

THE INFLUENCE OF BACKPACK CHEST STRAPS ON PHYSIOLOGICAL  
AND PERFORMANCE VARIABLES ASSOCIATED  
WITH SIMULATED ROAD MARCHING

By

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## ABSTRACT

This study compared physiological and performance variables during heavy load carriage while wearing an armored vest under a standard issue military backpack using three different chest strap conditions (no chest strap, NCS; standard chest strap, SCS; modified chest strap, MCS). Twenty subjects, all right-handed shooters, completed 4 laboratory visits. The subjects filled out paperwork, received consumables for the next visit, and performed a handgrip strength test during the first visit. The following 3 visits were testing visits with 2 treadmill walking trials per visit at a fixed speed (80.5 m/min) and grade (2%). Each testing visit corresponded to 1 of 3 conditions (NCS, SCS, or MCS) and included a baseline trial carrying only a training rifle (3.3 kg) followed by a pack trial wearing an armored vest, pack, and rifle (47 kg total). Heart rate (HR, bpm), relative oxygen consumption ( $RVO_2$ , ml/kg/min), minute ventilation ( $V_E$ , L/min), and breathing frequency (BF, breaths/min) were measured. Circumferences (bicep,  $C_B$ , and forearm,  $C_F$ , cm) and blood lactate (BL, mmol/L) were assessed once per trial on the non-trigger finger arm, while two-point discrimination (mm) was assessed once on the back of the trigger finger hand. Rating of perceived discomfort (RPD), fingertip oxygen saturation ( $SpO_2$ , %), and stride rate (SR, stride/min) were assessed twice each trial. Maximum handgrip strength was assessed in each hand simultaneously (HG right and left, kg) two times per trial. All variables were assessed using multivariate 2-factor RM ANOVA and Scheffe's post hoc test ( $\alpha = 0.05$ ). Baselines for all variables were similar. Pack trial means for HR,  $RVO_2$ ,  $V_E$ , and BF were higher than baseline but no difference between strap conditions. Fingertip  $SpO_2$  was lower during pack trials than baseline. There were no differences in  $V_T$ , BL, or left HG between conditions. NCS resulted in greater  $C_F$  and  $C_B$  than baseline with  $C_F$  also being greater than MCS. Right HG was greater for MCS than baselines and NCS. Right and left HG increased 2 minutes post walking. MCS and SCS provided the least evidence for negatively affecting physiologic and performance outcomes, whereas NCS provides the most evidence for negatively affecting outcomes.

## CHAPTER ONE

## INTRODUCTION

Packs are used to carry loads for business, survival, educational, recreational, or military purposes. Dempsey et al. (1996) stated that mail carriers who deliver mail via walking could use a satchel attached to the body in different ways. The satchel, however it was attached to the body, was a means of carrying the mail in an organized manner, as well as protection for the mail carrier. In general, each satchel had a shoulder strap attached to a pouch. Furthermore, some had belts to which the pouch attached to in order to provide more support. However, Nepalese porters transported goods over mountainous terrain using a basket which was supported by a head strap and situated on their backs (Bastien, Schepens, Willems, and Heglund 2005). Another ethnic group that used head supported load carriage was African women (Maloiy, Heglund, Prager, Cavagna, and Taylor 1986) who carried food and water to be used by their families.

Carrying loads everyday is also common for students who carry books in frameless backpacks with one and two shoulder straps, front packs, and double packs (Legg and Cruz 2004; Motmans, Tomlow, and Vissers 2006; Negrini 1999). Traditional backpacks with two shoulder straps can be used in different fashions, such as placing the pack on the front as a front pack or using two traditional backpacks to create a double pack (Motmans, Tomlow, and Vissers 2006). However, the backpacks with one shoulder strap were worn with the strap coming across the chest diagonally (Legg and Cruz 2004).

Backpacks are also used for recreational purposes. Recreational backpackers, for example, normally use backpacks with frames because the frame allows the backpackers to more easily carry heavy loads (Alpeche 2011). According to Alpeche and Trager USA (2011), backpacking significantly progressed as a recreational activity in the 1920's when the first pack board was invented by Lloyd Nelson. Backpacks prior to the 1920's did not have a frame (Alpeche 2011; Trager USA 2011). Today, most recreational backpacks, which come in many different colors, shapes, and sizes, have similar components. For example, modern backpacks tend to have two adjustable shoulder straps, a chest strap, and a waist belt, all of which allow the backpack load to be secured to the body when walking.

Even with a frame and a waistbelt for support, some backpackers carrying heavy loads complained of pain, numbness, or weakness at the shoulder from the shoulder straps (Corkill, Lieberman, and Taylor 1980; Nylund et al 2011; Rothner, Wilbourn, and Mercer 1975). These types of symptoms are also reported in military populations with common long duration heavy load carriage (Corkill, Lieberman, and Taylor 1980; Jones and Hooper 2005; Knapik et al. 1997; Knapik, Harman, and Reynolds 1996; Maurya et al. 2009; Nylund et al., 2011; Rothner, Wilbourn, and Mercer 1975). Often times, active duty military personnel are carrying a pack while wearing body armor because they are in combat scenarios (Crowder et al. 2007; Military Morons 2009; Stevenson et al. 2004). Wearing armor, which could weigh up to 20.5 kg with the supporting gear (Crowder et al. 2007), increases the load being carried, which can cause changes in physiological variables such as energy expenditure (Bastien, Schepens, Willems, and Heglund 2005;

Bastien, Willems, Schepens, and Heglund 2005; Beekley et al. 2007; Crowder et al. 2007; Maloiy, Heglund, Prager, Cavagna, and Taylor 1986; Sagiv, Ben-Gal, and Ben-Sira 2000). Heavy load carriage can also cause changes in field performances, such as grenade throws and other activities requiring muscle strength (Knapik et al. 1997; Knapik et al. 1996; Nylund et al. 2011).

Another consideration for heavy load carriage is the way the load is attached to the body. Many studies, for example, have described how the shoulder straps or harnessing are adjusted (Bryant et al. 2001; Knapik et al. 1996; Nylund et al. 2011; Rothner, Wilbourn, and Mercer 1975). Knapik et al. (1997) and Stevenson et al. (2004), for example, give more information than simply stating a backpack was worn using shoulder straps. In the Knapik et al. (1997) study, subjects used a hip belt to support the heavy load so that it reduced the load supported by the shoulders. However, Stevenson et al. (2004) states that all straps (shoulder, waist, sternum, etc) were adjusted to a standardized tension. Even though Knapik et al. (1997) and Stevenson et al. (2004) state what straps were used, they were not investigating the significance of using different types of straps.

Stevenson et al. (2004) also described how the fragmentation and tactical armored vests were worn either alone or under a backpack. However, there was no description of how the backpack straps were adjusted when wearing the backpack over either vest. Interestingly, Military Morons (2009) says that the shoulder straps of the pack generally slide laterally toward the deltoids when worn over armor. In fact, if a chest strap is not worn, the shoulder straps of the backpack can slide laterally the most. Changes in

position of the shoulder straps could cause compression in vulnerable areas of the upper body, such as the brachial plexus, or discomfort at the shoulders, potentially changing physiological and performance outcomes.

Anecdotal reports from recently deployed U.S. military ground troops in Iraq and Afghanistan suggest that heavy load carriage while wearing armor without a chest strap causes numbness, tingling, and/or pain in the upper extremities. Soldiers can try to alleviate this compression and discomfort by using either a standard chest strap or a modified chest strap. Typical pack design includes a standard chest strap which uses two smaller straps, one attached to each shoulder strap, that fasten across the sternum to pull the shoulder straps toward the midline of the body. Alternatively, a modified chest strap (Mystery Cinch™; Mystery Ranch, Bozeman, MT), which attaches to the armor, wraps around the shoulder straps, and fastens across the chest in order to pull the straps closer to the midline of the body. Since the modified chest strap attaches directly to the armor rather than the shoulder straps of the backpack, the manufacturer suggests that this design better alleviates shoulder discomfort. Both types of chest straps, standard and modified, are designed assuming shoulder discomfort and negative changes in physiological and performance outcomes will be alleviated when used. However, no published research has attempted to quantify whether either chest strap is positively influencing either physiological or performance outcomes when carrying a heavy load.

### Statement of Purpose

The purpose of this study was to compare physiological and performance measures resulting from heavy load carriage while wearing an armored vest under a standard issue military backpack. Specifically, the influence of two types of chest straps, standard and modified, on upper body and whole body measures were compared with the use of no chest strap.

### Hypothesis

The null hypothesis was that there were no differences between means for physiological and performance variables amongst the three test conditions: using the modified chest strap, or MCS; using the standard chest strap, or SCS; using no chest strap, or NCS. The alternative hypothesis was that physiological or performance variables would significantly differ between the test conditions.

$$H_0: \mu_{MCS} = \mu_{SCS} = \mu_{NCS}$$

$$H_a: \mu_{MCS} \neq \mu_{SCS} \neq \mu_{NCS}$$

Where:  $\mu_{MCS}$ ,  $\mu_{SCS}$ , and  $\mu_{NCS}$  are population means for physiological and performance variables. The physiological variables included heart rate (HR), oxygen consumption ( $VO_2$ ), oxygen saturation ( $SpO_2$ ), blood lactate (LA), forearm circumference, bicep circumference, two-point discrimination and rating of perceived discomfort (RPD). The performance variables were stride rate and handgrip strength in the left and right hands.

### Assumptions

It is assumed that subjects will follow exercise, nutrition, and hydration guidelines prior to each laboratory visit. It is also assumed that the participants will understand all instructions, written and verbal, and that all responses given by the subject will be honest and accurate.

### Limitations

1. The load carried will be a different percentage of body mass for each individual.
2. The backpack does not fit every subject perfectly but was sized as well as possible for each subject.
3. The armored vest was tightened so that it was fit similarly for each subject for each visit.

### Delimitations

1. This study was delimited to sub-maximal treadmill walking in a laboratory setting.
2. This study was delimited to using a standard Marine issued pack (FILBE) and plated body armor.
3. The study was delimited to carrying a fixed load (46.9 kg).
4. This study was delimited to subjects accustomed to load carriage (e.g., ROTC, active military, reserves, veterans, and hunters) from the Bozeman, MT, area.

Operational Definitions

Armored vest:	Ceramic plates and Kevlar® panels worn in a Modular Tactical Vest (MTV).
Backpack (or pack):	The standard Marine issued Family of Improved Load Bearing Equipment (FILBE) frame with bag and waist belt.
Blood Lactate:	The amount of lactate present in the blood due to anaerobic metabolism.
Chest strap:	A part of the original FILBE pack setup that has two straps and a buckle fastener attached to the shoulder straps.
Discomfort rating:	The self-assessed rating of discomfort on a 0-10 scale, where discomfort was defined as distressing, irritating, or causing soreness.
Dominant hand:	The preferred hand to be used for pulling the trigger when firing a rifle.
Handgrip strength:	The maximum amount of gripping force (kg) produced by the hand when measured over a three second period.
Heart rate (HR):	The number of heartbeats per minute measured by a telemetry-based heart rate monitor.
Lactate threshold (LT):	The point at which lactate accumulation rate in the blood surpasses the clearance rate due to the intensity of exercise.

- Modified Chest Strap: Two straps with a buckle fastener mounted on an armored vest with MOLLE/PALS webbing on the front; also called a Mystery Cinch™ (Military Morons, 2009).
- Oxygen consumption ( $VO_2$ ): The rate of oxygen usage by tissues as expressed by the ratio of amount of oxygen being extracted from the air per minute.
- Oxygen saturation ( $SpO_2$ ): The percentage of hemoglobin that is bound with oxygen when compared to total oxygen carrying capacity.
- Training rifle: A rubberized rifle made to the same dimensions and weight as a combat issued rifle.

## CHAPTER TWO

### REVIEW OF LITERATURE

#### Introduction

The success of the military is often gauged on the number of successful missions completed. Military personnel performance is of utmost importance in order to successfully complete those missions. A soldier's overall performance must account for individual abilities (Crowder et al. 2007) as well as the equipment functionality (Bryant, Doan, Stevenson, Pelot, and Reid 2000), especially when carrying a heavy load. Thus, characteristics of physiological performance, motor performance, and pack performance should be considered when evaluating heavy load carriage by soldiers.

#### Physiological Measurements

Many different physiological markers are easily collected in a controlled laboratory setting. The most common physiological marker measured in pack studies, other than energy expenditure, is heart rate. Other physiological markers, such as blood lactate, oxygen saturation and two-point discrimination, are pertinent to understanding the effects of carrying a heavy backpack.

#### Energy Expenditure

There is a long standing question of how to use the least energy to carry an external load. Maloiy, Heglund, Prager, Cavagna, and Taylor (1986) found that two

different tribes of African women, Luo and Kikuyu, do not increase energy expenditure with load carriage up to 20% of their body weight, after which there is a proportional increase in energy expenditure. Each tribe used a different carrying method; the Luo tribe carried loads balanced on their head, while the Kikuyu tribe used a head strap to support the load across the forehead (Maloiy, Heglund, Prager, Cavagna, and Taylor 1986). There was no difference in energy expenditure values between these two methods of load carriage and wearing a backpack. A similar study was completed on Nepalese porters by Bastien, Schepens, Willems, and Heglund (2005). The researchers found that Nepalese porters carrying basket loads supported by a head strap had lower energy expenditure values than those carrying the same load in a backpack.

Researchers have also investigated whether soldiers could carry head supported loads. Maloiy, Heglund, Prager, Cavagna, and Taylor (1986) state that it is harder to carry a load on the head than on the back for individuals not trained in doing so. The African women and Nepalese porters are often trained from childhood in carrying head supported loads (Bastien, Schepens, Willems, and Heglund 2005; Maloiy, Heglund, Prager, Cavagna, and Taylor 1986). Therefore, it was postulated that the training time needed for soldiers to use head supported load carriage would be unreasonable for military use. Another consideration of head supported loads, especially those balanced on top of the head, would be that the height of the load might be easier to see by the enemy in combat. The head supported load would also reduce the soldier's ability to scan the area for potential dangers by decreasing mobility at the neck.

Since loads are more conveniently carried on the back and training time is less, the military uses backpacks to transport loads for survival and during combat (Army Field Manual 1990). According to the Army Field Manual (1990), an approach load and combat load should be less than 32.7 kg and 21.8 kg, respectively. These weights are suggested because of the likelihood of soldiers tiring more quickly if heavier loads were carried.

Several studies have been completed that explore the relationship between energy cost and carrying a load (Bastien, Willems, Schepens, and Heglund 2005; Beekley et al. 2007; Bilzon, Allsopp, and Tipton 2001; Crowder et al. 2007; Lloyd and Cooke 2000; Sagiv, Ben-Gal, and Ben-Sira 2000). Sagiv, Ben-Gal, and Ben-Sira (2000) found that energy expenditure measured by oxygen uptake did not change between carrying 25 kg and 35 kg loads while walking on a treadmill. Bilzon, Allsopp, and Tipton (2001) studied running on a treadmill with an 18 kg load found that body size can play a role in the ability to carry loads. The authors found that lighter subjects had higher energy expenditure values and carried the pack for a shorter duration. However, Bastien, Willems, Schepens, and Heglund (2005) and Beekley et al. (2007) examined the effects of load as a percentage of body mass instead of an absolute mass. Bastien, Willems, Schepens, and Heglund (2005) found that loaded walking has a higher energy cost than unloaded, and there was an optimal speed for walking while loaded up to 75% of body mass. This speed was similar to the optimal speed for unloaded walking. Optimal speed was defined by the authors as the speed at which the mass specific gross energy cost (J/kg/m) was the lowest. However, the authors did not evaluate the data for differences in

oxygen consumption between conditions. Beekley et al. (2007) examined carrying 30%, 50%, and 70% of lean body mass and found significant increases in oxygen consumption with each increase in load as a percentage of body mass.

After examining absolute loads and percentage of body mass loads, the next scenario to examine would be the same load in different packs. Lloyd and Cooke (2000) assessed the metabolic differences between three packs with the same 25.6 kg load. The study subjects walked both downhill and uphill carrying one of two different types of AARN packs, or a traditional rucksack. Although there were no significant differences in oxygen consumption between the packs, the values for the AARN packs tended to be lower (Lloyd and Cooke 2000). Crowder et al. (2007) also evaluated the metabolic differences between two functionally equivalent military ensembles (FEMEs), each carrying the same load, and found no significant differences in oxygen consumption.

In summary, the articles described above suggest that differences in metabolic cost are observed when the load carried is compared as a percentage of body mass. This infers that heavier individuals can carry a greater percentage of their weight using less energy as Bilzon, Allsopp, and Tipton (2001) suggested. The researchers also suggest that energy expenditure does not change when the same load is placed within slightly different pack designs.

### Submaximal Heart Rate

Heart rate can give an indication of intensity of the work being performed, as well as increases as work rate increases (American College of Sports Medicine 2010; American College of Sports Medicine 1998). Therefore it is obvious that heart rate would

increase when load carriage increases during exercise. Sagiv, Ben-Gal, and Ben-Sira (2000) found a significant difference in heart rate between loaded and unloaded conditions (35 kg, 25 kg, and 0 kg). However, they did not find a difference in heart rate between pack loads of 25 and 35 kg, whereas Knapik et al. (1997) found a difference in heart rate between 34 kg and the 48 kg loads, between 38 kg and 61 kg loads, but not between 48 kg and 61 kg loads. The variations in heart rate responses described above could be due to work rate not increasing enough to cause significant differences in energy expenditure values. Beekley et al. (2007) increased work rate in a different fashion by increasing load as a percent of lean body mass (30%, 50%, and 70%). Significant differences in heart rate occurred between each pack load, which suggests that a load increase of 20% relative to lean body mass is sufficient to increase heart rate.

The type of pack carried could also be an influence on heart rate responses. Knapik et al. (1997) found that the use of a double pack, which distributed the load evenly between the front and back of the body, elicited lower heart rates than the ALICE pack on a 20 km road march. However, Crowder et al. (2007) found that heart rate was not significantly different between two FEMEs of about the same weight. Therefore, within each load trial, heart rate should not continually increase if the load remained constant since work rate would remain constant. Although, heart rate could see increases if there is prolonged distress or discomfort in the upper extremity.

### Blood Lactate

Blood lactate is not only an indication of exercise intensity (ACSM, 1998), but it is also a determinant of endurance performance (Farrell et al. 1979). Farrell et al. (1979)

found that distance runners ran at a velocity close to their lactate threshold, meaning there was a higher intensity of exercise than slower velocities. Sagiv, Ben-Gal, and Ben-Sira (2000) found that simply carrying a load did not increase work load enough to significantly increase blood lactate when walking on level ground. It was not until carrying a load while walking at a 10% grade that lactate accumulation passed lactate threshold. Sagiv, Ben-Gal, and Ben-Sira (2000) mention that low fingertip blood lactate levels could suggest that there is sufficient blood flow to the upper extremities. As a result of any restriction of blood flow to the arms due to heavy load carriage, blood would not be circulating as fast to and from the upper extremities allowing for the accumulation of lactate in the blood. Thus blood lactate measurements could give insight into the intensity of exercise or restriction of blood flow to the upper extremity.

#### Oxygen Saturation and Two-point Discrimination

Oxygen saturation is the percentage of hemoglobin that is bound with oxygen when compared to total oxygen carrying capacity. Changes in oxygen saturation, as measured by pulse oximetry, could also be an indication of restricted blood flow (Schutz 2001). Wong et al. (2007) measured oxygen saturation and oxygen tension, where oxygen tension is another indirect measurement of blood flow. Using transcutaneous oximetry of the heel, Wong et al. (2007) found that oxygen tension of the heel decreased with pressure loading unless the patient was given an oxygen challenge. The researchers found a decrease of heel oxygen tension in both operative and non-operative feet of post-hip surgery patients, who did not receive supplemental oxygen, by them simply having their feet on the bed. Wong et al. (2007) suggested that there was not enough blood flow

when the heel was on the bed. However, if oxygen saturation remained normal through an oxygen challenge, then oxygen tension in the tissues did not change. This suggested that continuous external pressure can cause changes in local blood flow and ultimately local oxygen saturation in someone not breathing supplemental oxygen.

Holloway, Daly, Kennedy, and Chimoskey (1976) did not investigate oxygen saturation, but they did examine the effects of forearm pressure loading on blood flow to the skin. The investigators did this by examining the clearance rates of a Xenon radioactive isotope, Xe-133. The authors found that as external pressure loading of the forearm increased from 0 to 10 mmHg, blood flow decreased rapidly. Blood flow decreased rapidly again with pressures above 30 mmHg and decreased once more with pressures above 120 mmHg, the latter of which resulted in no blood flow. However, between 10 and 30 mmHg, blood flow remained constant, though lower than that for the unloaded condition. Finally, when pressure was released a hyperemic flow response was not observed with pressures below 90 mmHg (Holloway, Daly, Kennedy, and Chimoskey 1976). Based on the above observations, fingertip pulse oximetry could provide indirect measurements of blood flow restriction due to external compression of the skin from a backpack.

External skin pressure may also compress nerves which could cause sensory loss (Rothner, Wilbourn, and Mercer 1975). Pressure at the shoulder and back can be caused by carrying a heavy load and the design of the backpack (Bryant et al. 2001; Piscione and Gamet 2006). Maurya, Singh, Bhandari, and Bhatti (2009) found that even though a heavy backpack was carried, no sensory loss occurred in the subject's hands in this case

study. Thus, heavy load carriage does not always mean sensory loss. However, if the pressure from the pack is compressing nerves, there could be an effect on sensory perception. Sensory perception is the ability of the nerves in the skin to feel touch, temperature, and pain (Nolan 1982; Sato et al. 1999). Sensory perception can be measured by two-point discrimination, which is a test to determine when a subject can no longer distinguish between two distinct points when touched on the skin (Nolan 1982; Sato et al. 1999). The hands are often used to test two-point discrimination because they are more sensitive than other areas of the arm (Nolan 1982; Sato et al. 1999). Sato et al. (1999) found an average two-point discrimination threshold of  $11.8 \pm 0.3$  mm on the back of the hand for a range of 3 mm to 40 mm.

### Performance Measurements

A useful performance measure for muscle function is handgrip strength (Schlusel, dos Anjos, de Vasconcellos, and Kac 2008). Schlusel, dos Anjos, de Vasconcellos, and Kac (2008) and Luna-Heredia, Martin-Pena, and Ruiz-Galiana (2005) found that the dominant hand in healthy adults tended to have greater handgrip strength. Furthermore, Schlusel, dos Anjos, de Vasconcellos, and Kac (2008) found that mean handgrip strength for 20-29 year old men was 45.8 kg and 43.8 kg for the right and left hands, respectively. The researchers also found mean handgrip strength for 20-29 year old women in the right (27.2 kg) and left (25.6 kg) hands. However, Schlusel, dos Anjos, de Vasconcellos, and Kac (2008) and Luna-Heredia, Martin-Pena, and Ruiz-Galiana (2005) found that handgrip decreased after 40 years of age. Another factor in

handgrip strength could be the use of the hands during sporting activities. Gobbi, Francisco, Tuy, and Kvitne (2005) studied three groups of off-road motorcyclists: motorcross, enduro, and desert rally. The researchers found desert rally riders' and enduro riders' dominant hand had higher handgrip strength values; however, motorcross riders' non-dominant hand had higher handgrip strength values. The authors suggested that motorcross riders have higher handgrip strength values in their non-dominant hand (left hand for all tested) because of the frequent use of the clutch lever located on the left handlebar. Therefore, handgrip strength values have been shown to differ with age, gender, hand dominance, and hand use during a sporting activity.

Performance measures can decrease after carrying a backpack due to muscle fatigue or motor weakness (Piscione and Gamet 2006; Rothner, Wilbourn, and Mercer 1975). Piscione and Gamet (2006) used arm abduction strength as a measure of muscle function, noting that muscle fatigue was greater in the upper trapezius than the middle deltoid when carrying a backpack without a frame and waistbelt. Compressive force directly at the shoulders was postulated to cause the muscle fatigue since there was not a greater activation of the muscle. The compressive force could have inhibited the electrical conduction of motor neurons (Piscione and Gamet 2006).

Knapik et al. (1997, 1991) investigated two performance measures, marksmanship and grenade throwing, in their studies. The investigators (1997) found that soldiers had more variability in shooting at the first target than the last two targets. Knapik et al. (1991) also found that the number of hits for marksmanship was not only more variable but there were fewer hits. The researchers suggested that the variability could be caused

by higher heart rates prior to firing at the first target, higher respiration rates, or fatigue induced tremors (Knapik et al. 1997; Knapik et al. 1991). Knapik et al. (1997) also found that grenade throwing accuracy was not affected by carrying a heavy load, but that the distance grenades were thrown decreased (Knapik et al. 1991).

These articles indicate that most performance measures decrease after carrying a heavily loaded backpack. Thus, load carriage in a backpack is a factor of performance no matter the style or weight. Performance variables of the upper body together with physiological variables can provide a better representation of what is happening to the body when carrying a backpack with a heavy load than either set of variables alone.

#### Backpack Functionality and Comfort

Several previous studies have evaluated the effects of compressive forces on the shoulders when wearing a pack. Bryant et al. (2001) studied the forces placed on different parts of the torso due to the configuration of the backpack and loads of 31.8 kg to 33.1 kg. The researchers found that the shoulders supported 70% to 80% of the mass and the lumbar region supported the remaining 20% to 30%, depending upon the type of pack. There were four load carriage systems studied, with all load carriage systems surpassing the pressure mark of 20 kPa at the shoulder indicating localized discomfort. Discomfort was reported 95% of the time when pressure was above 20 kPa (Bryant et al. 2001). All of the packs were deemed uncomfortable on the front and top of the shoulders, while only one of the four was uncomfortable at the back of the shoulders and scapulae. Jones and Hooper (2005) then studied the effects of wearing clothes underneath the shoulder straps

of the backpack, knowing that the straps cause pressure and discomfort. These researchers found that the pressure was still the same no matter the type or number of layers of garments.

Stevenson et al. (2004) not only studied packs, but fragmentation vests and tactical vests as well. According to the research completed by Stevenson et al. (2004), two of the three fragmentation vests created pressure points of 70 kPa and 89 kPa in areas with seams or closures. The researchers also found that two of the fragmentation vests were uncomfortable to users. There was not a fragmentation vest that was both comfortable and did not evoke high pressures; furthermore, only one of the tactical vests was within pressure limits. Pressure limits for the vest alone are important since most soldiers will also be carrying a pack. Stevenson et al. (2004) also tested three different packs while wearing a tactical vest. The investigators found that one pack (F), which combined the old and new systems, to have the best pack performance, meaning that it had less pack movement, lower pressures overall, and was more easily maneuverable. The "F" pack also was the pack that articulated with the tactical vest the best.

Functionality of the pack and its integration with personal protection (e.g. fragmentation or tactical vests) is important not only for comfort but for the safety of the soldier. However, when soldiers are in the field they may not fully use the equipment issued, such as backpack chest straps. Anecdotal evidence suggests many soldiers do not use a backpack chest strap in the field. Not using the equipment at all or as it was intended could result in a higher injury rates in addition to potentially increasing the risk of discomfort or loss of functionality.

### Pack Palsy

Pack palsy, also known as rucksack palsy or backpack palsy, is associated with heavy load carriage in a backpack (Corkill, Lieberman, and Taylor 1980; Knapik, Harman, and Reynolds 1996; Maurya, Singh, Bhandari, and Bhatti 2009; Nylund et al. 2011; Rothner, Wilbourn, and Mercer 1975). Backpack palsy is characterized by numbness or tingling in an arm, as well as sensory loss and/or motor weakness with little to no pain in an upper extremity (Corkill, Lieberman, and Taylor 1980; Knapik, Harman, and Reynolds 1996; Maurya, Singh, Bhandari, and Bhatti 2009; Nylund et al. 2011; Rothner, Wilbourn, and Mercer 1975). These symptoms are usually present in one side or the other, yet it is unclear if the palsy affects the non-dominant or dominant side first (Corkill, Lieberman, and Taylor 1980; Maurya, Singh, Bhandari, and Bhatti 2009; Rothner, Wilbourn, and Mercer 1975). Corkill, Lieberman, and Taylor (1980) reported in a case study that symptoms were relieved after the pack was removed for several minutes; however, the symptoms would immediately return if the pack was worn again.

Another symptom associated with pack palsy is scapular winging (Corkill, Lieberman, and Taylor 1980), which is when the scapula protrudes from the back abnormally. Muscle atrophy was also documented in the affected upper extremity for some cases of pack palsy (Corkill, Lieberman, and Taylor 1980; Maurya, Singh, Bhandari, and Bhatti 2009; Rothner, Wilbourn, and Mercer 1975). Pack palsy usually had a full recovery assuming cessation of heavy load carriage until symptoms are relieved and the muscle size returns to normal (Corkill, Lieberman, and Taylor 1980; Maurya, Singh, Bhandari, and Bhatti 2009; Nylund et al. 2011; Rothner, Wilbourn, and Mercer

1975). However, if heavy load carriage is continued recovery may be limited or not occur at all (Corkill, Lieberman, and Taylor 1980; Nylund et al. 2011).

There have been anecdotal reports of similar symptoms (i.e., tingling, numbness, etc.) from current U.S. military troops after heavy load carriage and wearing armor. Therefore, before the current study proceeded, pilot testing was completed. During pilot testing, the subjects received constant verbal reminders not to adjust the pack at the shoulders or shrug the shoulders to change the placement of the pack on the shoulders. This was in an attempt to exaggerate the scenario in which symptoms could occur. Most of the pilot test subjects reported discomfort in the upper extremity in the form of slight pain at the shoulders, tingling down the arm and hands, or taking more effort to raise their arms. However, extreme caution was taken to ensure that the backpack and armor setup was the safest for each individual.

### Summary

Pack weight, design, and duration of carriage are important factors to consider when examining the ability of soldiers to function at their best, both physiologically and functionally. These considerations of heavy load carriage could also affect the health and safety of soldiers. If soldiers are not completely healthy then their motor and physiological performance will be compromised. Providing soldiers with the best, and safest, equipment for training and combat increases the likelihood of successfully completing a mission.

CHAPTER THREE

THE INFLUENCE OF BACKPACK CHEST STRAPS ON PHYSIOLOGICAL  
AND PERFORMANCE VARIABLES ASSOCIATED  
WITH SIMULATED ROAD MARCHING

Contribution of Authors and Co-Authors

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## ABSTRACT

This study compared physiological and performance variables during heavy load carriage while wearing an armored vest under a standard issue military backpack using three different chest strap conditions (no chest strap, NCS; standard chest strap, SCS; modified chest strap, MCS). Twenty subjects, all right-handed shooters, completed 4 laboratory visits. The subjects filled out paperwork, received consumables for the next visit, and performed a handgrip strength test during the first visit. The following 3 visits were testing visits with 2 treadmill walking trials per visit at a fixed speed (80.5 m/min) and grade (2%). Each testing visit corresponded to 1 of 3 conditions (NCS, SCS, or MCS) and included a baseline trial carrying only a training rifle (3.3 kg) followed by a pack trial wearing an armored vest, pack, and rifle (47 kg total). Heart rate (HR, bpm), relative oxygen consumption ( $RVO_2$ , ml/kg/min), minute ventilation ( $V_E$ , L/min), and breathing frequency (BF, breaths/min) were measured. Circumferences (bicep,  $C_B$ , and forearm,  $C_F$ , cm) and blood lactate (BL, mmol/L) were assessed once per trial on the non-trigger finger arm, while two-point discrimination (mm) was assessed once on the back of the trigger finger hand. Rating of perceived discomfort (RPD), fingertip oxygen saturation ( $SpO_2$ , %), and stride rate (SR, stride/min) were assessed twice each trial. Maximum handgrip strength was assessed in each hand simultaneously (HG right and left, kg) two times per trial. All variables were assessed using multivariate 2-factor RM ANOVA and Scheffe's post hoc test ( $\alpha = 0.05$ ). Baselines for all variables were similar. Pack trial means for HR,  $RVO_2$ ,  $V_E$ , and BF were higher than baseline but no difference between strap conditions. Fingertip  $SpO_2$  was lower during pack trials than baseline. There were no differences in  $V_T$ , BL, or left HG between conditions. NCS resulted in greater  $C_F$  and  $C_B$  than baseline with  $C_F$  also being greater than MCS. Right HG was greater for MCS than baselines and NCS. Right and left HG increased 2 minutes post walking. MCS and SCS provided the least evidence for negatively affecting physiologic and performance outcomes, whereas NCS provides the most evidence for negatively affecting outcomes.

## Introduction

U.S. military troops often carry heavy backpack loads in the field. This heavy load carriage can increase physiological stress and negatively affect measures of field performances (Bastien, Schepens, Willems, and Heglund 2005; Bastien, Willems, Schepens, and Heglund 2005; Beekley et al. 2007; Crowder et al. 2007; Knapik et al. 1997; Knapik et al. 1996; Maloiy, Heglund, Prager, Cavagna, and Taylor 1986; Nylund et al. 2011; Sagiv, Ben-Gal, and Ben-Sira 2000). For example, Beekley et al. (2007) examined carrying 30%, 50%, and 70% of lean body mass and found significant increases in oxygen consumption with each increase in load as a percentage of body mass. The researchers also found an increase in heart rate with each increase in load carried (Beekley et al. 2007). However, Crowder et al. (2007) found that heart rate and oxygen consumption were not significantly different between two functionally equivalent military ensembles (FEMEs) of about the same weight. Therefore, heart rate and oxygen consumption should not continually increase within a test trial unless there are other contributing factors, such as fatigue.

Muscle fatigue can negatively influence field performances (Piscione and Gamet 2006; Rothner, Wilbourn, and Mercer 1975). For example, Knapik et al. (1991) found that grenade throw distance decreased after heavy load carriage, but grenade throw accuracy was not compromised (Knapik et al. 1997). Piscione and Gamet (2006) used shoulder abduction strength as a measure of muscle function, noting that muscle fatigue increased with an increase in load. The researchers also postulated that the decreased shoulder abduction strength could have been due to an inhibition of motor neuron

electrical conduction from compressive forces directly on the shoulder from backpack shoulder straps (Piscione and Gamet 2006).

While in the field, active duty troops are frequently required to carry a heavy backpack load and wear body armor, which increases the total load carried (Crowder et al. 2007; Military Morons 2009; Stevenson et al. 2004). Anecdotal reports from current U.S. military troops suggest that heavy load carriage while wearing an armored vest without using a chest strap can result in severe discomfort, numbness, and/or tingling in the upper extremities. These symptoms are similar to those reported in several case studies of pack palsy (Corkill, Lieberman, and Taylor 1980; Jones and Hooper 2005; Knapik et al. 1997; Knapik, Harman, and Reynolds 1996; Maurya et al. 2009; Nylund et al. 2011; Rothner, Wilbourn, and Mercer 1975). However, none of these cases stated whether armor was a contributing factor to the symptoms along with the heavy load carriage.

An armored vest can cause changes in the way a backpack fits the body. Interestingly, Military Morons (2009) says that the shoulder straps of the pack generally slide laterally toward the deltoids when worn over armor. In fact, if a chest strap is not worn, the shoulder straps of the backpack can slide laterally the most. Changes in position of the shoulder straps could cause compression in vulnerable areas of the upper body, such as the brachial plexus, or discomfort at the shoulders, potentially changing both physiological and performance outcomes.

Anecdotal reports from recently deployed U.S. military ground troops in Iraq and Afghanistan suggest that heavy load carriage while wearing armor and not using a chest

strap causes numbness, tingling, and/or pain in the upper extremities. Soldiers can try to alleviate this compression and discomfort by using either a standard chest strap or a modified chest strap. Typical pack design includes a standard chest strap which uses two smaller straps, one attached to each shoulder strap, that fasten across the sternum to pull the shoulder straps toward the midline of the body. Alternatively, a modified chest strap (Mystery Cinch™; Mystery Ranch, Bozeman, MT), which attaches to the armor, wraps around the shoulder straps, and fastens across the chest in order to pull the straps closer to the midline of the body. Since the modified chest strap attaches directly to the armor rather than the shoulder straps of the backpack, the manufacturer believes that this design better alleviates shoulder discomfort. Both types of chest straps are designed on the assumption that they will alleviate shoulder discomfort and mitigate negative changes in physiological and performance outcomes. However, no published research has attempted to quantify whether either chest strap is positively influencing either physiological or performance outcomes when carrying a heavy load.

Therefore, this study compared physiological and performance variables during heavy load carriage while wearing an armored vest under a standard issue military backpack. Specifically, the influence of two types of chest straps (standard and modified) on upper body and whole body measures were compared with the use on no chest strap.

## Methods

### Subjects

Low risk (American College of Sports Medicine 2010) volunteers between the ages of 18 and 45 years, all of whom were experienced heavy backpack load carriers, were recruited from the Bozeman, MT, area (e.g., ROTC, active duty military, reserves, and avid hunters). The participants were asked to complete a health history questionnaire, as well as an informed consent document, both of which were approved by the Montana State University Institutional Review Board.

### Study Design

This study evaluated 3 chest strap conditions, no chest strap, standard chest strap, and modified chest strap. There was a baseline trial and pack trial for each condition. The chest strap conditions were counterbalanced, with the baseline being tested first for each condition. The dependent variables of interest were heart rate, relative oxygen consumption, minute ventilation, breathing frequency, tidal volume, blood lactate, rating of perceived discomfort, fingertip oxygen saturation, earlobe oxygen saturation, bicep and forearm circumferences, two-point discrimination threshold, handgrip strength in the left and right hands, and stride rate.

### Procedures

All subjects completed four visits, the first of which allowed the participants to complete the necessary paperwork, pick up the consumables for the second visit, and complete a handgrip strength test. The remaining three visits were test sessions

corresponding to the three test conditions: standard chest strap, modified chest strap, or no chest strap. Subjects attended each test session in exercise attire and boots which ensured ankle stability with the heavy load carriage (approximately 47 kg total). Each test session included a 20-minute walking baseline trial and a 20-minute pack trial with the total time for each visit lasting about 75 minutes. Subjects were instructed to avoid exercise 48 hours before each test session and to avoid caffeine consumption three hours prior to the visit. The subjects were asked to consume a 237 ml Ensure Nutrition Shake, PowerBar, or Cliff Bar three hours prior to arrival, as well as drink at least 237 ml of bottled water during the three hours prior to each visit. This was done in an effort to establish similar nutrition and hydration levels prior to testing. The consumables were provided by the researchers before testing and were the same for each subject between visits.

Upon arriving for the first session, subject demographics (age, body height and mass) were recorded before performing a handgrip strength test and attaching several types of measuring equipment (e.g., chest strap for heart rate monitor; a pulse oximeter on the earlobe on fingertip; a facemask for the metabolic system). The fingertip pulse oximeter was placed on the index finger of the dominant hand, which was defined as being the preferred hand for pulling the trigger on a rifle. A second pulse oximeter was placed on the earlobe to monitor if there were differences in oxygen saturation between the measurement locations of the fingertip and the earlobe. Schutz (2001) stated that if heart rate values differ between the pulse oximeter and a heart rate monitor then it is likely due to low blood flow to the area. Therefore, by having two pulse oximeters, the

relationship between local blood flow of the arm and whole body blood flow could be evaluated.

The baseline trial, which was always tested first, consisted of the subject walking on a motorized treadmill for 20 minutes at 4.83 kph (3.0 mph) at a 2% grade. During the 20-minute trial, physiological and performance variables were measured at specific time intervals (see Table 3.1). After the baseline trial was complete, the measurement equipment was removed and cleaned, and the subject rested for a mandatory 10 minutes while the backpack and measurement equipment were fit to the subject for the pack trial. When the rest period was complete, the subject donned the armored vest (10.9 kg), pack (33.0 kg), and measurement equipment, all of which were adjusted using standard fitting procedures. Next, the 20-minute pack trial was performed, while carrying a training rifle (3.0 kg) with both hands, at the same treadmill speed and grade as for the baseline trial. All variables for the pack trial followed the same measurement timeline as described for the baseline trial (see Table 3.1).

During each 20-minute trial, measures of heart rate, oxygen consumption, minute ventilation, breathing frequency, and oxygen saturation were recorded continuously for the trial, while the perceived discomfort rating was assessed at minutes 5 and 20. Stride rate was assessed at minutes 6 and 16 by timing 10 heel strikes with one foot then extrapolating to number of strides per minute. Bicep and forearm circumference and two-point discrimination were recorded once per trial. For measures of circumference, the non-dominant arm was used. The bicep and forearm were marked at the largest circumferences prior to starting the trials in order to ensure measurements were taken in

the same locations. Subjects were asked to remark these areas in between lab visits as the ink began to wear off. The back of the dominant hand was used for two-point discrimination. The choice of arm used was to ensure that measurements could be taken effectively without forcing a position change of the subject's hands and arms. A fingertip blood lactate sample was taken once per trial on the non-dominant hand following the assessment of maximum handgrip strength at minute 20. Finally, handgrip strength was assessed a second time at minute 22.

Table 3.1. Measurement protocol for heart rate (HR), oxygen consumption ( $VO_2$ ), oxygen saturation ( $SpO_2$ ), rating of perceived discomfort (RPD), circumferences, handgrip strength, and blood lactate during 20-minutes of walking.

Minute	Measurement
5	HR, $VO_2$ , $V_E$ , BF, $SpO_2$ , RPD
6	Stride Rate
16	Stride Rate
17	Bicep and forearm circumferences on the non-dominant arm
18	Two-point discrimination on the dominant arm
20	HR, $VO_2$ , $V_E$ , BF, $SpO_2$ , RPD, handgrip strength, blood lactate
22	Handgrip strength

With the potential of nerve compression at the shoulder due to heavy load carriage, two-point discrimination was a useful tool of sensory perception based on studies completed by Nolan (1982) and Sato et al. (1999). In order to determine two-point discrimination thresholds, the aesthesiometer with two identical points was placed on the back of the dominant hand in a descending series of intervals. The subject was instructed

to look away from the instrument being used and to indicate when they could or could not feel two distinct points.

Another complication of compression at the shoulder could be decreased blood flow, which, in turn, could affect circumference measures of the arm via blood pooling. The circumference measures were taken by the same investigator to the nearest tenth of a centimeter while the subject was walking and carrying the training rifle. After the physiological variable measurements (HR,  $VO_2$ ,  $V_E$ , BF, and  $SpO_2$ ) were recorded at minute 20, the subjects were asked for their perceived discomfort ratings, measured on a scale of 0 to 10 that was adapted from a 0 to 10 pain scale (McCaffery and Beebe 1993), with 0 representing no discomfort and 10 being extreme discomfort. Knowing decreased blood flow and/or nerve conduction due to compression can alter motor function, handgrip strength was assessed at minutes 20 and 22 on both the dominant and non-dominant hands by placing the forearms on the bar at the front of the treadmill as the subject maximally squeezed the dynamometer for 3 seconds. Handgrip strength, in both hands simultaneously, was evaluated to assess handgrip strength recovery two minutes post walking with the pack and armor still being worn.

### Instrumentation

An oversized treadmill (Fitnexus Fitness Equipment, Inc., Irving, TX, USA) was used for all trials, while a portable metabolic system (Oxycon Mobile, Version 5.1, Jaeger, Viasys Healthcare, Germany), calibrated before each baseline trial, was used to measure  $VO_2$ ,  $V_E$ , BF, and  $SpO_2$  at the earlobe. Subjects breathed room air while an analyzer tube sampled the inspired and expired air breath by breath. For measurements of

HR, a Polar Accurex Plus heart rate monitor (Polar Electro, Inc., Lake Success, NY, USA) was used to collect 60 second averages. Another pulse oximeter (Model 8500, Nonin Medical Inc., Plymouth, MN, USA) was used to assess SpO<sub>2</sub> at the fingertip in the dominant hand index finger. A stopwatch (Accusplit Pro Survivor, A601X, Accusplit, Inc., Livermore, CA, USA) was used to measure stride rate. Upper limb circumferences were measured using a Gulick II measuring tape (Country Technology, Inc., Gays Mills, WI, USA), while two-point discrimination threshold was determined by using a Baseline® aesthesiometer (Fabrication Enterprises, Inc., White Plains, NY, USA). Handgrip strength tests were performed using handgrip dynamometers (T-18 Smedley III, Creative Health Products, Japan), and blood lactate was measured using a LactatePro portable blood lactate analyzer (Arkay Factory, Inc., Japan).

A standard issue Marine Family of Improved Load Bearing Equipment (FILBE) backpack and a Modular Tactical Vest (MTV) was used since it is the equipment that is used most commonly with the different types of chest straps. The standard chest strap used was that which comes attached to the shoulder straps of the FILBE backpack. When fitting the backpack to each subject, the shoulder straps were guided over the shoulder straps of the armor while the chest strap was fastened and tightened. Once the chest strap was set, the shoulder straps of the backpack were allowed to settle into a final position. Subjects were then asked, as well as reminded throughout the test trial, not to adjust the position of the shoulder straps while walking. The modified chest strap (Mystery Cinch™; Mystery Ranch, Bozeman, MT, USA) was attached to the armored vest at the second row of webbing on the front. When fitting the backpack to each subject, the

shoulder straps of the backpack were guided over the shoulder straps of the armor while the modified chest strap was fitted around the shoulder straps, fastened, and tightened. Once again, the shoulder straps were allowed to settle into a final position once the modified chest strap was set. Then the subjects were asked, and reminded throughout the test trial, not to make adjustments to the shoulder straps while walking.

### Data Processing

Change scores were calculated for those variables that were measured twice per trial, such as heart rate at minutes 5 and 20. Since the trends were found to be the same for all conditions as for the raw data, raw data was used for all data analysis and reporting. The collected data for HR,  $VO_2$ , VE, BF,  $SpO_2$ , and perceived discomfort rating (RPD) were summarized as averages within each trial and compared to baseline measurements. Minute ventilation and breathing frequency were used to calculate tidal volume and then averages for each trial were compared to baseline measurements. For bicep and forearm circumferences, handgrip strength, two-point discrimination, and blood lactate baseline measurements were compared directly with the three test conditions measured within the same trial.

### Statistical Analysis

All statistical analyses were performed using Statistix (Version 9.0, Analytical Software, Tallahassee, FL). Measures of heart rate, oxygen consumption, oxygen saturation, perceived discomfort rating, circumferences, handgrip strength, two-point discrimination, and blood lactate were evaluated for statistical significance using

multivariate two-factor repeated measures ANOVA ( $\alpha = 0.05$ ). Sheffes' post-hoc test was used to evaluate all pairwise comparisons ( $\alpha = 0.05$ ).

### Results

The demographics for 20 subjects (19 men, 1 woman) are summarized in Table 3.2.

Table 3.2. Subject demographics (Mean  $\pm$  SD)

	N	Age (years)	Height (cm)	Body Mass (kg)
All subjects	20	29 $\pm$ 6	177.5 $\pm$ 7.0	83.9 $\pm$ 15.5

### Physiological Variables

Baseline means across all three testing visits for all variables were statistically similar. In addition, there were no differences in blood lactate between chest strap conditions (Table 3.3). Mean values for heart rate, relative oxygen consumption, minute ventilation, and breathing frequency during the pack trial chest strap conditions were all statistically higher than baseline conditions (See Figure 3.1). Conversely, oxygen saturation at the fingertip was significantly lower during the pack conditions than the baseline conditions (Figure 3.2). For oxygen saturation at the earlobe, measures were too inconsistent to report and, therefore, were excluded from all analyses.

Tidal volume did not differ significantly between conditions but all pack conditions had higher means (Table 3.4). Although not significant, the no chest strap pack condition caused the largest average tidal volume. However, tidal volume decreased between minutes 5 and 20 (Table 3.5). Also, within the pack conditions the no chest strap

(NCS) condition tended to correspond with the highest values for heart rate, relative oxygen consumption, and tidal volume. Rating of perceived discomfort was higher for all chest strap conditions than all baselines, with no chest strap being higher than the modified chest strap (MCS) condition (Table 3.6). Rating of perceived discomfort also tended to increase with time within each condition (Table 3.7).

Table 3.3. Mean blood lactate ( $\pm$  SE) measured in millimoles per liter. The conditions referred to as standard and modified indicate the use of standard and modified chest straps.

Condition	Blood Lactate (mmol/L)
Standard	1.7 $\pm$ 0.3
No Chest Strap	1.5 $\pm$ 0.2
Modified	1.5 $\pm$ 0.1
Standard Baseline	1.2 $\pm$ 0.1
No Chest Strap Baseline	1.2 $\pm$ 0.1
Modified Baseline	1.2 $\pm$ 0.1

■ Bars indicate statistically similar values

Table 3.4. Mean tidal volume ( $\pm$  SE) measured in liters per breath. The conditions referred to as standard and modified indicate the use of standard and modified chest straps.

Condition	Tidal volume (L/breath)
No Chest Strap	1.7 $\pm$ 0.1
Modified	1.7 $\pm$ 0.1
Standard	1.7 $\pm$ 0.1
No Chest Strap Baseline	1.7 $\pm$ 0.05
Standard Baseline	1.6 $\pm$ 0.1
Modified Baseline	1.6 $\pm$ 0.1

■ Bars indicate statistically similar values

Table 3.5. Mean tidal volume ( $V_T$ , L/breath), breathing frequency (BF, breaths/min), and minute ventilation ( $V_E$ , L/min) at minutes 5 and 20 ( $\pm$  SE).

	Minute 5	Minute 20
$V_T$ (L/breath)	$1.7 \pm 0.03$	$1.6 \pm 0.03^\dagger$
BF (breaths/min)	$27.3 \pm 0.7$	$31.0 \pm 0.8^*$
$V_E$ (L/min)	$45.7 \pm 1.3$	$49.7 \pm 1.4^*$

$^\dagger$ Significant decrease from minute 5 ( $p < 0.05$ )

\*Significant increase from minute 5 ( $p < 0.05$ )

Table 3.6. Mean rating of perceived discomfort ( $\pm$  SE) measured on a 1-10 scale. The conditions referred to as standard and modified indicate the use of standard and modified chest straps.

Condition	RPD
No Chest Strap	$2.9 \pm 0.3$
Standard	$2.3 \pm 0.2$
Modified	$1.9 \pm 0.2$
Modified Baseline	$0.2 \pm 0.1$
No Chest Strap Baseline	$0.2 \pm 0.1$
Standard Baseline	$0.2 \pm 0.1$

■ Bars indicate statistically similar values

Table 3.7. Mean rating of perceived discomfort (RPD) at minutes 5 and 20 ( $\pm$  SE) measured on a 1-10 scale.

	Minute 5	Minute 20
RPD	$0.9 \pm 0.1$	$1.7 \pm 0.2^*$

\*Significant increase from minute 5 ( $p < 0.05$ )

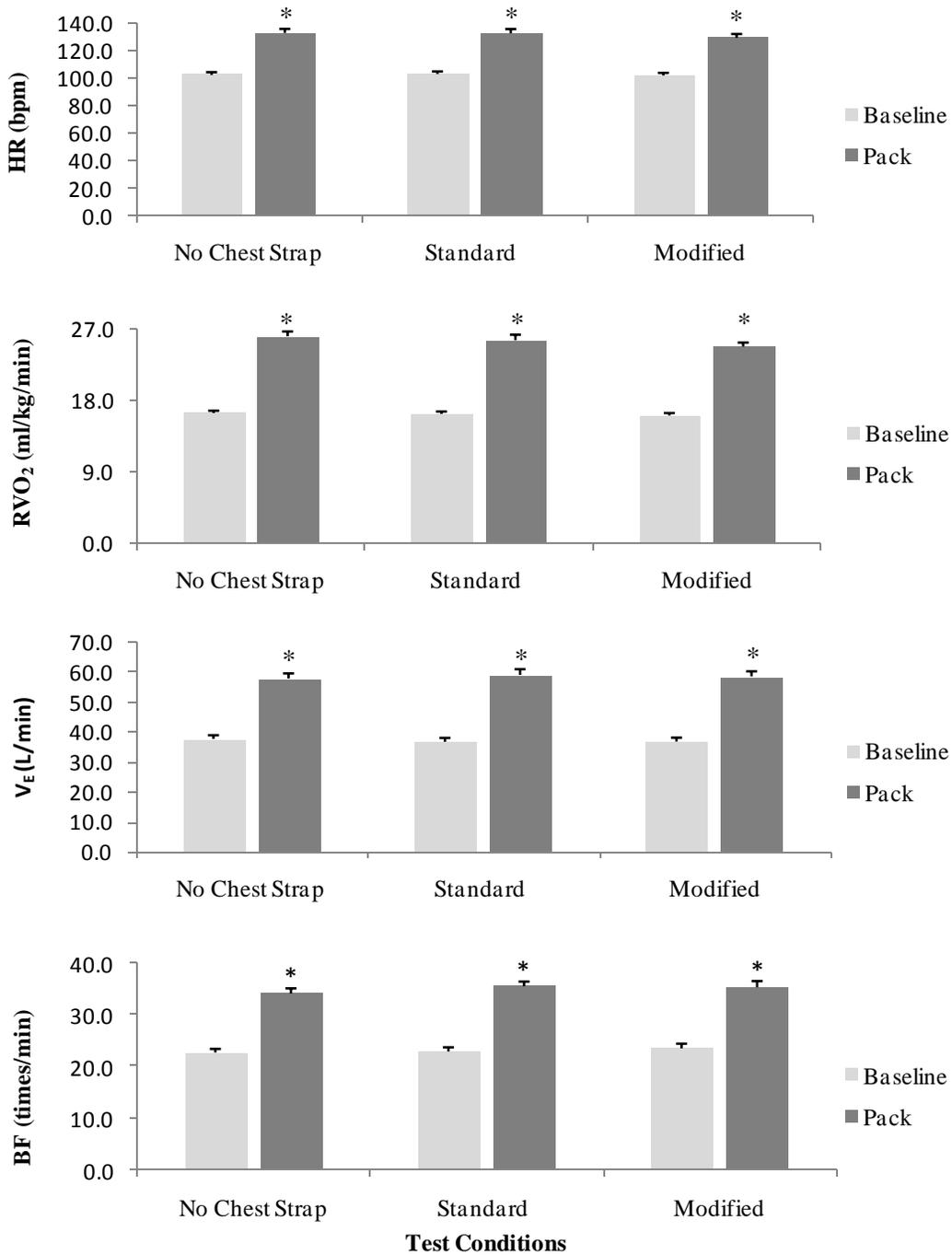


Figure 3.1. Mean values ( $\pm$  SE) for heart rate (HR), relative oxygen consumption (RVO<sub>2</sub>), minute ventilation (V<sub>E</sub>), and breathing frequency (BF) plotted for each condition. The conditions referred to as standard and modified indicate the use of standard and modified chest straps.

\*Significant increase from baseline ( $p < 0.05$ ).

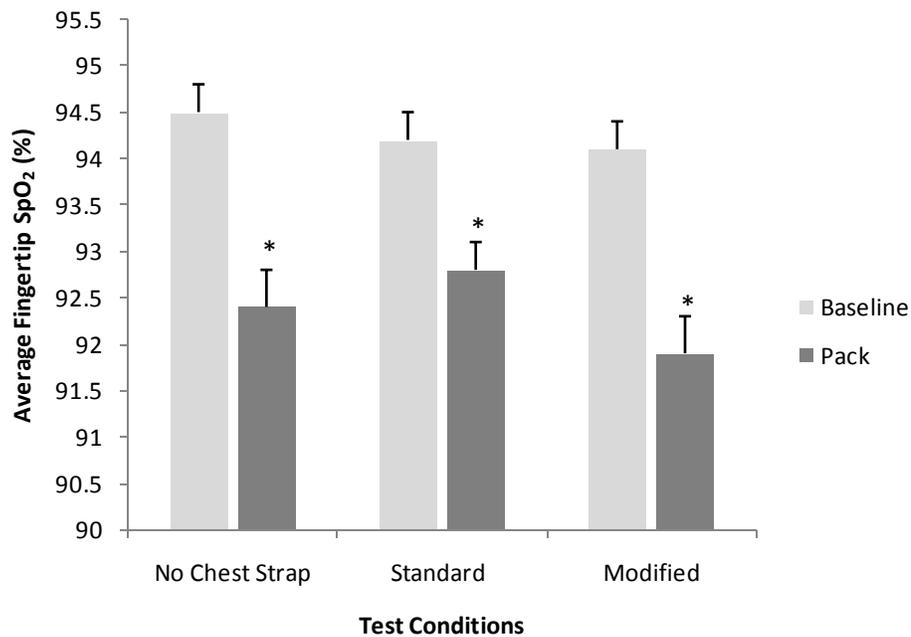


Figure 3.2. Mean values ( $\pm$  SE) for fingertip oxygen saturation ( $SpO_2$ ) plotted for each condition. The conditions referred to as standard and modified indicate the use of standard and modified chest straps.  
\*Significant decrease from baseline ( $p < 0.05$ )

Forearm circumference was greater for the standard chest strap (SCS) and NCS conditions than baseline, while the NCS condition was also greater than the MCS condition (Table 3.8). For bicep circumference, the NCS condition was greater than all baselines, but no differences within chest strap conditions. Two-point discrimination resulted in the NCS condition being greater than only the no chest strap baseline and the standard chest strap baseline (Table 3.9).

Table 3.8. Mean forearm ( $C_F$ ) and bicep ( $C_B$ ) circumferences ( $\pm$  SE) measured in centimeters. The conditions referred to as standard and modified indicate the use of standard and modified chest straps.

Condition	$C_F$ (cm)	$C_B$ (cm)
No Chest Strap	30.0 $\pm$ 0.5	35.2 $\pm$ 1.0
Standard	29.7 $\pm$ 0.5	34.7 $\pm$ 1.1
Modified	29.4 $\pm$ 0.5	34.2 $\pm$ 1.0
Standard Baseline	29.4 $\pm$ 0.6	34.0 $\pm$ 1.0
Modified Baseline	29.2 $\pm$ 0.5	34.0 $\pm$ 0.9
No Chest Strap Baseline	29.1 $\pm$ 0.5	33.8 $\pm$ 1.0

■ Bars indicate statistically similar values

Table 3.9. Mean two-point discrimination thresholds ( $\pm$  SE) measured in millimeters. The conditions referred to as standard and modified indicate the use of standard and modified chest straps.

Condition	Two-point Discrimination (mm)
No Chest Strap	19.7 $\pm$ 1.5
Modified Baseline	17.0 $\pm$ 2.2
Standard	16.9 $\pm$ 1.5
Modified	16.0 $\pm$ 1.9
Standard Baseline	13.8 $\pm$ 1.7
No Chest Strap Baseline	13.2 $\pm$ 1.4

■ Bars indicate statistically similar values

### Performance Variables

There were no differences between conditions in mean handgrip strength for the left hand. For the right hand, which was the dominant hand for all subjects, handgrip strength was higher for the modified chest strap condition than for all baselines and the no chest strap condition (Table 3.10). Although not significant, the standard chest strap also resulted in right handgrip strength being higher than baseline. There were also differences between the first measure at minute 20 and the second measure at minute 22 for the left hand and the right hand (Table 3.11). Stride rate was statistically similar

between test conditions, although the chest strap conditions resulted in slightly faster stride rates (Table 3.12). Mean stride rates measured at minute 16 ( $54.2 \pm 0.3$  strides/min) were slower than that for minute 6 ( $54.6 \pm 0.3$  strides/min).

Table 3.10. Mean handgrip strength (HG) for the right hand ( $\pm$  SE) from a three second maximum effort measured in kilograms. The conditions referred to as standard and modified indicate the use of standard and modified chest straps.

Condition	HG – right (kg)	HG – left (kg)
Modified	$55.9 \pm 1.6$	$49.5 \pm 1.6$
Standard	$53.4 \pm 1.8$	$50.0 \pm 1.7$
No Chest Strap Baseline	$52.9 \pm 1.5$	$49.5 \pm 1.5$
Standard Baseline	$52.7 \pm 1.8$	$50.0 \pm 1.7$
Modified Baseline	$52.2 \pm 1.6$	$49.2 \pm 1.8$
No Chest Strap	$51.8 \pm 1.5$	$47.2 \pm 2.0$

■ Bars indicate statistically similar values

Table 3.11. Mean handgrip strength (HG) at minutes 20 and 22 ( $\pm$  SE) measured in kilograms.

	Minute 20 (kg)	Minute 22 (kg)
HG- right	$52.4 \pm 1.0$	$53.9 \pm 0.9^*$
HG- left	$48.6 \pm 0.9$	$49.9 \pm 1.0^*$

\*Significant increase from minute 20 ( $p < 0.05$ )

Table 3.12. Mean stride rate ( $\pm$  SE) measured in strides per minute. The conditions referred to as standard and modified indicate the use of standard and modified chest straps.

Condition	Stride rate (strides/min)
No Chest Strap	$54.7 \pm 0.5$
Standard	$54.6 \pm 0.5$
Modified	$54.6 \pm 0.5$
Standard Baseline	$54.2 \pm 0.6$
Modified Baseline	$54.2 \pm 0.5$
No Chest Strap Baseline	$54.2 \pm 0.5$

■ Bars indicate statistically similar values

## Discussion

The subjects completed a total of 6 treadmill walking test conditions, one baseline and one backpack test per testing visit. Each testing visit corresponded to one of three chest strap conditions: no chest strap, standard chest strap, and modified chest strap. During the baseline conditions, the subjects were required to carry only a rubberized training rifle (3.0 kg). During the backpack test conditions, the subjects wore an armored vest, a backpack, and carried a training rifle (total 47 kg). It was hypothesized that there would be no differences in physiological and performance variables for the chest strap conditions.

### Physiological Variables

Since baseline values for all variables were statistically similar, it is assumed those measures represent a true walking baseline for this study. Previous researchers (Bastien, Willems, Schepens, and Heglund 2005; Beekley et al. 2007; Bilzon, Allsopp, and Tipton 2001; Crowder et al. 2007; Lloyd and Cooke 2000; Sagiv, Ben-Gal, and Ben-Sira 2000) have found increases in heart rate and oxygen consumption from unloaded to loaded walking suggesting an increase in workload. The current study also found increases in heart rate and relative oxygen consumption, as well as minute ventilation and breathing frequency, from the baseline conditions to the pack conditions, with no differences between pack conditions (Figure 3.2). These findings suggest that the increase in workload caused an increase in physiological stress. However, the increase in physiological stress was statistically similar between chest strap conditions. Statistical

differences may have developed if the walking conditions were longer or subjects were allowed to self-select a walking speed. For example, Knapik, et al. (1997) had pre- and post-testing for performance measures for a 20 km march with a 34 kg, 48 kg, or 61 kg loads in two types of packs. The researchers found there was an interaction between load mass and march time for heart rate before marksmanship measures, and a difference in heart rate between types of packs. Thus, marching time influenced both physiological and performance outcomes.

Measures of blood lactate accumulation can also be an indication of exercise intensity (ACSM, 1998) or, potentially, blood flow to the arms during heavy load carriage. However, Sagiv, Ben-Gal, and Ben-Sira (2000) found that during heavy load carriage (25 kg and 35 kg) on treadmill grades below 10%, blood lactate did not change. The researchers also mentioned that low fingertip blood lactate levels could indicate that there is sufficient blood flow to the upper extremities. The current study was performed at a treadmill grade of 2% and no trends developed for blood lactate data (Table 3.3). These findings suggested that the workload for the subjects was at an exercise intensity below threshold, which was expected of experienced heavy load carriers. Also, since there were no increases in fingertip blood lactate measures in the current study, this would suggest there is adequate blood flow to the hands and arms not allowing blood lactate to accumulate in the upper extremity. This could also mean that lactate was being taken up by muscles to be used as energy.

However, oxygen saturation at the fingertip did decrease from baseline (Figure 3.1). Wong et al. (2007) found, when using transcutaneous oximetry of the heel, that

oxygen tension of the heel decreased with pressure loading unless the patient was given an oxygen challenge. The researchers also suggested that this decrease in oxygen saturation when breathing room air could be due to decreased blood flow to the heel. Since our subjects breathed only room air, the cause of the decrease in fingertip oxygen saturation is most likely due to the pressure at the shoulder potentially causing decreased blood flow. However, Barnett, Duck, and Barraclough (2012) state that oxygen saturation is more accurately measured at the ear during walking. The current study also attempted to measure oxygen saturation at the earlobe, but due to an inability to consistently collect data, the earlobe oxygen saturation data was not analyzed.

Pulletz, et al (2010) found that tidal volume decreased with abdominal and thoracic restriction during breathing. The current study did not specifically restrict breathing, however, some subjects stated feeling as though they could not take a deep breath due to wearing the armored vest. Even though some reported feeling restricted in breathing, tidal volume did not change between conditions in the current study (Table 3.4). However, tidal volume did decrease with time (Table 3.5), which could indicate some fatigue of inspiratory muscles due to the muscles pushing against the armor and the shoulder straps of the backpack. Also, by tidal volume decreasing, breathing frequency had to increase with time in order for minute ventilation to also increase (Table 3.5).

Rating of perceived discomfort was expected to be higher during the pack trials than baseline since a heavy load (47 kg) was being carried. This is, in fact, what happened in the current study (Table 3.6), and, within each trial, RPD also tended to increase with time, which could indicate accumulating fatigue (Table 3.7). The backpack

straps and/or load shifted into a less favorable position causing increased neural compression and blood pooling, which could explain why RPD increased with time.

Forearm and bicep circumferences were used as an indirect measurement of blood pooling in the arms and were not expected to change. However, in the current study forearm and bicep circumferences for the no chest strap condition (NCS) were statistically higher than baseline, with forearm circumference for NCS also being greater than the modified chest strap condition (Table 3.8). This is presumably the result of blood pooling in the arms due to compression from the shoulder straps inhibiting blood flow back to the body.

Another concern of shoulder compression due to shoulder straps is sensory loss. Sensory loss can occur with external skin pressure compressing nerves (Rothner, Wilbourn, and Mercer 1975). Two-point discrimination was assessed on the back of the dominant hand as a measure of sensory function. This area was chosen because the hands are more sensitive than the arms (Nolan 1982; Sato, et al. 1999) and would not require the subject changing the position of the hand or arm. A case study performed by Maurya, Singh, Bhandari, and Bhatti (2009) found no sensory loss due to heavy load carriage, yet the study did not state the configuration of the 15.5 kg load involved. The current findings indicate that the baseline means were similar, with chest strap means also being similar. However, the two-point discrimination threshold for the no chest strap condition ranked higher than only the no chest strap baseline and standard chest strap baseline (Table 3.9). This would indicate decreased sensory function when using no chest strap during heavy load carriage while wearing an armored vest. However, the standard chest

strap and modified chest strap showed no differences from any baseline condition suggesting that sensory function was at least somewhat preserved when using one of these chest strap conditions.

### Performance Variables

Since handgrip strength is a useful measure of motor function (Schlusel, dos Anjos, de Vasconcellos, and Kac 2008), both hands were measured simultaneously in the current study. Piscione and Gamet (2006) state that muscle function can decrease due to fatigue after carrying a backpack. The researchers also state that the decrease could have occurred due to compression of the nerves not allowing for normal transmission of neural signals. The current study found no differences in handgrip strength for the left hand, which indicates heavy load carriage did not affect motor function of the left hand. Handgrip strength in the right hand, which was the dominant hand for all subjects in this study, was higher for the modified chest strap condition than the no chest strap condition and all baseline means (Table 3.10). This indicates that wearing armor during heavy load carriage and using a modified chest strap may retain motor function of the right hand instead of inhibit it. This finding is especially relevant because all the subjects in the current study were right handed shooters so the function of the right hand was retained. The trigger finger could be impacted by the use of chest straps under these conditions, but the current study did not focus on this type of performance variable.

Another aspect to potentially decreasing motor function is how long those effects last. Knapik et al. (1991) found that grenade throwing distance decreased while accuracy was not affected by heavy load carriage. However, Knapik et al. (1997) found in a later

study that soldier marksmanship decreased immediately following heavy load carriage but returned to normal after two minutes of rest. The current study found that handgrip strength after heavy load carriage and wearing armor was not different from baseline conditions but both baseline and pack conditions means increased two minutes post exercise (Table 3.11). Therefore, subjects' handgrip strength recovered within two minutes of ceasing exercise.

Stride rate was used, in the present study, as an indicator of lower body performance. Qu and Yeo (2007) state that load carriage (7.5 kg and 15.0 kg) and fatigue can negatively affect gait by increasing trunk and hip range of motion and increasing step width. The researchers did not specifically examine stride rate, but did assess step length variability and found no differences. Step length and stride rate are closely associated since walking speed is equal to the product of stride length (SL) and stride rate ( $\text{speed} = \text{stride length} \times \text{stride rate}$ ). The current study found that stride rate did not differ significantly between conditions, which would mean stride length did not change and is in accordance with the study by Qu and Yeo (2007). Although not significant, the no chest strap condition resulted in the fastest stride rate (Table 3.12). This suggests that not using a chest strap is potentially the most detrimental to stride rate because stride length would have shortened in order to maintain the same walking speed. Stride rate means also increased with time suggesting fatigue was involved in all conditions since stride length would decrease. If a longer bout of walking was performed under similar conditions, significant differences in stride rate may be seen between chest strap conditions that were not able to develop in the current walking trial of 20 minutes.

### Conclusions

The current study found that not using a chest strap provided the most evidence for negatively affecting physiological and performance outcomes when wearing an armored vest and carrying a heavy load. Specifically, this test condition was associated with significant increases (above baseline conditions) in forearm circumference, two-point discrimination threshold, and rating of perceived discomfort, as well as a significant decrease from baseline in handgrip strength of the right hand when compared to the standard and modified chest straps. The results for these variables suggested that not using a chest strap can lead to blood pooling in the forearm, a decrease in sensory function, an increase in discomfort, and a decrease in motor function of the hand and arm. Not using a chest strap also ranked the highest, although not significantly, for heart rate and relative oxygen consumption indicating a slightly higher intensity and greater energy expenditure for the condition.

The modified chest strap condition and the standard chest strap condition were statistically similar for all variables. Although not significantly different from the standard chest strap condition, the modified chest strap condition tended to have the least discomfort, the least blood pooling in the forearm, the least change in two-point discrimination threshold, and the least change in handgrip strength. Handgrip strength (motor function) retention in the right hand via wearing a chest strap was especially important in the current study since all subjects were right handed shooters. The modified chest strap condition also ranked the lowest for heart rate and relative oxygen consumption which indicates that slightly less energy was used to carry the heavy load

while wearing an armored vest. Some of these measures may have developed into significant differences if there were longer walking trials or subjects were allowed to choose a walking speed. Also, future studies should consider using performance measures to specifically assess the function of the trigger finger.

## CHAPTER FOUR

## CONCLUSIONS

Not using a chest strap was the most detrimental to physiological and performance outcomes when wearing an armored vest and carrying a heavy load. Not using a chest strap may inhibit blood flow, sensory function, motor function, and increase discomfort as seen by the increase in forearm circumference, increase in two-point discrimination threshold, decrease in handgrip strength, and increase in rating of perceived discomfort. Even though mean values for heart rate and relative oxygen consumption were not different, the no chest strap condition ranked the highest suggesting this condition results in greater physiological stress for an individual.

Using a standard or modified chest strap seems to negatively affect performance the least since mean values for all the variables tended to be more favorable for a lower physiological stress and less of a change in sensory and motor function. In fact, the modified chest strap condition indicates there may be an increased performance of the hands and arms. However, there are no statistical differences between the standard chest strap condition and the modified chest strap condition.

Future studies should attempt to use an entirely military population. The subjects in the current study were experienced with heavy load carriage in a backpack, but were not accustomed to wearing an armored vest under the backpack. If there was a purely military population accustomed to heavy load carriage and wearing armor, there would have been the potential to have longer trials with which may have provided the

opportunity to see significant differences between chest strap conditions for metabolic data, such as heart rate and oxygen consumption. In future attempts to monitor oxygen saturation at the earlobe during exercise, a clip-on type sensor would probably resolve any discrepancies when collecting data due to the assurance of the light source and receiver being directly over each other. Future studies may also benefit from the load in the pack being actual pieces of a combat load in order to investigate how actual combat loads could affect the fit of the backpack at the shoulders.

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APPENDICES

APPENDIX A

SUBJECT CONSENT FORM

**SUBJECT CONSENT FORM FOR PARTICIPATION IN HUMAN RESEARCH  
MONTANA STATE UNIVERSITY - BOZEMAN**

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**PROJECT TITLE:** The influence of backpack chest straps on physiological and performance variables associated with simulated road marching

**FUNDING:** Equipment supplies provided by Mystery Ranch LTD, Bozeman, MT.

**PROJECT DIRECTOR:** Jana Hollins, Masters of Science Candidate, Exercise Physiology Department of Health & Human Development, Movement Science Laboratory  
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**PURPOSE OF STUDY:** You are being asked to participate in a study that is comparing the use of two different types of chest straps (standard chest strap and the Mystery Cinch™) to not using a chest strap while carrying a backpack and wearing an armored vest. The standard chest strap is the one that comes attached to the shoulder straps of a backpack, while the Mystery Cinch™ attaches to the armored vest and wraps around the shoulder straps of a backpack (see photos below). The backpack you will wear will be a standard issue Marine pack (FILBE) and contain a 60 lb load. The armored vest you will wear will also be standard issue weighing approximately 23 lb. Since the study is focusing on use of military equipment, you will carry a training rifle (i.e., a rubber and plastic replica of an M16). You will be walking on a treadmill at a fixed speed and grade while wearing and carrying the military equipment listed above.

According to anecdotal reports, marching while carrying a heavy backpack load could influence arm and shoulder comfort. A possible contributor to this comfort is chest straps since chest straps are designed to pull the shoulder straps of a backpack inwards towards the midline of the body away from the shoulders. However, no research has been completed, to our knowledge, on chest straps and their influence on physiological and performance variables, as well as perceived comfort. Therefore, we are interested in how these variables may be influenced by the different chest strap conditions pictured below. This information, along with comfort, will help determine what set up of the equipment could be the most useful and comfortable for individuals in the military.

Figures A, B, & C. Examples of chest strap test conditions while carrying a heavy backpack load and wearing an armored vest.



A. No chest strap

B. Standard chest strap

C. Mystery Cinch™

Each subject will be given an Informed Consent Document that explains the purpose of the study, along with the expected risks and benefits of participation. Each subject will be screened using the responses provided in a Health History Questionnaire (HHQ). The Primary Investigator reserves the right to request that any participant receive documented medical clearance prior to testing if indicated by responses on the HHQ. These procedures are in compliance with policies formulated by the American College of Sports Medicine<sup>1</sup>. Finally, each participant should be physically fit enough to easily perform 20 minutes of unloaded and 20 minutes of loaded backpack (approximately 103 lb total) treadmill walking at 3 mph and a 2% grade. Ideally, you should also have recent experience (previous 3 months) with carrying and/or hiking with heavy backpack loads (e.g., 50+ lbs).

**STUDY PROCEDURES:** If you agree to participate, you will be asked to make four visits to the Movement Science / Human Performance Laboratory (MSL) at Montana State University. All visits should occur within a 3-week period.

Lab Visit #1. During the first lab visit, you will read and sign an approved consent document, fill out a health history questionnaire, practice a handgrip strength test, and obtain consumables (food and water) for subsequent lab visits. The handgrip strength tests will be done on both hands simultaneously by squeezing a dynamometer maximally for three seconds. Depending on time and availability, fitting of the equipment may occur during the first or second visit. The first lab visit will last 30-45 minutes.

Lab Visit #2. The second lab visit will be scheduled to occur between two and 21 days following the first lab visit. This time line helps ensure there are no significant changes in your physical fitness. You will be asked to complete a 20-minute baseline trial (no armor or pack) followed by a 20-minute pack trial (using 1 of 3 chest strap conditions). You will be asked to arrive at the lab ready for loaded treadmill walking which should include

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<sup>1</sup>American College of Sports Medicine (2010). *ACSM's Guidelines for Exercise Testing and Prescription* (8th edition). Williams & Wilkins, Philadelphia, Pa.

wearing appropriate exercise clothing (shorts, t-shirt) and footwear (boots), as well as refraining from exercise 24 hours prior to testing. To help provide consistency of metabolism measures, you will be given a choice to consume either an 8 oz Ensure Nutrition Shake (250 kcals), PowerBar (240 kcals), or Clif Bar (240 kcals) 3 hrs prior to lab arrival, and an 8 oz bottle of water (0 kcals) between 1 and 3 hrs prior to lab arrival. You will be able to choose what food you would like to consume, but keep in mind that you must consume the same type of food prior to each lab visit. We also ask that no other food or drink be consumed during this same 3 hr pre-testing window. The food and bottled water will be provided to you at the end of the first lab visit.

Once arriving at the lab, you will be measured for body weight and height, as well as asked your age. Then, handgrip strength will be measured as previously stated. Next, you will be prepped with measuring equipment for the metabolic system: chest strap for monitoring heart rate, facemask for energy expenditure and respiratory values, and pulse oximeter on the earlobe. A second pulse oximeter, which measures oxygen saturation, will also be attached to the index finger of the dominant hand. Once all the measuring equipment is attached, a baseline trial (no armor or pack) will be performed by walking on the treadmill for 20 minutes at the set speed and grade (3 mph and 2% grade). This trial will be filmed from beginning to end so that it can potentially be analyzed at a later date. During this trial, respiratory values and energy expenditure will be measured continuously. You will be asked to rate your discomfort twice during the trial based on a 0 – 10 scale, with 0 being no discomfort and 10 being extreme discomfort. Stride rate will also be measured using a handheld stopwatch two times during the trial. Bicep and forearm circumferences will be taken using an anthropometric tape measure on the non-dominant arm while you are walking and carrying the training rifle. Following circumference measures, two-point discrimination will be assessed by touching a plastic instrument with two identical, moveable points to the back of the dominant hand several times until you can no longer distinguish between the two points. This test is designed to test sensory nerve function and will be done with you walking and carrying the rifle. At minute 20 the treadmill is stopped and handgrip strength will be measured with a fingertip blood lactate sample taken immediately following. The measure of fingertip blood lactate involves puncturing the end of a finger with a sterile lancet, collecting a droplet of blood, and then covering the site with a sterile bandage. Another handgrip strength test will be performed at minute 22. The baseline trial provides baseline measurements, as well as a sufficient warm-up before heavy load carriage.

Upon completion of the baseline trial, there is a 10-minute rest period. During this time, the measuring equipment will be removed, cleaned, and recalibrated. Also during this time, the FILBE backpack will be fit to you for the pack trial. Once the rest period is complete, you will be asked to don a standard plated armored vest (23 lbs) and backpack with a 60-pound load (frame + load = 73 lbs). One of three chest strap conditions will be employed (no strap, standard chest strap, or Mystery Cinch™). Once the armor and pack are on, you will be fit with the same facemask as the baseline trial for the pack trial. You will also be asked to carry a training rifle (approximately 7 lbs) using both hands during

this trial while walking for 20 minutes at the same speed and grade as the baseline trial. Including the metabolic system (3 lbs), the total weight carried during the pack trial will be 103 lbs. All measurements and filming for this trial will follow the same timeline as the baseline trial. Upon completion of both trials, you will be asked to fill out a questionnaire about the comfort of the pack with armor. The second visit to the lab will last 75-90 minutes.

Lab Visits #3 and #4. The third and fourth lab visits will be scheduled to occur between two and 21 days following the second lab visit, with at least 2 days between visits. This time line helps ensure that fatigue from the previous visit will not impact measurements during the current visit, as well as not allowing time for significant changes in your physical fitness. Visits three and four will follow the same testing protocol as visit two. However, a different chest strap condition will be used for the pack trial at each visit. The third and fourth visits to the lab will also last 75-90 minutes each.

**POTENTIAL RISKS:** There are several potential risks worth noting for this study. First, submaximal treadmill walking presents a minimal risk of injury, for example, falling while testing. To minimize this chance of injury, multiple 12 inch crash pads will be placed to the rear of the treadmill (standard procedure). The subjects may experience some degree of discomfort and mild bruising at the fingertip puncture site after testing, but this should disappear within 48-72 hrs. The measuring devices (e.g., face mask for energy expenditure measurement) may feel somewhat restricting or uncomfortable during testing, but all possible adjustments will be used to achieve the greatest comfort for each subject. There is always a risk of injury associated with carrying a heavy load, such as to the low back. In order to minimize risk of injury, those experienced in carrying heavy loads will be recruited, the waist belt on the backpack will be used to support most of the weight on the hips, and the backpack will be fit as well as possible to each individual. The performance of any exercise testing protocol also involves a chance of precipitating a cardiac event (such as abnormal heart rhythms) or even death. However, the possibility of such an occurrence is very slight (less than 1 in 10,000 for maximal exercise testing) since 1) you are in good physical condition with no known symptoms of heart disease and 2) the test will be administered by trained personnel (National Safety Council CPR and First Aid certified and aware of the lab's emergency action plan) 3) risk is lowest for submaximal testing, such as the testing for the present study. *These risks are certainly much lower than those experienced by athletes training extremely hard or engaged in actual race competition.* All possible precautions will be taken to ensure subjects' safety and make them feel comfortable before any testing takes place. Also, you are encouraged to inform the investigators of any discomfort associated with any aspect of the testing protocols.

**SUBJECT COMPENSATION:** Upon completion of all aspects of this study, you will be provided with several forms of indirect and direct compensation. You will be given a Mystery Ranch t-shirt (\$20 market value), drawstring backpack, and Human Performance Lab bracelet. You may also request a copy of publications or presentations based on data collected in this study from the Project Director, Jana Hollins.

**BENEFITS:** There are no direct benefits to you as a volunteer for this study.

**CONFIDENTIALITY:** The data and personal information obtained from this study will be regarded as privileged and confidential with only the Project Directors having access to this information. Your right to privacy will be maintained in any ensuing analysis and/or presentation of the data by using coded identifications of each person's data.

**FREEDOM OF CONSENT:** You may stop testing at any time, or withdraw consent for participation in writing, by telephone or in person without prejudice or loss of benefits (described above). *Participation is completely voluntary.*

In the UNLIKELY event that your participation in the study results in physical injury to you, the Project Director will advise and assist you in receiving medical treatment. No compensation is available from Montana State University for injury, accidents, or expenses that may occur as a result of your participation in this study. Additionally, no compensation is available from Montana State University for injury, accidents, or expenses that may occur as a result of traveling to and from your appointments at the Movement Science / Human Performance Laboratory. *Further information regarding medical treatment may be obtained by calling the Project Director, Jana Hollins or the Lab Director, Dan Heil (406-994-6324; dheil@montana.edu).* You are encouraged to express any questions, doubts or concerns regarding this study. The Project Director will attempt to answer all questions to the best of her ability prior to any testing. The Project Director fully intends to conduct the study with your best interest, safety and comfort in mind. *Additional questions about the rights of human subjects can be answered by the Chairman of the Human Subjects Committee, Mark Quinn, at 406-994-4707.*

**PROJECT TITLE: The influence of backpack chest straps on physiological and performance variables associated with simulated road marching**

**STATEMENT OF AUTHORIZATION**

I, *the participant*, have read the Informed Consent Document and understand the discomforts, inconvenience, risks, and benefits of this project. I, \_\_\_\_\_ (*print your name*), agree to participate in the project described in the preceding pages. I understand that I may later refuse to participate, and that I may withdraw from the study at any time. I have received a copy of this consent form for my own records.

**Signed:** \_\_\_\_\_ **Age** \_\_\_\_\_ **Date** \_\_\_\_\_

*Subject's Signature*

**Signed:** \_\_\_\_\_ **Date** \_\_\_\_\_

*Investigator*

APPENDIX B

HEALTH STATUS QUESTIONNAIRE

**Health Status Questionnaire - Montana State University  
Movement Science/Human Performance Laboratory**

**INSTRUCTIONS**

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Complete each of the following questions as accurately as possible by filling in the blanks or checking the most appropriate box. All information provided is confidential and no information will be released without your written consent.

Today's Date \_\_\_\_\_

**GENERAL INFORMATION**

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Mr.       Ms.       Miss       Mrs.       Dr.

Last Name \_\_\_\_\_ First Name \_\_\_\_\_

Mailing Address \_\_\_\_\_

Home Phone \_\_\_\_\_ Office Phone \_\_\_\_\_

Occupation \_\_\_\_\_

Employer \_\_\_\_\_

Person to Contact in Emergency: Name \_\_\_\_\_

Relationship \_\_\_\_\_

Phone \_\_\_\_\_

• Descriptive information:

Gender:      Male       Female       Body Weight \_\_\_\_\_

Age \_\_\_\_\_ Date of Birth \_\_\_\_\_ Body Height \_\_\_\_\_

• Why are you filling out this questionnaire?

You have volunteered for a research study or project.

You are being screened for fitness testing in the Movement Science Lab.

Other reason...\_\_\_\_\_

**MEDICAL HISTORY**

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Name of your physician \_\_\_\_\_

(Address/phone?) \_\_\_\_\_

• Family History:

Did your father, or other first degree male relative (like a brother) die before the age of 55?

No  Yes

If Yes, cause? \_\_\_\_\_

Age at death? \_\_\_\_\_

Which relative? \_\_\_\_\_

Did your mother, or other first degree female relative (like a sister) die before the age of 65?

No  Yes

If Yes, cause? \_\_\_\_\_

Age at death? \_\_\_\_\_

Which relative? \_\_\_\_\_

• List any food or drug allergies: \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

• List any medication you are currently taking (non-prescription and prescription, including oral contraceptives). Please comment on the reason for each medication.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

• Please describe any recent illnesses, hospitalizations, or surgical procedures:

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

- 
- Any of these health symptoms that occurs frequently (ranked as either a 4 or 5 below), either at rest or during physical exertion, is the basis for a prompt medical evaluation. Circle the number indicating how often you have each of the following:

	0 = Never	1 = Practically never	2 = Infrequently			
	3 = Sometimes	4 = Fairly often	5 = Very often			
a. Coughing up blood.	0	1	2	3	4	5
b. Abdominal pain.	0	1	2	3	4	5
c. Low-back pain.	0	1	2	3	4	5
d. Chest pain.	0	1	2	3	4	5
e. Neck, jaw, arm, or shoulder pain.	0	1	2	3	4	5
f. Leg pain.	0	1	2	3	4	5
g. Swollen joints, especially the ankles.	0	1	2	3	4	5
h. Feel faint.	0	1	2	3	4	5
i. Feeling of dizziness.	0	1	2	3	4	5
j. Breathless with slight exertion.	0	1	2	3	4	5
k. Palpitation or fast heart rate.	0	1	2	3	4	5
l. Unusual fatigue with normal activity.	0	1	2	3	4	5
m. Abnormal/labored breathing at night.	0	1	2	3	4	5

For any score of "4" or higher, use the space below to explain the frequency and the conditions under which you experience that particular symptom:

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- Do you currently work in an environment where smoking is allowed?

Yes       No

If “Yes”, where do you work AND how frequently do you work in this environment?

- Do you drink alcoholic beverages on a regular basis?       Yes       No  
(ie. at least once/week)

If “Yes”, please answer the following:

1) How frequently do you drink?

2) What alcoholic beverages do you typically consume?

- Have you exercised regularly in the past 4 weeks?       Yes       No

If “Yes”, describe in terms of frequency, duration, intensity, and type of exercise:

- Do you consider yourself physically active due to work-related demands, home or farm chores, etc.?       Yes       No

If “Yes”, describe in terms of frequency, duration, intensity, and type of exercise:

- Please describe anything not already described on this questionnaire that might cause you problems during exercise (use the space below).

- Are there any other health-related problems or concerns NOT addressed on this questionnaire that we should know about?

Yes       No

If “Yes”, please describe: