFR studies to be compared on a meaningful basis so that optimal protocols can be identified and applied [6].

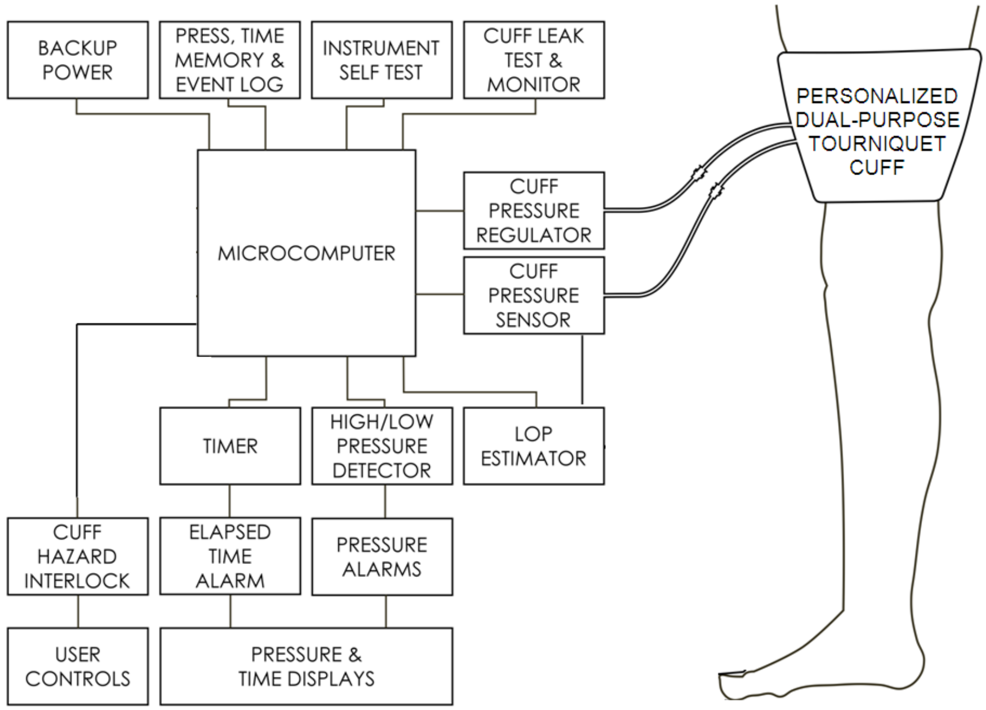

Figure 2: Modern surgical-grade tourniquet instrument and cuff adapted for BFR rehabilitation, showing elements that provide improved safety, accuracy and reliability to consistently achieve optimal patient outcomes.

LIMITATIONS OF OTHER APPROACHES

In early studies the most commonly used method for determining LOP to set restriction pressure was based on the use of Doppler ultrasound by a specifically trained clinician. However, this method is time-consuming, requires additional equipment, and the accuracy of LOP measurement is highly dependent on the specific training and experience of the measuring clinician. Alternatively, Jessee et al. [1] developed equations to predict a patient's LOP, taking into account some of the determinants of LOP investigated in their study, but these equations do not account for all variables known to affect LOP [4] and their application may be too complex and time-consuming for routine clinical use. Additionally, some low-cost, non-tourniquet cuffs [7] and other devices such as elastic knee wraps [8] have been proposed for BFR rehabilitation, but their effectiveness is unproven and they present safety hazards, Figure 3. This is because they do not have the ability to automatically take into account each patient's LOP when setting the restriction pressure level for individual patients, they apply unknown and inconsistent pressures to a patient's limb that can be much higher or much lower than the intended restriction pressure [4,9], and they lack important safety features proven in surgical-grade tourniquet instruments and cuffs such as safe limits on pressures and protocols, accurate pressure regulation and low pressure levels and gradients beneath cuffs [4].

CONCLUSION

In view of the above, it is crucial to use surgical-grade tourniquet technology with automatic LOP measurement capability, adapted to incorporate and deliver optimal protocols, for safe and effective application of BFR to consistently achieve optimal patient outcomes in rehabilitation.

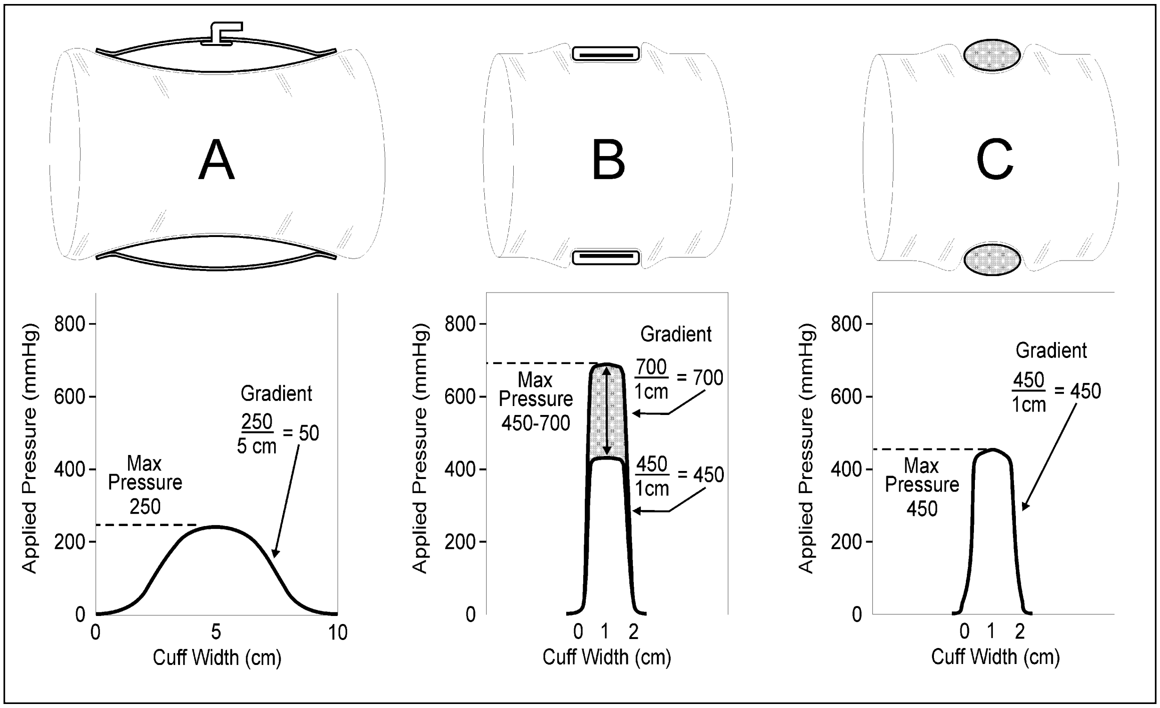

Figure 3: A comparison of applied pressures and pressure gradients typically produced by (a) a modern pneumatic surgical tourniquet cuff, (b) a non-pneumatic, non-surgical strap-type tourniquet and (c) a non-pneumatic elastic ring designed to combine exsanguination and tourniquet functions. Each tourniquet was selected and applied as recommended by the respective manufacturer to stop arterial bloodflow in an upper limb. Higher levels of pressure and higher pressure gradients are associated with higher probabilities of patient injuries. Reproduced from McEwen J., Casey V., (2009). CMBEC32. Calgary, Canada; 2009 May 20-22.

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