Research

Supportive Pad Impact on Upper Extremity Blood Flow While Wearing a Military Backpack

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Abstract

Introduction: The Spine Buddy\textsuperscript{®} supportive pad was developed to be inserted underneath military backpacks to help disperse heavy loads.

Purpose: The purpose of this study was to determine the impact the additional supportive pad has on upper extremity blood flow when wearing a heavy military backpack.

Methods: Forty healthy participants (age = 26.4 ± 5.5 yr, height = 1.74 ± 0.11 m, body mass = 79.6 ± 20.4 kg: mean ± SD) were equally randomized into an AB:BA crossover study design. Twenty participants were in the AB group, and twenty were in the BA group. The study involved a 15-minute rest period between each of the 2 conditions: A (wearing a 45.3 kg military backpack) vs B (wearing a 45.3 kg military backpack with an additional ergonomic support pad underneath). Participants wore the backpack for 2 minutes during each condition (A or B) and then upper extremity blood flow measurements were taken. Outcome measures were index finger pulse oximetry and radial artery spectral Doppler Resistance Index (RI) assessed under each condition. An independent samples t-test was used to make comparisons between A and B conditions.
Results: No statistically significant difference was shown between pulse oximetry or RI between A and B conditions.

Conclusion: Preliminarily, the results of this study suggest that wearing an additional support pad underneath a military backpack has no short-term impact, positive or negative, on pulse oximetry or upper extremity blood flow.

Introduction

Low back pain (LBP) is common. Research has shown that LBP is the fifth most common reason for all physician visits\(^1\)\(^-\)\(^2\) and it is the second leading cause of disability in persons under 45 years of age.\(^3\) Surveys have found that within the past year 7.6% of people reported at least one occurrence of an episode of severe acute LBP.\(^4\) LBP is economically expensive for multiple reasons. In 1998 the cost of treating LBP was $26.3 billion dollars in the US\(^5\) and those costs have continued to rise both locally and globally.\(^6\)\(^-\)\(^9\) In addition to these medical economic costs there are also societal economic costs due to lost work productivity from absenteeism\(^10\)\(^-\)\(^13\) and presenteeism,\(^14\)\(^-\)\(^15\) as well as the more subjective costs of reduced quality of life for the duration of LBP.\(^6\)\(^,\)\(^15\)\(^-\)\(^18\)

Musculoskeletal injuries, to include LBP, are common in the military.\(^19\)\(^-\)\(^20\) The primary reason for medical evacuation of US military personnel in Iraq and Afghanistan is musculoskeletal injuries,\(^21\) and these types of injuries remain a common reason for active duty military to receive healthcare.\(^22\)\(^-\)\(^24\) Musculoskeletal injuries also represent a common reason that leads to premature discharge from military service.\(^25\) Military soldiers, particularly warfighters, routinely wear heavy backpacks and are at risk for developing LBP due to the strenuous physical nature of their work.\(^25\)\(^-\)\(^27\) Research even suggests that military service is a predictor for LBP later in life.\(^28\)\(^-\)\(^29\) Any action to reduce the prevalence and incidence of back pain in soldiers should be pursued.

Various countermeasures can be used to reduce prevalence of back pain in the military to include strengthening exercises.\(^30\)\(^-\)\(^31\) Another alternative is the use or ergonomically effective equipment to reduce repetitive strain injuries associated with the high physical demands of being a soldier. One such proposed ergonomic device is the Spine Buddy® supportive pad. It is an ergonomically designed foam pad that can be added underneath a military backpack between the pack and the wearer. The supportive pad was developed to help distribute the weight of heavy military backpacks more evenly on the body frame instead of being held primarily on the shoulders.

As with any new device to be considered for use by the military it must undergo extensive testing to prove its value to soldiers. The purpose of this study was to determine if the Spine Buddy® supportive pad had any positive impact on upper extremity blood flow while wearing a heavy military backpack.

Methods

This study was reviewed and approved by the Institutional Review Board for human subjects at the sponsoring university in accordance with the Declaration of Helsinki. All subjects were provided a written and oral explanation of the study procedures prior to participation.
Study Design and Setting

This was a randomized trial of the immediate effect of wearing an additional supportive pad underneath a heavy military backpack on upper extremity blood flow. Forty participants were randomly and equally assigned to 1 of 2 groups: AB versus BA (Figure 1). “A” condition involved participants wearing a 45.3 kg (100 lb) military backpack for two minutes. “B” condition involved participants wearing a 45.3 kg military backpack with an additional support pad underneath for two minutes. Participants were given a 15-minute rest period without a backpack on in between the two tested conditions to allow upper extremity blood flow to recover. Measurements at the end of each condition, A vs B, included pulse oximetry and Doppler blood flow readings. This study took place in a research lab with a room temperature that was regulated as close as possible to 24°C.

Fig 1. Experimental design.

Participants and Randomization

The first twenty participants were recruited to the AB group and the last twenty participants were recruited to the BA group to avoid selection bias. College students were recruited for the study through word-of-mouth. All study applicants provided an informed written consent on college-approved documents. They were then screened against inclusion and exclusion criteria. To reduce any possible anxiety, study participants were clearly instructed about the basic sequence of their portion of the research study. Sample size was not determined with a power analysis for this pilot study. Participant attributes are listed in Table 1. Both males and females were chosen for this study because it is possible that they both could face combat scenarios. Additionally, in some branches of the military (e.g., Army and Marines) men and women are both expected to be capable of carrying heavy military backpacks dependent on their Military Occupational Specialty (MOS).
Table 1. Participant baseline attributes.

<table>
<thead>
<tr>
<th></th>
<th>AB group</th>
<th>BA group</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sex (M/F)</td>
<td>14/6</td>
<td>13/7</td>
<td></td>
</tr>
<tr>
<td>Age (y)</td>
<td>26.1 ± 5.1</td>
<td>26.6 ± 6.0</td>
<td>0.783</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>81.2 ± 21.5</td>
<td>78.0 ± 19.6</td>
<td>0.628</td>
</tr>
<tr>
<td>Height (m)</td>
<td>1.75 ± 0.11</td>
<td>1.73 ± 0.11</td>
<td>0.474</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>26.1 ± 5.1</td>
<td>25.9 ± 5.2</td>
<td>0.913</td>
</tr>
</tbody>
</table>

Data listed as mean ± SD unless listed as a ratio.
Between-groups baseline data compared with an independent samples t-test.

Inclusion/exclusion criteria

Inclusion criteria were:
- 1) Body Mass Index under 30 kg/m²
- 2) between the ages of 18-50 years of age
- 3) informed written consent was provided

Study participants with any of the following were excluded from the study:
- 1) diagnosis of any cardiovascular, respiratory, neurological, or muscular disorder
- 2) presence of pain in their lumbar spine or lower limbs rated greater than a 3 on a 0-10 Numeric Rating Scale (NRS)

Military backpack wear protocol

The military backpack was filled with two sandbags to make it weigh 45.3 kg. The backpack was loaded onto a metal depth jump platform that was approximately waist-height for most study participants. Two researchers that were prior service U.S. Army Infantry soldiers assisted participants with placing the military backpack on properly and tightening the shoulder straps, chest strap, and waist belt. Once participants had the backpack placed on their back a timer was started. At the conclusion of 2-minutes study dependent variables were measured.

Intervention

The intervention phase of the study involved placing the Spine Buddy® supportive pad (Figures 1-3) underneath a military backpack for participants and adjusting the backpack straps accordingly for participant comfort. The added supportive pad was designed to dampen force exerted on the spine while wearing a heavy military backpack. The impact adding this type of supportive pad to a typical military backpack had not been studied before. Researchers hypothesized that the supportive pad may
marginally displace some weight while wearing the military backpack and that may impact upper extremity blood flow. The Spine Buddy® supportive pad utilized in this study was the camouflage Gap 1-waterproof model (International Neck & Back Cushion Enterprises, Humble, TX, USA) with a gap down the middle of the pad, anteriorly, to ergonomically accommodate the spinous processes of the thoracic spine. The support pad was composed of a woven Nylon cover with an internal 1340 polyurethane foam core. The foam had the following attributes as determined by the ASTM D-3574 test method: $1.30 \pm 0.1$ lbs/cu ft density, 12 min lbs/inch tensile strength, 1.5 min lbs/sq inch tear strength, and 160% elongation. The foam was made by Microcell (Hyannis, MA, USA).

Fig 2. Participant wearing the military backpack and measurements used in this study.
Fig 3. Anterior illustration of the Gap 1-waterproof Spine Buddy® pad
(a) left picture, 1340 polyurethane foam core insert
(b) right picture, the camouflage waterproof nylon insert cover with straps to secure to a backpack frame.

Assessments

Cardiovascular measurements were taken standing after participants wore the backpack for 2 minutes during each condition, A vs B. Two measurements were employed for analysis of cardiovascular response: bilateral pulse oximetry readings at the index finger and spectral Doppler blood flow recording at the radial artery.

Pulse oximetry was measured bilaterally using the Pulse Ox 5500® Finger unit (SPO Medical, Sylmar, CA, USA). The index finger of each hand was used for pulse oximetry recordings. The dependent variable, percent saturation of oxygen on hemoglobin was determined. Values for each upper extremity were then averaged together to provide an overall value for statistical analysis during A vs B conditions for pulse oximetry.

Doppler blood flow from the radial artery was measured bilaterally using the Nicolet VersaLab SE® (Care Fusion, Golden, CO, USA) with Aquasonic Clear® ultrasound gel (Parker Laboratories, Fairfield, NJ, USA). A research assistant palpated the participant’s radial artery bilaterally and made a 1 cm red pen
mark around the location of each radial artery where measurements would be taken. This was performed in an attempt to reduce bias regarding placement of the probe head during each reading (A vs B conditions). A 4 MHz probe was used. Recordings were made at 25 mm/s, gain was set to 5, and scale was adjusted to 2 KHz. The ultrasound probe head was placed at a 45° angle to the artery site of measurement. During all Doppler recordings the participant’s elbow was placed at a 90° angle at their side (as shown in Figure 2). Values for each upper extremity for Resistance Index (RI) were merged together for statistical analysis during A vs B conditions. RI is a common measure of distal blood flow resistance.\(^{32-35}\) The formula for RI is as follows: \(\text{RI} = (S - D) / S.\) \(^{32}\) S is the peak blood velocity in a blood vessel. D is the end-diastolic velocity in a blood vessel.

**Statistical Analysis**

Data were analyzed in SPSS version 20.0 (IBM, Armonk, NY, USA). Results were reported as mean ± standard deviation (SD) unless otherwise specified. An independent samples t-test was used to compare between-group differences for baseline group data and blood flow dependent variables measured. Levene’s test for equality of variance violation was observed. The alpha level of \(p < 0.05\) was considered statistically significant for all between-group variables.

**Results**

Between-groups comparison indicated that there were no statistically significant differences between the groups for either pulse oximetry, \(t(78)= 0.432, p=0.667,\) or Doppler blood flow, \(t(78)= -0.729, p=0.468.\) Table 2 demonstrates the relationships between all of the cardiovascular dependent variables measured.

Table 2. Change in index finger pulse oximetry and radial artery spectral Doppler blood flow. Comparisons were made between 40 participants tested under conditions A (45.3 kg backpack) vs B (45.3 kg backpack with a support pad underneath).

<table>
<thead>
<tr>
<th></th>
<th>Cardiovascular measures</th>
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<tbody>
<tr>
<td>Pulse oximetry (%)</td>
<td></td>
</tr>
<tr>
<td>Control group (A)</td>
<td>97.5 ± 2.6</td>
</tr>
<tr>
<td>Support pad group (B)</td>
<td>97.2 ± 2.6</td>
</tr>
<tr>
<td>(p)-value</td>
<td>0.667</td>
</tr>
<tr>
<td>Resistance Index (RI)</td>
<td></td>
</tr>
<tr>
<td>Control group (A)</td>
<td>0.988 ± 0.048</td>
</tr>
<tr>
<td>Support pad group (B)</td>
<td>0.995 ± 0.022</td>
</tr>
<tr>
<td>(p)-value</td>
<td>0.468</td>
</tr>
</tbody>
</table>

Data listed as mean ± SD. Between-group data were compared with an independent samples t-test.
Discussion

The purpose of this study was to determine if wearing a supportive pad underneath a heavy military backpack would positively impact upper extremity blood flow. Preliminarily, the results from this study suggest there was no impact on upper extremity blood flow in response to wearing the Spine Buddy® supportive pad underneath a heavy military backpack. For perspective, previously this lab engaged in a study of the Spine Buddy® supportive pad analyzing its ability to impact static single-leg balance and 5 mph jogging gait while wearing a 15.9 kg backpack. The additional assistive pad was found to not impact either balance or gait. However, following a survey of participant preference, 70% of participants that wore the pad stated they preferred the additional pad as opposed to no support pad. Contextually, bearing in mind the results of this study and our lab’s previous work on this topic it preliminarily appears that wearing the additional supportive pad has no direct impact on soldier performance, but that it likely is more of an issue of user comfort. Further studies on the product are warranted to corroborate these findings.

Military soldiers often develop musculoskeletal health conditions\(^{19-20}\) and depending on the severity of their condition they can lead to premature discharge.\(^{25}\) Studies have demonstrated that soldiers commonly develop LBP,\(^{25-27}\) particularly as they age.\(^{28-29}\) Any equipment that can help reduce the prevalence and incidence of LBP for military soldiers should be studied. Additional support pads for military backpacks may be one such form of equipment. However, extensive testing must be performed to determine how they impact soldier performance acutely and if they truly lower incidence of LBP over time.

Future directions of research should analyze how firing of weapons in the prone position will be impacted by soldiers wearing a military backpack with the Spine Buddy® supportive pad attached. Also due to the way the supportive pad extends to the base of the posterior neck, studies should be performed on how the pad impacts whiplash in military vehicles (e.g., related to Improvised Explosive Devices/IEDs). Lastly, research should be performed comparing different compressive core densities of the supportive pad to see how they impact performance of common military tasks under various forms of inclement weather (e.g., rain, snow, intense heat, etc.).

Limitations

This pilot study was underpowered. Following a post-hoc power analysis using G*Power version 3.1.3 (Universität Kiel, Germany),\(^{36-37}\) researchers determined study power was 0.716. This analysis was in accordance with a post-hoc power analysis between two independent means with a desired effect size of 0.5, \(a\) of 0.05, and 40 participants per compared group. As a result of this analysis, this study was considered under-powered and the possibility of type II error exists. Ideally, to have a power of 0.90 researchers would need 70 participants per compared independent study group.

Participants in this study only wore the military backpack for 2 minutes under each condition. It would have been more realistic to have participants wear the backpack for an hour under each condition and possibly complete a physical military task (e.g., a 12-mile road march).

Study recruitment was not optimal. Researchers recruited the first 20 participants to the AB group and the last 20 participants to the BA group. Fortunately, the distribution of males and females in each
group was reasonably similar. For future studies a computer-randomized intervention list developed prior to participant recruitment would be more optimal.

**Conclusions**

Prior to this study there was no research into how additional supportive pads worn underneath military backpacks impact upper extremity blood flow. The purpose of this experiment was to determine if wearing an additional supportive pad underneath a heavy military backpack would positively impact upper extremity blood flow by distributing the backpack weight more evenly on the torso. Preliminarily, the findings of this study suggest that wearing the Spine Buddy® support pad has no positive or negative impact on upper extremity blood flow while wearing a heavy military backpack.

**Funding sources and potential conflicts of interest**

This study was supported by a grant from the Spine Buddy® company.

**References**


