Effects of Intermittent Pneumatic Compression on Leg Blood Flow and Vascular Function After Spinal Cord Injury

Lena Marie Cialdella

University of Southern Mississippi

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EFFECTS OF INTERMITTENT PNEUMATIC COMPRESSION ON LEG BLOOD FLOW AND VASCULAR FUNCTION AFTER SPINAL CORD INJURY

by

Lena Marie Cialdella

A Thesis
Submitted to the Graduate School
and the School of Kinesiology
at The University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Master of Science

Approved:

________________
Dr. Daniel Credeur, Committee Chair
Assistant Professor, School of Kinesiology

________________
Dr. Scott Piland, Committee Member
Professor, School of Kinesiology

________________
Dr. David Dolbow, Committee Member
Assistant Professor, School of Kinesiology

________________
Dr. Karen S. Coats
Dean of the Graduate School

May 2016
ABSTRACT

EFFECTS OF INTERMITTENT PNEUMATIC COMPRESSION ON LEG BLOOD FLOW AND VASCULAR FUNCTION AFTER SPINAL CORD INJURY

by Lena Marie Cialdella

May 2016

Intermittent pneumatic compression (IPC) can increase leg blood flow (BF) in able-bodied persons. Whether IPC can alter leg BF and improve vascular function in people with SCI is currently unknown. PURPOSE: To test the hypothesis that acute IPC will increase leg BF, and improve vascular function in SCI. METHODS: Participants (n=8; injury level: T3 and below; A.S.I.A. class A-C; age: 41±17 yrs) were recruited for a 1-hour IPC session performed in one leg (experimental leg; EXP), with the other serving as a control (CON). IPC consisted of sequential, foot-to-calf compressions (4-s inflate, 16-s deflate; 3 compressions/min). Posterior-tibial artery BF (Doppler-ultrasound) was examined at rest, and at 15 and 45 mins of IPC. Vascular function was assessed using the flow-mediated dilation approach (FMD) before and after IPC. RESULTS: Resting posterior-tibial artery diameter, BF, FMD% and FMD normalized to shear area-under-curve (FMD%/AUC) were similar between legs at rest. A two-way repeated measures ANOVA (leg x time) revealed that during IPC, BF tended to increase (P=0.063) in EXP leg (8±2 to 11±3 mL/min at 15 mins; +42±23%), with no change occurring in the CON leg (9±4 to 10±5 mL/min at 15 mins). No main effects were noted for FMD following IPC; however, 7 of 8 subjects demonstrated increases in FMD%/AUC for EXP leg (+89±55% improvement; P=0.095, d= 0.362). CONCLUSION: Though no statistical
difference was found, there were notable effect sizes reported, thus giving the study further explanation of merit.
DEDICATION

I want to dedicate this thesis to my family whose support, encouragement, and love helped me be successful throughout this endeavor.
ACKNOWLEDGMENTS

I would like to formally thank Dr. Daniel Credeur and Dr. David Dolbow, without whom this research would not have been completed. I would also like to extend an appreciation to Dr. Scott Piland, Dr. Susi Folse, Dr. Beth Bryant-Claxton, L.I.F.E. of Mississippi, and The University of Southern Mississippi.
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<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>SCI</td>
<td>Spinal Cord Injury</td>
</tr>
<tr>
<td>AB</td>
<td>Able-Bodied</td>
</tr>
<tr>
<td>CVD</td>
<td>Cardiovascular Disease</td>
</tr>
<tr>
<td>FES</td>
<td>Functional Electrical Stimulation</td>
</tr>
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<td>IPC</td>
<td>Intermittent Pneumatic Compression</td>
</tr>
<tr>
<td>FDA</td>
<td>Federal Drug Administration</td>
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<td>ASIA</td>
<td>American Spinal Injury Association</td>
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<td>ECG</td>
<td>Electrocardiography</td>
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<td>HR</td>
<td>Heart Rate</td>
</tr>
<tr>
<td>BP</td>
<td>Blood Pressure</td>
</tr>
<tr>
<td>DEXA</td>
<td>Dual-Energy X-Ray Absorptiometry</td>
</tr>
<tr>
<td>BF%</td>
<td>Body Fat Percentage</td>
</tr>
<tr>
<td>BMD</td>
<td>Bone Mineral Density</td>
</tr>
<tr>
<td>LTPAQ-SCI</td>
<td>Leisure Time Physical Activity Questionnaire for Spinal Cord Injury</td>
</tr>
<tr>
<td>EXP</td>
<td>Experimental</td>
</tr>
<tr>
<td>CON</td>
<td>Control</td>
</tr>
<tr>
<td>FMD</td>
<td>Flow-Mediated Dilation</td>
</tr>
<tr>
<td>BF</td>
<td>Blood Flow</td>
</tr>
<tr>
<td>ROI</td>
<td>Region of Interest</td>
</tr>
<tr>
<td>(s⁻¹)</td>
<td>Shear Rate</td>
</tr>
<tr>
<td>AUC</td>
<td>Area Under Curve</td>
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<tr>
<td>FMD%</td>
<td>Normalized FMD</td>
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<td>$\Delta%$</td>
<td>Percent Change</td>
</tr>
<tr>
<td>$BL$</td>
<td>Baseline</td>
</tr>
<tr>
<td>$MAP$</td>
<td>Mean Arterial Pressure</td>
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CHAPTER I
INTRODUCTION

More than a quarter of a million Americans are currently living with a spinal cord injury (SCI), with approximately 12,000 new cases occurring each year (National Institute of Neurological Disorders and Stroke [NINDS], 2015). These individuals also have a considerably higher pre-mature death rate (228%) compared to able-bodied (AB) individuals, which is largely attributable to cardiovascular and metabolic diseases (Groah et al., 2012; Myers, Lee, & Kiratli, 2007; Sabatier et al., 2006). Furthermore, the lifetime cost for an individual living with SCI in the U.S. is estimated to be >$3 million, with annual expenses for SCI treatment across the nation being >$9 billion each year (National Spinal Cord Injury Statistic Center [NSCISC], 2015). This presents a major, albeit potentially modifiable, public health challenge.

Increased cardio-metabolic risk after SCI stems from unhealthy body composition changes (i.e., loss of muscle and bone mass and increased fat mass), along with impairments in vascular health, particularly in the legs (Hitzig, Miller, Eng, & Sakakibara, 2012; Myers et al., 2007; Phillips & Krassioukov, 2015; West, Alyahya, Laher, & Krasioukov, 2013). Importantly, vascular dysfunction precedes the development of numerous chronic disease states, including ischemic heart disease, type 2 diabetes mellitus, and stroke (Grundy et al., 1999; Libby, Ridker, & Maseri, 2002; Thijssen et al., 2012). Therefore, strategies sought to improve vascular function in SCI are vital to improving the cardio-metabolic health profile and reducing premature mortality in this population.
In AB individuals, vascular function is maintained through regular elevations in blood flow induced shear stress which occur during walking and other forms of physical activity. Shear stress, which represents the frictional force of blood moving across the vascular endothelium, stimulates endothelial-derived vasodilators, most notably, nitric oxide, which promote smooth muscle relaxation and increased blood flow to the physically active region (Thijssen et al., 2009). Nitric oxide also performs a myriad of anti-atherogenic functions and is considered the most important molecule governing endothelial health (Green, Jones, Thijssen, Cable, & Atkinson, 2011).

Due to paralysis of the lower extremities, individuals with SCI cannot voluntarily engage the lower-body. Wheelchair operation, as well as adapted physical activities (e.g., wheelchair basketball, quad rugby, and adapted tennis) provide the SCI individual an opportunity to engage the upper-body, which in turn provides some beneficial systemic effects on cardio-metabolic health outcomes, such as reducing traditional risk factors of cardiovascular disease (CVD), such as blood lipid levels, and indices of body composition (Myers et al., 2007; Phillips et al., 2015; Totosy de Zeptnek, Ditor, Au, & MacDonald, 2015). However, the vasculature of the lower extremities still remain vulnerable to pathology (Credeur, Stoner, & Dolbow, 2016). The legs of individuals with SCI can be exercised via functional electrical stimulation (FES). This technology works by sending electrical impulses via leads placed on the quadriceps, hamstring, buttocks, and calf muscles, in a sequence which allows an individual with paralysis to perform leg ergometry exercise (Kressler, Ghersin, & Nash, 2014). Importantly, FES cycling use has been shown to be effective in improving body composition and leg vascular function with regular use (Griffin et al., 2009; Stoner, Sabatier, Mahoney, Dudley, & McCully, 2007).
Unfortunately, FES cycles are expensive (~$20,000) and a physician’s prescription is required for use, making this technology not readily accessible to a majority of individuals with SCI.

Recent evidence demonstrates that intermittent pneumatic cuff compression (IPC) applied to the calf and foot can also acutely increase blood flow and shear stress in leg arteries of able-bodied individuals (Sheldon et al., 2012). IPC is a non-invasive FDA approved therapy commonly used to treat individuals with symptoms of venous insufficiency and claudication pain in peripheral arterial disease (Chang et al., 2012; Roseguini et al., 2012; Sheldon, Roseguini, Laughlin, & Newcomer, 2013). This therapy is performed by inflating and deflating pneumatic cuffs, which are secured around the calf and foot region, in regular intervals for a period of time (i.e., 1 hour, 3 inflation cycles/minute) to simulate the mechanical compression of muscle contractions. While the use of IPC in clinical AB populations has been extensively tested (Delis, Azizi, Stevens, Wolfe, & Nicolaides, 2000a; Delis et al., 2000b; Labropoulos et al., 2005; Manfredini et al., 2014; Roseguini et al., 2012; van Bremmelen, Char, Giron, & Ricotta, 2003), the efficacy of its use for improving vascular health in individuals with SCI is currently unknown.

Therefore, the purpose of this study was to determine whether a single IPC session can acutely enhance blood flow and vascular function in the lower limbs of those with SCI. We hypothesized that a single session of IPC will transiently increase blood flow and shear rate, thus, providing an acute enhancement in vascular endothelial function of lower extremity arteries in people with SCI.
CHAPTER II
METHODS

Experimental Design

This study consisted of a pre-test with multiple post-tests intervention control group experimental design.

Subjects

Eight subjects with chronic SCI participated in this study. Subjects were recruited from the surrounding Hattiesburg and Gulfport, MS area. Following a detailed explanation of the experimental measures and protocols, each subject provided written informed consent prior to participating in any facet of the study. Inclusion for participation consisted of the following: ≥2 years post spinal injury; T3 neurological injury level and below; American Spinal Injury Association (ASIA) classification A, B and C; wheelchair reliant; 18-75 years of age. Exclusion criteria consisted of pressure wounds on the buttocks or feet, unhealed bone fractures or history of fragility fractures, severe osteoporosis (T-score of -4 or less), uncontrolled autonomic dysreflexia, unstable cardiovascular or metabolic disease, and <2 years post spinal injury. All experimental procedures and protocols conformed to the Declaration of Helsinki and were approved by the University of Southern Mississippi Institutional Review Board (Appendix A).

Experimental Measurements

Cardiovascular Measures. Subjects were instrumented with a lead II surface electrocardiography (ECG) (Logiq P5; GE Medical systems, Milwaukee, WI, USA) for continuous measurement of heart rate (HR), and blood pressure (BP) was measured via automated sphygmomanometry (Omron HEM907XL- Intellisense) performed on the
right upper-arm periodically during the experimental protocol. Posterior-tibial artery diameter and blood velocity signals were obtained using a high resolution (30 Hz) duplex-Doppler ultrasound system (Logiq P5; GE Medical systems, Milwaukee, WI, USA). The artery was imaged 3-5 cm superior to the calcaneus and ~1 cm posterior to the medial malleolus on the right and left ankles, separately, using an 11-MHz linear array transducer. Diameter and blood velocity signals were obtained simultaneously in duplex mode, operating at a pulsed Doppler frequency of 5-MHz. Measurements were performed with the velocity cursor placed mid-vessel and the sample volume was adjusted to encompass the entire vessel lumen without extending beyond it. To ensure consistency and stability in the measurement, probe placement was marked on the skin using a permanent marker, and the transducer was stabilized using a custom-designed clamp. In addition, all probe settings were kept consistent for each limb throughout the study.

*B**ody Composition Measures. Height was determined with a standard tape measure with the subject in a supine position. Every effort was made to extend the knee fully for precise measurement. Weight was determined through the use of a wheelchair scale (Scale Tronix). Subjects were weighed while in their wheelchair, after which they were transferred to the examination table using a mechanical lift (Invacare), then the wheelchair weighed separately. Dual-Energy X-Ray Absorptiometry (DEXA) (Lunar Prodigy Advance) was performed to determine total body and regional lean and fat mass, %body fat (%BF), and total body bone mineral density (BMD). Importantly, T-scores for BMD were used to determine possible osteopenia and osteoporotic values. To do this, subjects were transferred from their wheelchair, via the mechanical lift, and positioned supine on the DEXA scanner. Their legs were strapped proximal and distal to the knees
to steady the distal femur and proximal tibia, with a slight internal rotation of the hips to position the greater trochanter in the best scanning position, and for the safety of the participant in the event of an untimely muscle spasm (Charmetant, Phaner, Condemine, & Calmels, 2010; Shields, Schlechte, Dudley-Javoroski, Zwart, & Clark et al., 2005).

**Experimental Protocol**

**Study Visits**

*Screening Study Visit.* On the first day, subjects provided written informed consent (Appendix B), and completed a detailed medical history questionnaire (Appendix C), and a leisure time physical activity questionnaire for people with spinal cord injury (LTPAQ-SCI)© (Ginis, Phang, Latimer, & Arbour-Nicitopoulos, 2010) (Appendix D). A familiarization session was then performed to acquaint subjects to the experimental measurements (i.e., Doppler-Ultrasound, and mechanical lift), and to ensure quality ultrasound images could be obtained. The leg that provided the best quality image served as the experimental leg (EXP) and the other leg served as the control (CON). Following the vascular screening, anthropometric measures and the DEXA scan were performed. For convenience, some subjects completed all facets of the study in a single visit.

*Experimental Study Visit.* Study visit two consisted of the experimental visit (Figure 1). All subjects reported to the laboratory during the morning hours (6:00 – 11:00 am) following an overnight fast. Subjects also refrained from caffeine and alcohol for 12 hours, and any strenuous physical activity for 24 hours. After providing a review of the experimental procedures, the subjects were then transferred to the examination table using the mechanical lift, positioned semi-recumbent, and instrumented for ECG, BP, and
Doppler-Ultrasound measurements. Subjects rested quietly for 30 minutes before baseline testing was performed.

**Figure 1.** Timeline for the experimental study visit.

**Vascular Function Testing.** All testing was performed in a dimly lit, temperature (22-23° Celsius) and humidity (~50%) controlled room. Following 30 minutes of semi-recumbent rest, vascular function was assessed in both posterior-tibial arteries by the same ultrasonographer. The rationale for choosing this artery stems from previous evidence suggesting that the posterior-tibial artery experiences a lesser degree of atrophy following traumatic SCI, as compared to larger vessel of the leg (e.g., popliteal and femoral arteries) (Stoner et al., 2007). Furthermore, examining the posterior-tibial artery was a unique aspect, given that it permitted the assessment of vascular changes within the region of compression, in contrast to a more proximal vessel (i.e., popliteal).
Vascular endothelial function testing was performed using the Flow-Mediated Dilation (FMD) technique, in accordance with previously published guidelines (Corretti et al., 2007; Thijssen et al., 2010). After the attainment of a quality ultrasound signal, two minutes of baseline data were recorded, followed by inflation of a proximally placed pneumatic cuff (220 mmHg) (Hokanson; Bellevue, WA), positioned ~1 cm distal from the fibular head around the subject's calf, for 5 minutes. Data were recorded continuously from the last 30 seconds of occlusion and until 4 minutes post cuff-release using an image capturing system (El Gato), and analyzed off-line via an automated edge-detecting software (QUIPU, FMD Studio) by the same study personnel, separate from the ultrasonographer. The 3 largest diameter values following cuff-release were averaged and considered the peak change, and used to calculate FMD as described under Data Analysis below. Baseline posterior-tibial artery FMD measurements were randomized between limbs, and were separated by at least 10 minutes. Absolute blood flow (BF in mL/min) data were also recorded and analyzed off-line on the Doppler Ultrasound unit (GE, Logiq P5). It is important to note, that while between-day reliability was not performed on SCI individuals for this study, previous work has reported good day-day reliability of posterior-tibial artery FMD in AB individuals (Black, Cable, Thijssen, & Green, 2008). Furthermore, the stability of this measurement was examined after 60 minutes of quiet rest in SCI individuals (n=2), and importantly, no apparent differences were noted for posterior-tibial artery FMD% (e.g., baseline = 29±11%, vs. 60 mins rest=33±9%).

**Intermittent Pneumatic Compression.** To best administer IPC, the same rapid inflation system used during vascular endothelial function testing, was also used to administer the intervention. To do this, two separate cuffs, one small cuff (SC5; 5 cm
bladder) positioned around the mid-foot and another larger cuff (CC17; 17 cm bladder) positioned around the calf (~1 cm distal to the fibular head) of the EXP leg, were connected to a single inflation unit (Hokanson E20-Rapid Cuff Inflator). During inflation, the foot cuff always inflated first (~0.5 second delay), followed shortly by the calf cuff, thus, providing a sequential foot-to-calf compression cycle, similar to that of a commercially available IPC device (e.g., ArtAssist®). In addition, the Hokanson cycle timer was adjusted to deliver three automated compressions per minute (4-s inflation/ 16-s deflation) at 120 mmHg, over the course of an hour. Traditional IPC therapy (e.g. ArtAssist®) consists of 3-s inflation/ 15-sec deflation (Sheldon et al., 2012). The rationale for the timing adjustment in the current study was to account for an approximate 1-s delay in the Hokanson inflation unit reaching the desired pressure. For proof of concept, we examined popliteal artery BF responses to 5 minutes of IPC therapy between this experimental (Hokanson) vs. traditional (ArtAssist®) IPC approach in one AB participant, and importantly, no marked differences were noted for the magnitude of initial increase (% mL/min) between devices (e.g., Hokanson=+166% vs. ArtAssist=+161%).

Hemodynamics during IPC. To examine the hemodynamic profile, posterior-tibial artery blood velocity signals (antegrade and retrograde velocity) were acquired on both the Doppler-ultrasound and image capture software, as described in detail above. Three compression cycles (~1 minute of data), were recorded at baseline, and following minutes 15 and 45 of IPC. Following 60 minutes of IPC therapy, the FMD tests were repeated in both legs. In order to detect the transient changes in vascular endothelial function, the
order of FMD tests was not randomized, and the EXP leg was always assessed immediately following completion of IPC (~3 mins post treatment).

Analysis

Data Analysis

All ultrasound data were outsourced at 30-Hz, and acquired onto a designated laptop (Mac Book) using a commercially available analog video capture unit (El Gato). Data were then analyzed off-line, in accordance with guidelines (Thijssen et al., 2010), by playing pre-recorded videos through the Cardiovascular Suite software. A region of interest (ROI) was selected on each video to ensure a clear portion for the edge-detection software to analyze posterior-tibial artery diameters. Blood velocity signals were also simultaneously analyzed using the same software by obtaining the flow-envelope (area under tracing) for both the antegrade (positive area) and retrograde (negative area) velocity signals. Mean velocity was defined as the difference between antegrade and retrograde velocity signals. Blood flow (mL/min) was calculated as; 

\[(\pi \times \text{diameter}/2)^2 \times \text{mean velocity} \times 60.\] 

Blood flow was also analyzed on the Duplex Doppler-ultrasound using internal software (GE) in addition to analyses performed on the Cardiovascular Suite software.

To determine BF and shear rate responses during IPC, velocity signals were analyzed and averaged between compression cycles in order to minimize any potential artifact from movement due to cuff inflation/deflation. Vascular endothelial function was determined as the peak change in posterior-tibial artery diameter from baseline following cuff release, and expressed in both absolute (mm) and relative (%) terms; i.e., FMD change=((peak diameter-baseline diameter)/baseline diameter)*100. Shear rate (s\(^{-1}\)) was
calculated as $8 \times \text{mean velocity/diameter}$ (van Brussel, F, van Brussel, B, Hoeks, Roodt, & Henry et al., 2015) and shear rate incremental area-under-the-curve (AUC) up until the time (sec) peak diameter was calculated using the trapezoidal method (i.e., change in shear rate/second), and importantly, was used to normalize FMD% to the stimulus (FMD%/AUC) (Padilla et al., 2008; Thijssen et al., 2012).

Statistical Analysis

To examine differences between vascular function, and blood flow (BF) indices at rest, during, and after IPC therapy, separate 2-way (leg x time) repeated measures ANOVA’s were performed. Bonferroni post hoc tests were selected to examine possible interactions between study measurements. Independent sample T-tests were utilized to compare relative changes in BF and vascular function between legs (EXP vs. CON), pre and post IPC therapy. Cohen’s $d$ effect sizes were also calculated to examine meaningfulness of changes in vascular function and BF between legs, pre to post IPC therapy. All statistical analyses were performed using Sigma Plot Analysis software and SPSS (IBM, Watson Analytics). Statistical significance was set $a priori$ at $p<0.05$, and moderate to large effect sizes were considered clinically meaningful.
CHAPTER III

RESULTS

Subject Data

Individual participant demographics are summarized in Table 1. The average age and duration of SCI was 41±6 years and 20±19 years, respectively. Within the cohort, three subjects had diagnosed metabolic disease (type 2 diabetes), and one had a history of cardiovascular complications (coronary artery disease). Importantly, all subjects were asymptomatic at rest and no differences were noted between the participant’s responses pre and post IPC, as compared to the cohort.

Table 1

Subject Demographics

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age (yrs)</th>
<th>Sex</th>
<th>Race</th>
<th>Ht. (m)</th>
<th>Wt. (kg)</th>
<th>%BF</th>
<th>BMD</th>
<th>T-score</th>
<th>Injury Level</th>
<th>SCI (yrs)</th>
<th>ASIA class</th>
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<td>27</td>
<td>M</td>
<td>C</td>
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<td>103.8</td>
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<td>36</td>
<td>M</td>
<td>C</td>
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<td>4</td>
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<td>M</td>
<td>C</td>
<td>1.8</td>
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<td>5</td>
<td>34</td>
<td>F</td>
<td>AA</td>
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<td>C</td>
<td>1.5</td>
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<td>8</td>
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<td>3.7</td>
<td>T-12,</td>
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Avg±Sd 41±16 1.7±0.1 93±26 38±11 1.3±0.2 20±19

Note. C (Caucasian), AA (African American), %BF (body fat percentage), BMD (bone mineral density), ASIA class (American Spinal Injury Association) classification scale.
Hemodynamic Responses to IPC

Table 2 summarizes hemodynamic data at rest, and during IPC for both legs. Figure 2 represents a Doppler-Ultrasound image from one subject showing BF at baseline and following 15 mins of IPC in the EXP leg. Although not statistically significant, a majority of subjects demonstrated a biphasic pattern for BF and shear rate responses to IPC in the EXP leg (n=6), characterized by a transient increase (~50%) at 15 mins, with a return to baseline at 45 mins. When comparing peak Δ% in BF during IPC, occurring at either 15 or 45 mins, the EXP leg tended to show a positive response (+42±23%, P=0.063, d=0.27), with no change observed in the CON leg (-7±15%) (Figure 3). To note, CON leg BF data were not collected in one subject due to physical limitations (i.e., history of blood clots in that leg).

Table 2

<table>
<thead>
<tr>
<th></th>
<th>EXP Leg</th>
<th>CON Leg</th>
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<tbody>
<tr>
<td></td>
<td>Rest</td>
<td>15mins</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>70±10</td>
<td>67±11</td>
</tr>
<tr>
<td>MAP (mmHg)</td>
<td>90±5</td>
<td>91±9</td>
</tr>
<tr>
<td>Diameter (cm)</td>
<td>0.17±0.01</td>
<td>0.17±0.05</td>
</tr>
<tr>
<td>Mean Velocity(cm/sec)</td>
<td>6.3±1.2</td>
<td>6.6±2.0</td>
</tr>
<tr>
<td>BF (ml/min)</td>
<td>8.0±2.4</td>
<td>10.7±3.2</td>
</tr>
<tr>
<td>Ant Shear (s⁻¹)</td>
<td>254±111</td>
<td>258±141</td>
</tr>
<tr>
<td>Ret Shear (s⁻¹)</td>
<td>-39±37</td>
<td>-37±35</td>
</tr>
<tr>
<td>Mean Shear (s⁻¹)</td>
<td>215±125</td>
<td>221±150</td>
</tr>
</tbody>
</table>

Note: HR (Heart Rate), MAP (Mean Arterial Pressure), BF (Blood Flow), Ant (Antegrade), Ret (Retrograde). ⁰same data as EXP leg.
Figure 2. Blood Flow Response after 15 minutes of IPC. Image is a representation of blood flow responses to IPC as seen on the Duplex Doppler-ultrasound. Panels A) and B) depict the blood flow pattern of the same participant at baseline, and after 15 minutes of IPC in the EXP leg, respectively. Note the approximate 50% increase in mean velocity as shown by the bottom sweep in each panel.

Figure 3. Blood Flow Response during IPC. Panel A) depicts blood flow measures during IPC in the EXP leg and CON leg. Panel B) depicts the percent change (%Δ) of peak blood flow between the EXP and CON leg, respectively.

<table>
<thead>
<tr>
<th></th>
<th>EXP</th>
<th>CON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td></td>
<td></td>
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<tr>
<td>15 mins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>45 mins</td>
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</tbody>
</table>

Limb: P=0.901  
Time Point: P=0.203  
Interaction: P=0.138

P=0.063
Table 3 summarizes results from FMD testing before and after IPC therapy for both the EXP (n=8) and CON (n=6) leg. Of note, FMD testing was not performed on the CON leg in two subjects due to physical limitations (n=1), and an inability to obtain optimal image quality for analysis (n=1).

Table 3

<table>
<thead>
<tr>
<th></th>
<th>EXP pre</th>
<th>EXP post</th>
<th>CON pre</th>
<th>CON post</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Diam. (cm)</td>
<td>1.7 ± 0.1</td>
<td>1.7 ± 0.1</td>
<td>1.5 ± 0.1</td>
<td>1.6 ± 0.1</td>
</tr>
<tr>
<td>Peak Diam. (cm)</td>
<td>2.2 ± 0.1</td>
<td>2.3 ± 0.1</td>
<td>2.0 ± 0.2</td>
<td>2.0 ± 0.2</td>
</tr>
<tr>
<td>Abs. Δ (mm)</td>
<td>0.4 ± 0.1</td>
<td>0.5 ± 0.1</td>
<td>0.5 ± 0.1</td>
<td>0.3 ± 0.1</td>
</tr>
<tr>
<td>%Δ</td>
<td>24.7 ± 4.0</td>
<td>32.8 ± 7.8</td>
<td>30.6 ± 3.6</td>
<td>21.9 ± 5.3</td>
</tr>
<tr>
<td>Peak Shear (s⁻¹)</td>
<td>648 ± 57</td>
<td>603 ± 69</td>
<td>493 ± 120</td>
<td>469 ± 113</td>
</tr>
<tr>
<td>Shear AUC</td>
<td>18481 ± 3448</td>
<td>15398 ± 2201</td>
<td>15971 ± 6001</td>
<td>14221 ± 3945</td>
</tr>
</tbody>
</table>

Note: Diam. (Diameter), Abs. (Absolute), AUC (Area under Curve)

Figure 4 represents individual data responses for normalized FMD pre and post IPC for both legs. For FMD%/AUC, no statistical differences were noted for changes between the EXP and CON leg, pre- and post-IPC. However, when these data were expressed as a change score (%Δ) (Figure 5), the EXP leg tended to show an improvement in a majority of subjects (+89±55%, P=0.095; effect size d= 0.362), with no change occurring in the CON leg (-21±21%).
Figure 4. Normalized FMD Response for Individual Data pre- and post-IPC. This graph depicts individual and mean summary data for FMD%/AUC at baseline and 60-minutes post-IPC for the EXP and CON leg.

Figure 5. Improvement in Vascular function following IPC. Graph represents the percent improvement (%Δ) in FMD%/AUC between EXP and CON legs following 60 mins IPC.
CHAPTER IV
DISCUSSION

This study sought to determine the efficacy of a novel therapy, IPC, in targeting leg blood flow and vascular function in people with SCI. Uniquely, we show for the first time, that IPC can be implemented safely in paralyzed legs of people with paraplegic SCI. Contrary to our initial hypotheses, there were no significant main effects of IPC to increase blood flow, or to improve vascular function. However, there was a tendency for a majority of subjects to show positive effects on these study outcomes. Collectively, these preliminary data demonstrate that one hour of IPC therapy may acutely increase leg blood flow, and improve vascular function in some people with SCI.

Leg Blood Flow

Effects of IPC on Leg Blood Flow

Previous research has demonstrated that IPC can transiently increase arterial BF and shear rate when applied to the lower legs of AB individuals. For example, one study reported that popliteal artery BF and shear rate increased two-fold within the first 15 mins of IPC (Sheldon et al., 2012). In other studies, IPC significantly increased popliteal artery inflow in patients with peripheral vascular disease (Delis et al., 2000a), as well as altered popliteal venous outflow in tetraplegic SCI subjects (Nash, Mintz, Montalvo, & Jacobs, 2000). Uniquely, for the first time, we examine posterior-tibial artery BF responses to IPC in paraplegic SCI subjects. In this study, no significant main effects were noted for IPC to alter leg BF and shear rate in people with SCI. One potential explanation for the lack of agreement between our data and others could be attributed to the artery chosen to undergo Doppler-ultrasound scanning, which was the posterior-tibial artery near the
ankle. Because of its location (i.e., between compression cuffs), it is possible that the hyperemic stimulus to IPC may have been dampened, thus, reducing our ability to examine a measurable effect on conduit artery blood flow. Interestingly, our data did show a tendency ($P=0.063$; $d=0.265$) for peak increases in blood flow to be greater in the EXP, as compared to the CON leg. After further examination of these data, we found that some individuals achieved a peak response within 15 mins ($N=6$), while others took as long as 45 mins ($N=2$) to achieve this peak BF response. Therefore, it is plausible that some individuals may have reached their peak increase in BF beyond the measurement intervals (i.e., between 15 and 45 mins). Future work will be needed to further examine the time course of BF responses to IPC in people with SCI.

While this study was not designed to test mechanisms, a discussion of the potential contributors to hyperemia following mechanical compression is worth considering. IPC therapy has been shown to provide a muscle pump-like effect on the peripheral vasculature (Delis, Nicolaides, Labropoulos, & Stansby, 2000c). Following application of an external pressure ($120 \text{ mmHg}$), the resulting vascular compression would, in theory, displace venous volume back to the heart, widen the arterial-venous pressure gradient, and in turn, increase arterial inflow within the stimulated region (Laughlin, 2005). Repeated compressions could also further elevate arterial inflow through increased shear stress on the arterial wall, with subsequent production and release of endothelial-derived vasodilators. For example, IPC performed bilaterally on the legs in rats has been shown to increase the expression of endothelial derived nitric oxide synthase—the enzyme catalyzing the reaction to produce nitric oxide—as well as, stimulate nitric oxide-mediated vasodilation, with subsequent hyperemia within the
microvasculature of cremaster muscles (Chen et al., 2002; Liu, Chen, Seber, Johnson, & Urbaniak, 1999). Whether this mechanism plays a role for the hyperemic response to IPC in humans, warrants further investigation.

Leg Vascular Function

*Effects of IPC on Leg Vascular Function*

Repetitive increase in shear stress (i.e., dynamic exercise and external peristaltic pneumatic compression—EPC) have been shown to transiently modulate vascular endothelial function in healthy AB individuals (Martin, Borges, & Beck, 2015; Padilla, Harris, & Wallace, 2007). Given this evidence, we posited that IPC could also serve as a means to enhance leg vascular function in people with SCI. Contrary to this hypothesis, no significant main effect was noted for IPC to alter vascular function in SCI. This finding is in agreement with one report demonstrating that acute IPC does not improve leg vascular function in healthy AB individuals. Our data did show a tendency for FMD normalized to shear AUC to improve in the EXP leg (P=0.095; d=0.362), with a majority of individuals exhibiting positive effects (7 out of 8). This leaves the question of whether IPC may influence vascular function in some individuals with SCI, and not others. Interestingly, a more recent report indicated that 60 minutes of EPC applied to the legs can indeed significantly improve leg vascular function (i.e., popliteal artery) in healthy AB individuals (Martin et al., 2015). It is important to emphasize that this study utilized a different type of compression stimulus consisting of a sequential distal-to-proximal pneumatic compression applied to 5 regions on the leg at a lower pressure (i.e., 70 mmHg compared to 120 mmHg), but different tempo (60-s inflate/30-s deflate, for 1 hour). This variation of the compression stimulus likely produced their observed improvement in
vascular function, as opposed to the previous IPC research in AB individuals (Sheldon et al., 2012). Indeed, future studies are warranted to determine whether alterations in the IPC stimulus (i.e., number of compression regions, inflation pressure, and duty cycle) can alter vascular function in people with SCI, as well as AB individuals.

Limitations and Clinical Implications

Experimental Limitations

There are a few experimental limitations that are worth discussing. Our subjects varied in age (27-75 years), neurological injury level, duration of SCI, and ASIA impairment, all of which could have confounding influences on study results. Given the inherent difficulty in matching people with SCI, we had to temper our inclusion criteria to accept a wide range of individuals to achieve a sufficient sample number. Indeed, future efforts will be needed to discern whether such factors could play a role in modulating vascular responses to IPC therapy. Still, with a low sample number, and heterogeneous SCI group, our data showed tendency and moderate effects for IPC to increase BF, and improve vascular function in some individuals, which perhaps, warrants further investigation with a larger, and more homogenous SCI cohort.

Uniquely, our study investigated the posterior-tibial artery which permitted the examination of vascular changes within the region of compression. However, given this location, it is possible that the hyperemic stimulus may have been minimized, thus, reducing our ability to examine a measureable effect. Future research will be needed to determine whether a more proximal vessel, such as the popliteal artery or femoral artery, responds differently to acute, and or chronic IPC in people with SCI.
Clinical Implications

A majority of people with SCI are subjected to prolonged periods on inactivity due to paralysis below the level of injury. It is well known that physical activity has positive effects of cardio-metabolic health outcomes (American College of Sports Medicine, 2014). Interestingly, a recent report indicated that achieving the physical activity recommendations in SCI through 16 weeks of upper-body exercise does not provide comparable benefits as AB individuals, in terms of improving cardio-metabolic health outcomes (Totosy de Zepetnek et al., 2015). Upper-body exercise training alone may not provide a sufficient stimulus to vulnerable regions, like the paralyzed legs (Credeur et al., 2016). Therefore, targeting this region with alternative efficacious, and economically viable therapies may provide a means to further combat cardio-metabolic health declines, when used alone, or possibly in combination with other traditional approaches (e.g., FES cycling, and arm ergometry). The exploratory nature of this project provides evidence to support that external stimuli applied to the paralyzed region may have beneficial effects in some individuals within our study sample. Therefore, future research should continue examining whether novel therapies, like IPC, can serve as an effective means to enhance vascular health outcomes in people living with SCI.
CHAPTER V

CONCLUSION

In summary, these preliminary data indicate that one hour of IPC therapy can be implemented safely in the paralyzed legs of people with SCI. While no statistical differences were noted for study outcomes, a majority of subjects tended to exhibit positive effects on blood flow ($P=0.063$; $d=0.265$) and vascular function ($P=0.095$; $d=0.362$). Therefore, future studies should further evaluate the effects of IPC therapy on cardio-metabolic health outcomes when performed acutely and chronically in people living with SCI.
APPENDIX A

IRB APPROVAL

THE UNIVERSITY OF SOUTHERN MISSISSIPPI

INSTITUTIONAL REVIEW BOARD
118 College Drive #5147 | Hattiesburg, MS 39406-0001
Phone: 601.266.5997 | Fax: 601.266.4377 | www.usm.edu/research/institutional.review.board

NOTICE OF COMMITTEE ACTION

The project has been reviewed by The University of Southern Mississippi Institutional Review Board in accordance with Federal Drug Administration regulations (21 CFR 26, 111), Department of Health and Human Services (45 CFR Part 46), and university guidelines to ensure adherence to the following criteria:

- The risks to subjects are minimized.
- The risks to subjects are reasonable in relation to the anticipated benefits.
- The selection of subjects is equitable.
- Informed consent is adequate and appropriately documented.
- Where appropriate, the research plan makes adequate provisions for monitoring the data collected to ensure the safety of the subjects.
- Where appropriate, there are adequate provisions to protect the privacy of subjects and to maintain the confidentiality of all data.
- Appropriate additional safeguards have been included to protect vulnerable subjects.
- Any unanticipated, serious, or continuing problems encountered regarding risks to subjects must be reported immediately, but not later than 10 days following the event. This should be reported to the IRB Office via the "Adverse Effect Report Form".
- If approved, the maximum period of approval is limited to twelve months. Projects that exceed this period must submit an application for renewal or continuation.

PROTOCOL NUMBER: 15040702
PROJECT TITLE: Effect of Intermittent Pneumatic Compression on Leg Blood Flow and Vascular Function after Spinal Cord Injury
PROJECT TYPE: New Project
RESEARCHER(S): Daniel Credeur, Ph.D.
COLLEGE/DIVISION: College of Health
DEPARTMENT: Human Performance and Recreation
FUNDING AGENCY/SPONSOR: N/A
IRB COMMITTEE ACTION: Expedited Review Approval
PERIOD OF APPROVAL: 05/01/2015 to 04/30/2016
Lawrence A. Hosman, Ph.D.
Institutional Review Board
## APPENDIX B

INFORMED CONSENT

| **INSTITUTIONAL REVIEW BOARD** |
| **LONG FORM CONSENT** |

### LONG FORM CONSENT PROCEDURES

This completed document must be signed by each consenting research participant.
- The Project Information and Research Description sections of this form should be completed by the Principal Investigator before submitting this form for IRB approval.
- Signed copies of the long form consent should be provided to all participants.

**Last Edited August 26th, 2014**

<table>
<thead>
<tr>
<th><strong>Today's date:</strong></th>
<th>11-10-15</th>
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</thead>
</table>

### PROJECT INFORMATION

Project Title: Effect of Intermittent Pneumatic Compression on Leg Blood Flow and Vascular Function after Spinal Cord Injury

Principal Investigator: Lena M. Cialdella, BS  
Phone: 812-230-9396  
Email: lena.cialdella@eagles.usm.edu

College: College of Health  
Department: Kinesiology

### RESEARCH DESCRIPTION

1. **Purpose:**

   Recent evidence demonstrates that brief episodic compressions applied to the calf and foot region can improve circulation through blood vessels in the legs of healthy non-disabled individuals. Whether this approach has the ability to change blood flow and vascular health when performed on those with spinal cord injury is currently unknown. Therefore, the purpose of this study will be to investigate whether a single session of episodic compressions (3 compressions per minute, for 60 minutes) applied to the lower leg can improve circulation and vascular health of lower extremity arteries in those with chronic spinal cord injury.

2. **Description of Study:**

   You will be in the study for 2 visits; one visit for consenting, artery screening, and body composition assessments which will last approximately 90 minutes, and the second visit lasting about 3 hours. You can stop participating at any time. Your decision to withdraw from the study will not affect in any way your medical care and/or benefits.

   Below is a detailed description of the procedures to be performed during each visit to the laboratory:

   **VISIT 1:** You will make a trip to room 125 of the Human Performance and Recreation building at USM, to Dr. Daniel Credeur’s Lab for a review of the inclusion/exclusion criteria and to discuss the informed consent including an oral explanation of the study purpose, protocol, and potential risks and benefits. After signing the informed consent, you will complete a detailed medical health history form and a physical activity survey. Next, you will be transferred from your wheelchair to an examination table using a mechanical lift where you will undergo artery screening. An ultrasound probe will be placed over the skin of your legs to establish whether a good quality artery image can be obtained. Following this procedure, you will undergo a series of assessments to determine your height and weight, and also your body composition through DEXA scanning (Dual Energy X-Ray Absorptiometry). Following these assessments, you will be scheduled for Visit 2.
VISIT 2: During the experimental study visit, you will be asked to report to the laboratory at your scheduled time. All experimental study sessions will be scheduled to begin in the morning hours (6:00-11:00am) following an overnight fast and having been refrained from caffeine intake and alcohol for 12 hours, and any strenuous physical activity for 24 hours prior to participating.

Upon arrival to the laboratory, you will be asked to use the restroom. Next, you will be transferred to the exam table and positioned slightly upright. You will then be instrumented for baseline assessments of heart rate using electrocardiography (ECG), blood pressure, and vascular health testing (described below in detail). After baseline assessments, a blood pressure cuff positioned around your calf and/or foot will be periodically inflated and deflated (3 inflations/deflations per minute) for an hour. Ultrasound measurements on your leg will be taken twice during this time period (after 5 mins and 45 mins) to determine blood flow. Lastly, the flow-mediated dilation tests will be repeated on both legs.

Procedures to be performed:

Height and Weight - Your height will be determined with a tape measure while you are supine on the examination table, and your weight will be determined using a specialized wheelchair scale (you will be weighed while in your wheelchair, then the wheelchair will be weighed separately after you are transferred to the exam table).

Doppler-Ultrasound - An ultrasound probe will be placed over the skin on the inside both of your ankles and also behind your knees in conjunction with a water-based gel to improve the conduction of the signal. This safe, non-invasive procedure will determine the size of your artery and also the speed of blood moving through it.

Body Composition - You will be transferred from your wheelchair onto a table to undergo Dual-Energy X-Ray Absorptiometry (DEXA) scanning. Your legs will be secured with special straps for your safety. This scanning will determine your body-composition, including lean and fat mass, and bone mineral density.

Blood Pressure - A blood pressure cuff will be wrapped around your upper-arm to periodically measure blood pressure.

Heart Rate - After cleaning your skin with an alcohol swab, electrodes (patches) will be placed on the surface of your chest just below your shoulders and also on the side of your abdomen for heart rate measurements per the ECG.

Vascular Health Testing - A blood pressure cuff will be placed around your calves. This cuff will be inflated, as is done when your blood pressure is being measured, but instead of deflating the cuff immediately it will remain inflated for 5 minutes. We will measure the blood flow to your foot by placing a probe over the artery of your ankle or behind your knee, during and after inflating the cuff. The probe will provide a measure of the speed at which your blood is travelling through your artery as well as the size of your blood vessel.

Intermittent Pneumatic Compression (IPC) - IPC is a non-invasive FDA-approved therapy which includes the administration of brief 120 mmHg cuff compressions (4 sec each) around your calf and foot region performed sequentially over the course of an hour (~3 compressions/min). Blood flow in your ankle and behind your knee will be measured using the ultrasound machine periodically during the IPC session. The FMD procedure will be performed on both ankles and/or behind the knees before and after 60 minutes of IPC.

3. Benefits:

If you agree to take part in this study, there may or may not be a direct medical benefit to you. You may expect to benefit from taking part in this research to the extent that you are contributing to medical knowledge. Our hope is that the information gained from this study will develop future recommendations for the prevention and/or treatment of vascular diseases among individuals with spinal cord injury.

4. Risks:

While in the study, you are at risk for the side effects described below. You should discuss these with the investigator and/or your doctor. There may also be other side effects that we cannot predict:
ECG: Some people may have a skin irritation from the patches that connect the wires on the chest to the computer. Skin and hair are pulled slightly when the patches are removed after the test. Research personnel will attach and remove the patches as carefully as possible.

Blood pressure cuff inflation: The blood pressure cuff will squeeze the arm tightly; however, any discomfort will be alleviated as soon as the pressure in the cuff is released.

DEXA Scanning: The DEXA scan measurements emit small amounts of radiation, however, they have been found to have no biological effects and are equivalent in radiation exposure to that of natural background radiation.

Participant Transfers: The risks of transferring you to and from your wheelchair includes bumping of your limbs and falling. However, trained personnel will be there to assist with transfers using a specialized heavy-duty lift equipped with a harness system and straps to transfer you from your wheelchair to various testing apparatuses.

Intermittent Pneumatic Compression: There are no known risks associated with the use of low frequency IPC. In fact, this therapy is routinely used in patients subjected to bedrest to improve circulation through peripheral arteries and veins, thus, reducing occurrence of blood clots.

For the reasons stated above the investigators will observe you closely while giving the treatment described herein. If you have any worrisome symptoms or symptoms that has described to you, notify the investigators immediately.

5. Confidentiality:

Information produced by this study will be stored in the investigator’s file and identified by a code number only. The code key connecting your name to specific information about you will be kept in a separate, secure location. Information contained in your records may not be given to anyone unaffiliated with the study in a form that could identify you without your written consent, except as required by law. It is possible that your medical and/or research record, including sensitive information and/or identifying information, may be inspected and/or copied by the study sponsor and/or federal or state government agencies in the course of carrying out their duties. If your record is inspected or copied by the study sponsor (and/or its agents), or by any of these agencies, the University of Southern Mississippi will use reasonable efforts to protect your privacy and the confidentiality of your medical information. The results of this study may be published in a medical book or journal or used for teaching purposes. However, your name or other identifying information will not be used in any publication or teaching materials without your specific permission.

6. Alternative Procedures:

An alternative is to not participate in this research study.

7. Participant’s Assurance:

This project has been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations.

Any questions or concerns about rights as a research participant should be directed to the Chair of the IRB at 901-266-5997. Participation in this project is completely voluntary, and participants may withdraw from this study at any time without penalty, prejudice, or loss of benefits.

Any questions about the research should be directed to the Principal Investigator using the contact information provided in Project Information Section above.

CONSENT TO PARTICIPATE IN RESEARCH
Participant's Name: __________

Consent is hereby given to participate in this research project. All procedures and/or investigations to be followed and their purpose, including any experimental procedures, were explained to me. Information was given about all benefits, risks, inconveniences, or discomforts that might be expected.

The opportunity to ask questions regarding the research and procedures was given. Participation in the project is completely voluntary, and participants may withdraw at any time without penalty, prejudice, or loss of benefits. All personal information is strictly confidential, and no names will be disclosed. Any new information that develops during the project will be provided if that information may affect the willingness to continue participation in the project.

Questions concerning the research, at any time during or after the project, should be directed to the Principal Investigator with the contact information provided above. This project and this consent form have been reviewed by the Institutional Review Board, which ensures that research projects involving human subjects follow federal regulations. Any questions or concerns about rights as a research participant should be directed to the Chair of the Institutional Review Board, The University of Southern Mississippi, 118 College Drive #5147, Hattiesburg, MS 39406-0001, (601) 266-5997.

Include the following information only if applicable. Otherwise delete this entire paragraph before submitting for IRB approval: The University of Southern Mississippi has no mechanism to provide compensation for participants who may incur injuries as a result of participation in research projects. However, efforts will be made to make available the facilities and professional skills at the University. Participants may incur charges as a result of treatment related to research injuries. Information regarding treatment or the absence of treatment has been given above.

-----------------------------------------------
Research Participant                          Person Explaining the Study
-----------------------------------------------

Date                                        Date
# University of Southern Mississippi, Laboratory of Applied Physiology
## Medical Health History Form

All of the information provided in this form is voluntary.

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<thead>
<tr>
<th>Date:</th>
<th>Biographical information:</th>
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<tbody>
<tr>
<td>Last Name:</td>
<td>First:</td>
</tr>
<tr>
<td>Occupation:</td>
<td>Email:</td>
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<tr>
<td>Home Phone: ( )</td>
<td>Work: ( )</td>
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<td>Address:</td>
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<td>DOB: / /</td>
<td>Age:</td>
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### Highest Education Achieved:

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<tr>
<th>Race:</th>
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</table>
| **Hispanic or Latino** - A person of Mexican, Puerto Rican, South or Central American, or other Spanish culture or origin, regardless of race. The term "Spanish origin," can be used in addition to "Hispanic or Latino."

| **American Indian or Alaska Native** - A person having origins in any of the original peoples of North, South, or Central America, and who maintain a tribal affiliation or community attachment.

| **Asian** - A person having origins in any of the original peoples of the Far East, Southeast Asia, or the Indian subcontinent, including, for example, Cambodia, China, India, Japan, Korea, Malaysia, Pakistan, the Philippine Islands, Thailand, and Vietnam. (Note: Individuals from the Philippine Islands have been recorded as Pacific Islanders in the previous data collection strategies.)

| **Black or African American** - A person having either origins in any of the black racial groups of Africa. "Haitian" can be used in addition to "Black" or "African American."

| **Native Hawaiian or Pacific Islander** - A person having origins in any of the original peoples of Hawaii, Guam, Samoa, or other Pacific Islands.

| **White** - A person having origins in any of the original peoples of Europe, the Middle East, or North Africa.

### Primary Care Physician:

<table>
<thead>
<tr>
<th>Name:</th>
<th>Office Phone:</th>
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<tr>
<td>Address:</td>
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### Emergency Contact:

<table>
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<th>Name:</th>
<th>Relationship:</th>
<th>Phone #:</th>
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</table>
**Medications:** Include over the counter drugs/ oral contraceptive/ dietary supplements

Name/ Dosage/ How often taken:

<table>
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<tr>
<th>Name</th>
<th>Dosage</th>
<th>How often taken</th>
</tr>
</thead>
<tbody>
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</table>

**Allergies:**

**Smoking History:**

Do you smoke Cigarettes? Pipe/ Cigar? Other? If you quit, what year did you quit?

# of packs smoked per day ________________ For how many years _________________
### Alcohol Consumption History:

- **Do you currently drink alcohol?**
- **If you drank alcohol previously, when did you stop?**
- **If you ever did drink alcohol, what is (was) the volume consumed?**

<table>
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<th># of years</th>
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<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Please explain any &quot;YES&quot; answers</td>
<td></td>
</tr>
<tr>
<td>high blood pressure</td>
<td></td>
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<td>chest pain/ history of heart attack</td>
<td></td>
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<tr>
<td>extra heart beats or racing</td>
<td></td>
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<tr>
<td>abnormal electrocardiogram (ECG)</td>
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<tr>
<td>other heart trouble (e.g. murmur, valve problems)</td>
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<td>high cholesterol</td>
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<td>stroke</td>
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</tr>
<tr>
<td>thyroid problems</td>
<td></td>
</tr>
<tr>
<td>difficulty breathing</td>
<td></td>
</tr>
<tr>
<td>emphysema/ asthma/ chronic bronchitis</td>
<td></td>
</tr>
<tr>
<td>tuberculosis</td>
<td></td>
</tr>
<tr>
<td>chronic infection</td>
<td></td>
</tr>
<tr>
<td>stomach/ GI problems</td>
<td></td>
</tr>
<tr>
<td>hepatitis</td>
<td></td>
</tr>
<tr>
<td>bleeding disorder</td>
<td></td>
</tr>
<tr>
<td>kidney/ urinary problems</td>
<td></td>
</tr>
<tr>
<td>joint injuries/ joint pain</td>
<td></td>
</tr>
<tr>
<td>arthritis (rheumatoid or osteoarthritis)</td>
<td></td>
</tr>
<tr>
<td>migraine headaches</td>
<td></td>
</tr>
<tr>
<td>vision problems (exclude corrected near/ far sightedness)</td>
<td></td>
</tr>
<tr>
<td>surgical procedures</td>
<td></td>
</tr>
</tbody>
</table>
**Medical Health History Form**

### Inclusion Criteria for SCI Participants:

1. Adults with chronic T3 – L5, (AIS- A, B, or C) SCI (2 years post injury)
2. Wheelchair reliant (unable to walk with or without support)
3. Between 18 and 75 years of age

### Exclusion Criteria:

1. No evidence of pressure wounds on buttocks or feet
2. Unhealed bone fracture or history of low trauma (fragility) fracture
3. Severe Osteoporosis (T score of -4 or less or a history of fragility fractures)
4. Uncontrolled autonomic dysreflexia
5. Less than 2 years post injury

**Where is the location of your injury?**

**How long have you had the diagnosis of SCI?**

<table>
<thead>
<tr>
<th>Injury Questions:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>Please explain any “YES” answers</td>
<td></td>
</tr>
<tr>
<td>Do you have a history of uncontrolled autonomic dysreflexia?</td>
<td></td>
</tr>
<tr>
<td>Have you suffered a bone fracture recently?</td>
<td></td>
</tr>
<tr>
<td>Have you been diagnosed with orthostatic hypotension?</td>
<td></td>
</tr>
<tr>
<td>Have you been diagnosed with Osteoporosis?</td>
<td></td>
</tr>
<tr>
<td>Do you have a history of bone fragility fractures?</td>
<td></td>
</tr>
<tr>
<td>Do you have any decubitus ulcers or ulcers on the feet?</td>
<td></td>
</tr>
</tbody>
</table>

**Please sign and date:**

Signature: _____________________________ Date: ___________________________
Leisure Time Physical Activity Questionnaire for People with Spinal Cord Injury

(LTPAQ-SCI)

INSTRUCTIONS: I am going to ask you about the time you spent engaging in mild, moderate, and heavy intensity LTPA in the last 7 days. Leisure Time Physical Activity (LTPA) is physical activity that you choose to do during your free time, such as exercising, playing sports, gardening, and taking the dog for a walk (necessary physical activities such as physiotherapy, grocery shopping, pushing/wheeling for transportation are not considered LTPA). Please refer to the intensity chart (next page) for descriptions of what mild, moderate and heavy intensity LTPA feel like.

1. Mild intensity LTPA requires very light physical effort; mild intensity activities make you feel like you are working a little bit, but you can keep doing them for a long time without getting tired...

   During the last 7 days, on how many days did you do mild intensity LTPA? _______

   On those days, how many minutes did you usually spend doing mild intensity LTPA? _______

2. Moderate intensity LTPA requires some physical effort; moderate intensity activities make you feel like you are working somewhat hard, but you can keep doing them for a while without getting tired...

   During the last 7 days, on how many days did you do moderate intensity LTPA? _______

   On those days, how many minutes did you usually spend doing moderate intensity LTPA? _______

3. Heavy intensity LTPA requires a lot of physical effort. Heavy intensity activities make you feel like you are working really hard, almost at your maximum. You cannot do these activities for very long without getting tired. These activities may be exhausting.

   During the last 7 days, on how many days did you do heavy intensity LTPA? _______

   On those days, how many minutes did you usually spend doing heavy intensity LTPA? _______

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### How hard are you working?

<table>
<thead>
<tr>
<th></th>
<th>Nothing at All</th>
<th>Mild</th>
<th>Moderate</th>
<th>Heavy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activity</td>
<td>Includes activities that even when you are doing them, you do not feel like you are working at all.</td>
<td>Includes physical activities that require you to do very light work. You should feel like you are working a little bit but overall you shouldn't find yourself working too hard</td>
<td>Includes physical activities that require some physical effort. You should feel like you are working somewhat hard but you should feel like you can keep going for a long time.</td>
<td>Includes physical activities that require a lot of physical effort. You should feel like you are working really hard (almost at your maximum) and can only do the activity for a short time before getting tired. These activities can be exhausting</td>
</tr>
</tbody>
</table>

### How does your body feel?

<table>
<thead>
<tr>
<th></th>
<th>Breathing &amp; Heart rate</th>
<th>Muscles</th>
<th>Skin</th>
<th>Mind</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stays normal or is only a little bit harder and/or faster than normal</td>
<td>Noticeably harder and faster than normal but <strong>NOT</strong> extremely hard or fast</td>
<td>Fairly hard and much faster than normal.</td>
<td>Fairly hard and much faster than normal.</td>
</tr>
<tr>
<td>Breathing &amp;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heart rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Muscles</td>
<td>Feel loose, warmed-up and relaxed. Feel normal temperature or a little bit warmer and not tired at all</td>
<td>Feel pumped and worked. Feel warmer than normal and starting to get tired after awhile.</td>
<td>Burn and feel tight and tense. Feel a lot warmer than normal and feel tired.</td>
<td>Burn and feel tight and tense. Feel a lot warmer than normal and feel tired.</td>
</tr>
<tr>
<td>Skin</td>
<td>Normal temperature or is only a little bit warmer and not sweaty</td>
<td>A little bit warmer than normal and might be a little sweaty</td>
<td>Much warmer than normal and might be sweaty</td>
<td>Much warmer than normal and might be sweaty</td>
</tr>
<tr>
<td>Mind</td>
<td>You might feel very alert. Has no effect on concentration</td>
<td>Require some concentration to complete</td>
<td>Requires a lot of concentration (almost full) to complete</td>
<td>Requires a lot of concentration (almost full) to complete</td>
</tr>
</tbody>
</table>


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