NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

THE EFFECTS OF LOAD DISTRIBUTION AND GRADIENT ON LOAD CARRIAGE

by

Shanell L. Colclough

December 2010

Thesis Advisor: Eugene P. Paulo
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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** December 2010	**3. REPORT TYPE AND DATES COVERED** Master's Thesis	
4. TITLE AND SUBTITLE The Effects of Load Distribution and Gradient on Load Carriage			**5. FUNDING NUMBERS**
6. AUTHOR(S) Colclough, Shanell L.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government. IRB Protocol number __NPS.2005.0037_____.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; public distribution is unlimited			**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

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14. SUBJECT TERMS Load carriage, backpack, rucksack, load distribution, load preference, gradient, human systems integration, HSI			**15. NUMBER OF PAGES** 113
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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THE EFFECTS OF LOAD DISTRIBUTION AND GRADIENT ON LOAD CARRIAGE

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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN HUMAN SYSTEMS INTEGRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2010

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ABSTRACT

The objective of this research was to evaluate the effects of load distribution and gradient on military personnel while wearing a backpack. A secondary objective was to identify anatomical locations most affected during this task, and to verify that one load configuration may not be suitable for all individuals, especially when the activity is conducted on multiple gradients. Participants were asked to simulate the common military task of road marching on a treadmill while wearing a backpack. Load distribution was either high or low and gradient was either level (0%) or a positive incline (11%). Methods used to assess the effects of load distribution and gradient on load carriage were Heart Rate Variability, Regional Body Discomfort Diagram, questionnaires, and Rating of Perceived Exertion. An analysis of each dependent variable: heart rate, Regional Body Discomfort Diagram, and Rating of Perceived Exertion, showed that participants preferred the high backpack load condition and that they experienced more discomfort while walking uphill. According to the questionnaire responses, participants felt the most discomfort on the shoulder and neck areas. The findings of this research have implications for Human Factors Engineering design of backpacks, exercise and conditioning, and the importance of current and routine training.

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LIST OF ACRONYMS AND ABBREVIATIONS

ALICE	All-Purpose Lightweight Individual Carrying Equipment
ANOVA	Analysis of Variance
BFM	Basic Fighter Maneuvers
COM	Center of Mass
DLI	Defense Language Institute
EIB	Expert Infantryman’s Badge
EMG	Electromyography
ESQ	Environmental Symptoms Questionnaire
HFE	Human Factors Engineering
HR	Heart Rate
HRV	Heart Rate Variability
HSI	Human Systems Integration
MOLLE	Modular Lightweight Load-Carrying Equipment
NPS	Naval Postgraduate School
PAR-Q	Physical Activity Readiness- Questionnaire
RBDD	Regional Body Discomfort Diagram
RPE	Rating of Perceived Exertion
SPSS	Statistical Package for the Social Sciences
USA	United States Army
USAF	United States Air Force
USN	United States Navy

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EXECUTIVE SUMMARY

Carrying heavy loads over unpredictable terrain for long distances is a requirement common to military personnel (Lui, 2007). The platoon's combat load varies by mission and includes the supplies physically carried into the fight. Subsequently, today's soldiers and Marines are carrying more equipment, supplies, and ammunition than ever before, in part for their need to be self-sustaining for longer periods of time. Also, the soldier's load has increased as a result of additional digital equipment and increased battery requirements (Department of the Army, 2002). While there are many important factors to consider when outfitting the military with backpacks, this thesis examined load distribution and gradient. These factors can directly and indirectly affect the efficiency of load carriage as it relates to exposure to injury, fatigue, and ability to complete a mission. It is important that load distribution and gradient be taken into consideration throughout the design, training, and loading of backpacks.

The objective of this research was to discover the ways in which military personnel are affected by load distribution, identify the body parts which are affected during this task by use of the Regional Body Discomfort Diagram (RBDD), and to verify that one load configuration may not be suitable for all individuals, especially when the activity is conducted on multiple gradients. Possible relationships between these factors were also explored.

Participants were asked to simulate the common military task of road marching, at a comfortable, yet realistic pace on a treadmill while wearing a backpack. Load distribution and gradient were the independent variables. Load distribution was either high or low and gradient was either level (0%) or a positive incline (11%). Methods used to assess the effects of load distribution and gradient on load carriage were Heart Rate Variability (HRV), RBDD, questionnaires, and Rating of Perceived Exertion (RPE). An analysis of each dependent variable: heart rate, Regional Body Discomfort Diagram, and Rating of Perceived Exertion, showed that the majority of participants preferred the high backpack load condition and that they experienced more discomfort while walking uphill. The Wilcoxon signed rank test showed that the difference between the two loads (high,

low) was statistically significant. The first two tests compared high and low load conditions at a zero degree (level) angle. Results for back of the body showed a significance level of $p<.04$, meaning we can reject the null hypothesis and conclude the difference between the low and high load placements on the RBDD scores is statistically significant for the back of the body. Likewise, there was a statistically significant difference between the low and high load placements for the front of the body, at a significance level of $p <.05$. The last two signed ranked tests compared load conditions at a thirty degree (uphill) angle. Results showed significance levels of $p<.67$ and $p<.85$ respectively, on RBDD scores. Therefore, we can conclude that the difference between those scores is not statistically significant.

The participants clearly experienced more discomfort from the low pack placement while marching on the level gradient. RBDD results showed that participants felt the most discomfort on the shoulder and neck area. The waist and chest areas of several participants also sustained a notable amount of discomfort during the study. Questionnaire responses matched the results from the Wilcoxon signed rank test, in that participants preferred the high load distribution. Another common complaint amongst participants was that the majority of the weight rested on the shoulders. This finding has implications for the HFE design of backpacks, particularly exploring ways to distribute the weight more evenly across the entire back.

This research did not find any significant relationship between anthropometric measures and load distribution preference. A larger sample size would likely provide some insight on the possibility of a relationship between the two. It would be feasible to explore this area with further research.

Military personnel should be mindful that their backpacks should be packed based not only on military guidelines and personal preference, but the gradient in that they will be traversing and which pack placement will yield the least amount of fatigue, injury, and discomfort over time. The activity of road marching for training purposes as well as combat operations will continue to be an integral part of military operations. Optimistically, by use of after action reports, soldier interviews, and further research, the military, medical and research communities can continue to gain more insight regarding characteristics of the soldier’s load (e.g., weight, load configuration, load placement), with the intentions of reducing stress, fatigue and injuries to our servicemen.

ACKNOWLEDGMENTS

I would first like to extend my extreme gratitude to my advisor, Dr. Eugene Paulo and second reader, Dr. Michael McCauley. The knowledge, professionalism, commitment, and patience of these two faculty members made the completion of this thesis possible. I will always appreciate the support and encouragement you lent me when I needed it most.

I would also like to thank the students who took time out of their busy schedules to participate in this research.

I cannot forget to thank Mr. James Davis for the countless number of questions he answered during this journey. Your intelligence, work ethic, and kindness will always be much appreciated.

Last, but certainly not least, I wish to thank my supportive and loving family. The road has not been easy but you have always been in my corner and have supported me no matter what the obstacle.

This thesis is dedicated to my beautiful sons, Chance E. Henry and Christian C. Henry. You have changed my life, and I will be eternally grateful.

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I. INTRODUCTION

A. OVERVIEW

The U.S. infantry soldier must perform physically demanding tasks while trying to remain mobile, lethal, and undetected. Tasks include the carriage of moderate to very heavy loads under a variety of circumstances such as moving by foot over intermediate and long distances, repeatedly sprinting across the battlefield, negotiating various obstacles, and rapidly seeking and emerging from cover (Harman et al., 2003). Because of mission requirements or the limited transportation assets of some types of units (e.g., U.S. Army light infantry), service members must often depend on their personal mobility to move individual equipment. The pace of dismounted offensive operations is limited to the foot speed of the infantryman. To this end, the carrying of loads is an important aspect of military operations that can become critical in some situations, such as those involving medical emergencies and operations where the Soldier may have to sustain himself for an extended amount time.

The U.S. Army field manual on foot travel (Department of the Army, 1990) states that a fighting load, which the soldier carries while fighting on the battlefield, can be up to 48 lb (22 kg). The approach march load (including the fighting load and additional equipment such as clothing, helmet, weapons, rations, and ammunition), which the soldier carries when approaching the battlefield, may be up to 72 lb (33 kg). When terrain is impassible to vehicles, greater loads are authorized. Numerous studies conclude that backpack loads have a huge impact on soldiers' load carrying ability.

The platoon's combat load varies by mission and includes the supplies physically carried into the fight. Subsequently, today's soldiers and Marines are carrying more equipment, supplies, and ammunition than ever before. Also, the soldier's load has increased as a result of additional digital equipment and increased battery requirements (Department of the Army, 2002). This trend is unlikely to change in the near future. Therefore, it is important that critical factors such as load distribution and gradient are analyzed for their effects on load carriage.

B. AREA OF RESEARCH

Load placement or distribution is an important characteristic of load carriage while wearing a backpack. Most soldiers have a preference in rucksack (backpack) configuration (i.e., top-heavy, bottom-heavy, or evenly distributed). However, this preference may vary depending on the mission, equipment being carried, and the terrain. Load carriage distribution may be important with regard to the soldiers' ability to walk, run, and maintain balance and muscular endurance.

Walking, running, climbing, and even crawling through different types of terrain can pose challenges for servicemen. According to the U.S. Army field manual on infantry rifle platoon and squad (Department of the Army, 2002), the infantry platoon must be able to move over terrain not trafficable by wheeled vehicles with the infantry squad. Terrain factors such as surface type: desert, snow, dirt, etc and grade: level, hilly, etc., can affect one's load carriage ability. However, we are unaware of any studies that have analyzed the effect of both load placement and gradient on the load carriage ability of military personnel while carrying a rucksack. The purpose of this study is to gain insight as to the factors affecting load carriage of military personnel, specifically load distribution and gradient, in a controlled setting.

Due to the subjective nature of discomfort, a three-prong approach was used in generating data for research -- subjective questionnaire, physiological measurements, and laboratory experiment. Legg, (1985) utilized this three-prong approach in his comparison of different methods of load carriage. Legg stated that "We believe that it is wise to supplement objective physiological measurements with subjective opinion. However, it is important that the subjective data should be gathered as objectively as possible, by using appropriate experimental designs, carefully structured questionnaire techniques and standardized subjective rating methods. We have also found it profitable to conduct field studies to supplement our laboratory experiments."

C. RESEARCH QUESTIONS

1. Primary Question

What are the effects of load distribution and gradient on load carriage while wearing a rucksack?

2. Secondary Questions

Is there a relationship among heart rate variability, perceived ratings of discomfort, and perceived rating of exertion?

Is there a relationship among anthropometric body measurements and preference for load carriage placement?

D. SCOPE

This is a repeated measures, within-subjects research study (2x2). Experienced active duty military officers (males) performed a “road march” on a motorized treadmill with a load under two different load configurations (high and low) and over two different terrain gradients (level and uphill). The load configuration order was counterbalanced. The load was carried using a Camelbak military backpack. Participants carried a load equivalent to approximately 15–23% of their body weight (35 lb or 15 kg). As a secondary research question, anthropometric data was collected in to determine if differences among weight, stature, body type, etc. have an effect on participant performance. Differences in these body dimensions and measurements could answer questions regarding differences in load carriage performance and preference. Methods for measuring performance included:

- Heart Rate Variability (HRV)
- Regional Body Discomfort diagram (RBDD)
- Post-field questionnaire
- Rating of Perceived Exertion (RPE)

E. HSI CONSIDERATIONS

HSI is a technical and managerial concept bringing together various disciplines with the goal of appropriately incorporating humans into the design, production, and operation of programs and systems (Booher, 2003). The seven domains of HSI as defined by the Department of Defense Instruction 5000.02 are: Manpower, Personnel, and Training (MPT), Human Factors Engineering (HFE), Safety, Occupational Health, Personnel, Survivability, and Habitability. This thesis has relevance to several of the HSI domains, however, it will specifically focus on three.

1. **Human Factors Engineering**
2. **System Safety**
3. **Training**

Carrying heavy loads over unpredictable terrain for long distances is a requirement for military personnel. Load distribution and walking gradient are important factors in terms of the efficiency of load carriage and should be taken into consideration in both the design and loading of backpacks (Liu, 2007). Human factors engineering (HFE), as defined by Booher (2003) is the integration of human characteristics into system definition, design, development, and evaluation to optimize human-machine performance under operational conditions. This thesis directly relates to HFE as it explores how well the end user is able to perform common military tasks while wearing a loaded backpack under various conditions.

System safety should always be an important factor when it comes to the design and development of any system or product. System safety faces a continual problem in demonstrating how to increase system safety without decreasing system performance to unacceptable limits or making the system unaffordable (Booher, 2003). This thesis explored system safety as it related to discomfort, potential for injury, and weight limitations in load carriage.

Booher (2003) describes the traditional role of training as one in which a specific, fully developed system is taken as a starting point and within which training applies its trade toward equipping people with the knowledge, skills, and abilities and devices necessary to interact with the system. In the present study, researchers gathered information regarding the training participants received on how to load a pack and made suggestions regarding additional training based on participant feedback and questionnaire responses.

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II. LITERATURE REVIEW

A. OVERVIEW

An infantry soldier must perform physically demanding tasks, while trying to remain mobile, lethal, and undetected. These tasks include the carriage of moderate to very heavy loads under a variety of circumstances such as moving by foot over intermediate and long distances, repeatedly sprinting across the battlefield, negotiating various obstacles, and rapidly seeking and emerging from cover (Harman et al., 2003). The soldier's load is a main concern of the leader. How much is carried, how far, and in what configuration are important mission considerations (Department of the Army, 2002). As required by the U.S. Department of the Army (1994), two of the many physical demands for the infantry soldier include:

- Frequently perform all other tasks while carrying a minimum of 65 pounds, evenly distributed over the entire body
- Frequently walk, run, crawl, and climb over varying terrain for a distance of up to 25 miles

For this study, participants were asked to simulate the common military task of road marching, at a comfortable, yet realistic pace on a treadmill while wearing a backpack. Road marching with loads is a fundamental task required of all soldiers, especially the infantryman (Knapik et al., 1991). The Army field manual on foot marches describes road marching as the physical movement of the infantry company over long distances to position itself for future operations (Department of the Army, 1990). The main purpose of the road march is to relocate rapidly and not gain contact with the enemy. Road marches are conducted using fixed speeds and timed intervals (1990). A simple way to assess the effects of two load distributions and two terrain gradients is to evaluate the performance of the participants while executing specified tasks. Energy expenditure during walking with and without loads has been studied previously to examine physical and psychological tolerance as well as physiological responses in military research (Abe et al., 2004).

A description of previous and current issue military rucksacks is given in this chapter. Load distribution and placement also is discussed. Depending on the mission, equipment being carried, and the terrain, it may be feasible to vary load placement to best fit the user's needs. Additionally, the effects of gradient on load carriage will be introduced. Moreover, as a result of a lack of preparation, overloading, or even poor design, infantrymen can encounter a host of medical problems and injuries, as described in this section.

B. MILITARY PACKS

Current issue military load bearing equipment systems include the ALICE and MOLLE packs. References to both packs will be made throughout this chapter; therefore, a detailed description of system features, including human factors issues will be addressed.

1. ALICE

Figure 1. ALICE pack

The U.S. Army's ALICE (All-purpose Lightweight Individual Carrying Equipment) pack was introduced in 1974 and is characterized by an external frame, double quick-release shoulder pads and kidney pads. It comes in two sizes, medium and large. The medium can carry up to 23 kg while the large, which stands about two feet tall, carries up to 32 kg ("Go ask ALICE," 2000). One of the purported advantages of this type of externally-framed backpack is the reduction of shoulder stress.

2. MOLLE

The MOLLE (Modular Lightweight Load-carrying Equipment) pack is the latest edition to current generation load bearing equipment used by the United States Armed Forces. The system is highly modular and allows for attachment of various MOLLE-compatible pouches and accessories. This system was developed in 1996 and was initially fielded in 2001 by the U.S. Army. In contrast to the ALICE, the MOLLE pack has an internal frame.

Figure 2. MOLLE pack

Natick Labs' goal in developing the MOLLE system was to create a more versatile load-carriage system that would reduce fatigue. The MOLLE attempts to address load distribution, which is one of the many concerns surrounding load carriage. The taller, narrower design of the MOLLE is one of the main design features that distinguish it apart from the ALICE (see Table.1). This feature claims to afford a more optimal load center of mass placement on the body compared to the ALICE. The pack is designed to allow soldiers to transfer the rucksack's weight from their shoulder to their hips and tailor their loads to specific missions (Soldiers, 1998).

3. Camelbak

Due to limited resources, in this experiment, participants carried a load using the Camelbak BFM (Basic Fighter Maneuvers) rucksack. A camelback is a rucksack that has an internal water reservoir, which stores water for users to drink while on the move. Keeping troops hydrated in the heat of battle can be a difficult challenge, especially for those fighting in hot climates. The Defense Language Institute (DLI) in Monterey, CA currently uses the Camelbak for military training exercises. Its shorter, compact design is closest to that of the ALICE. Camelbaks have been used by members of the United States Army (USA), United States Navy (USN), United States Air Force (USAF), and United States Marine Corp (USMC). Table 1 provides a summary of specifications for each pack.

Figure 3. Camelbak

Pack Type	Weight (kg)	Dimensions (mm)	Capacity	Frame
ALICE	2.94	559 x 508 x 483	32 kg	external
MOLLE	5	635 x 330 x 304	54 kg	internal
Camelbak	2.53	533 x 330 x 254	42 L	internal

Table 1. Summary of Pack Specifications

C. LOAD DISTRIBUTION

Although load mass is one of the most highly studied aspects of load carriage, load distribution and placement are arguably as critical to the safety and effectiveness of a soldier. Much of the research on load carriage has shown that the most practical method is to carry the load as close as possible to the center of mass of the body. In this regard, the backpack and double pack (half the load carried on the front of the body and half on the back) methods have been shown to have a lower energy cost than most other forms of load carriage (Knapik & Reynolds, 1997). Energy cost is a measure of human energy use and capabilities. Heart rate and oxygen consumption are typical body indicators for this measurement. The double pack offers more even distribution over the torso. Although it is impossible to make the load equal on the front and back of the body, both the ALICE and MOLLE systems allow part of the load to be moved forward onto the load-carrying vest. This redistribution might be expected to reduce energy cost, improve body posture, and reduce injuries; all of which can become critical over the course of long marches (Knapik & Reynolds, 1997). Some of the disadvantages of the double pack include limitations on movement and field of vision, difficulties donning and doffing, increased heat retention, and decreased ability to aim and fire weapons effectively and accurately.

In another examination of load distribution using a double pack, Johnson, Knapik and Merullo, (1995) assessed symptoms reported by Special Forces soldiers when carrying various loads of 34, 48, or 61 kg (75, 105, or 135 lb). In addition to a double pack, the U.S. Army’s ALICE pack also was used in the study. Each of the 15 soldiers completed a 20-km (12.4 mi) road march while wearing one of the six pack configurations (ALICE or double pack) x mass (34, 48, or 61 kg). Symptoms were assessed using the Environmental Symptoms Questionnaire (ESQ), developed by Sampson and Kobrick (1980). The ESQ was developed to provide a standardized procedure for assessment of symptoms experienced by soldiers exposed to environmental extremes. It subsequently was revised to incorporate a more comprehensive tool for measuring subjective reactions to severe heat and cold, as well as to diet, physical exercise, and medications (Sampson & Kobrick, 1980). Eight relevant symptom factors: alertness, cardiopulmonary discomfort, distress, exertion, muscle discomfort, subjective heat illness, tiredness, and well-being were analyzed using a 2 x 3 (pack x mass) repeated measures ANOVA. Results revealed no significant difference between packs prior to each march. Post-march results showed that the distress factor and the subjective heat-illness index were most intense at 61 kg with the double pack. A two-way analysis of variance on road march times showed a significance of pack, indicating that the soldiers took more time to march with the double pack than with the ALICE pack (Sampson & Kobrick, 1980).

In a study by Bobet and Norman (1984), the effect of two different load placements (just below the mid-back and just above shoulder level) on the spine, upper back, and heart rate were investigated during load carriage. The electromyography (EMG) and heart rates were telemetered while 11 participants walked on a smooth level surface. EMG is a medical technique used to measure the response of muscle and nerve activity to electrical stimulation. The high load placement resulted in significantly higher levels of muscle activity than did the lower placement. Heart rate was not significantly different between the two placements. With the high placement, the load was less stable and tended to sway more over the course of the stride. This increased swaying must be compensated for by the trapezius (upper back, neck, head) muscle, if the carrier is to be able to walk with any stability (Bobet & Norman, 1984). Based on back muscle tension levels, it appears as though a mid-back placement would have been preferable for this task.

In their review of military aspects of load carriage, Knapik and Reynolds (1997) reported mixed results based on load carriage placement. Placement of the load high in the pack tends to destabilize posture to a greater extent than lower placements, especially among taller men. Alternatively, low load placements result in significant forward body lean. This result can be attributed to the fact that the lower load is closer to the ankles, requiring more forward body rotation to bring the pack center of mass over the feet (Bloom & McNeal, 1987). The additional forward body rotation tends to bring the body's center of mass over the front half of the foot, which could increase the likelihood of foot strain and injury (Knapik & Reynolds, 1997).

Grimmer, Danise, Milanese, Pirunsan, & Trott (2002) studied postural responses to backpack loads in adolescents. Backpack loads were positioned with their center of gravity at upper, middle, and lower spinal positions. The second independent variable, mass, was distributed as 3%, 5%, and 10% of students' body weight. Participants wore adhesive paper dots on anatomical landmarks that contrasted to skin color. Still pictures were then taken for each combination of position and mass. Vertical and horizontal coordinates were calculated for the center of each anatomical landmark on each photograph using digitizing software (Grimmer et al., 2002). The use of coordinate values allowed for comparisons of posture change between and within subjects. The results showed that positioning the backpack high on the spine produced the largest postural response. This finding contradicts the "rule-of-thumb" that higher load positioning is better.

The relationship between the location of the center of mass (COM) of a loaded backpack and the metabolic cost of carrying a heavy load in a framed backpack was analyzed in a study conducted by Obusek, Harman, Frykman, Palmer, & Billis (1997). A custom, external frame backpack was fabricated in which the location of a 24.9 kg lead brick could be moved, resulting in 9 different COM positions and a pack weight of 34 kg (Obusek et al., 1997). A COM index was created by dividing both the horizontal and vertical distance of the COM from a fixed point. High index values indicate a COM position low on the pack and away from the body, low values indicate a high and close

COM (Obusek et al., 1997). Six soldiers walked on a level treadmill at 5.6 km/hr for 5 minutes while wearing the pack in each of the 9 COM positions. Oxygen consumption (VO_2) was measured at 30 second intervals during the final 90 seconds of each condition. Results showed that high metabolic costs were associated with high index values (i.e., COM position low on the pack and away from the body). These data suggest that backpack COM is an important factor in the energy cost of load carriage and should be considered in the design and loading of backpacks (Obusek et al., 1997).

Mackie, Stevenson, Reid, and Legg (2005) studied the effects of simulated school load carriage configurations on shoulder strap tension forces and shoulder interface pressure. A load carriage simulator (mannequin) was used for data collection. Gait speed, backpack weight, load distribution, shoulder strap length and use of a hip-belt were manipulated so that 32 possible combinations of load carriage configuration were evaluated (Mackie et al., 2005). Load distribution was measured in terms of how close or distant the bulk of the load was to the inner wall of the backpack. Five textbooks were used to pack the backpack with the heaviest books closest to the back of the mannequin for the ‘close’ load distribution condition and the heaviest books farthermost from the back of the mannequin for the ‘distant’ load distribution condition. Having the weight distributed farthermost away from the back increased overall shoulder strap forces by 6% and peak shoulder strap forces by 10%. Load distribution had much less of an effect on the shoulder strap forces and pressure at the shoulder than load weight, hip-belt use, and shoulder strap adjustment (Mackie et al., 2005).

Knapik et al., (1991) examined soldier performance and mood states following a strenuous 20 km road march. Eighty-nine soldiers were directed to complete the road march as quickly as possible, while carrying loads of approximately 46 kg. Following the road march, soldiers completed three physical tasks: marksmanship, vertical jump, and grenade throw. Pre-march scores for the three activities were obtained 1–3 days prior to the road march. Soldiers completed the Profile of Mood States (POMS) questionnaire within 30 minutes of starting the road march and immediately following the post-march grenade throw (Knapik et al., 1991). Lastly, soldiers reported discomfort, soreness, and pain using a modified version of Corlett and Bishop's regional body discomfort technique. Results showed a decline in performance for marksmanship and the grenade throw. POMS scores revealed a considerable increase in fatigue and a notable increase in anger. There was an expected decrease in vigor. Soldiers reported the highest levels of soreness, pain, and discomfort in the feet (Knapik et al., 1991).

D. TERRAIN AND GRADIENT

Walking, running, climbing, and even crawling through different types of terrain, especially in foreign geographic areas, can pose unwelcome obstacles for servicemen. Terrain factors such surface type (sand, snow, gravel) and grade (level, uphill, downhill) can greatly affect one's load carriage ability. Load carriage over rough terrain may include gradients between 0–5 percent (Legg, Ramsey, & Knowles, 1992).

When moving uphill on a constant slope at a given speed and time, there is a vertical lift, and work is performed against gravity. In their study on the metabolic cost of backpack and shoulder load carriage, Legg et al., (1992) incorporated uphill walking with load carriage. Eleven male soldiers walked on a motorized treadmill for 5 minutes at each of three gradients (0, 2.5, and 5%) while carrying a 26 kg load either on each shoulder or strapped to a backpack frame. Heart rate and oxygen uptake were both significantly lower for backpack load carriage than shoulder load carriage for all three gradients.

The energy cost of walking with loads has been found to depend primarily upon the walking speed, body weight, and load weight, together with terrain factors such as gradient and surface type (Hasiman, 1988). Haisman and Goldman (1974) analyzed the effect of terrain on the energy cost of walking with back loads and handcart loads. Eight soldiers carried a 20 kg back load or pulled a handcart weighing 20, 60, or 100 kg at two speeds (0.89 or 1.34 m/s) on three surface types (blacktop road, dirt road, or grassland). Each subject performed 24 30-min walks. Energy cost was measured three times during each 30-min walk using respirometers. Results showed that energy costs for walking on both the dirt road and grass were significantly higher than for those on the blacktop.

Knapik & Reynolds (1997) assert that the most advantageous distribution of the load in the pack may depend on the type of terrain. On roads or well graded paths, placement of heavy items high in the pack is preferable to maintain a more upright body posture and possibly reduce low back problems. Consequently, a more even distribution of the load within the pack may be more helpful on uneven terrain (Knapik & Reynolds, 1997).

E. ANTHROPOMETRY

Anthropometric information describes the dimensions of the human body. The military has always had a particular interest in the body dimensions of soldiers for a variety of reasons, among them the necessity to provide uniforms, armor, and equipment that fit (Kroemer et al., 1997). The design of load carriage must take into account the range of dimensions in key anthropometric variables in the population to be fitted, especially back length and waist circumference (Haisman, 1988).

The simplest inertial property is weight, a force that can be measured easily with a variety of scales (Kroemer et al., 1997). The service member's height and weight may be a important factor in load carriage. Additionally, the size of lean body mass, which is total weight minus fat, also is an important factor in load carriage. Excess body fat is dead weight in the performance of work and degrades the performance of physical tasks involving movement of the body and external load (Haisman, 1988). Individuals who are larger and those who have a high body weight can carry greater loads.

F. PHYSICAL CONDITIONING

Knapik et al., (1990) studied four groups of soldiers who engaged in a 9-week training program consisting of endurance training, resistance training, interval training, and callisthenic exercises. Additionally, 0 to 4 loaded road marches a month were combined with the training program. The authors found that groups that performed either 2 or 4 loaded road marches per month during the training period covered the 20 km course significantly ($p<0.05$) faster than groups that trained with either 0 or 1 loaded road march per month.

Physical training that includes aerobic exercise, resistance exercise, and road marching have been shown to increase march performance and may reduce injuries. Therefore, fitness programs that are specific to unit needs should be performed on a regular basis. Loads carried by service members during training should resemble those expected to be carried in unit operations. Load and distance should be increased gradually over sessions until a maintenance level has been achieved (Knapik & Reynolds, 1997).

G. MEDICAL PROBLEMS

Injuries associated with load carriage, while generally minor, can adversely affect an individual's mobility and thus reduce the effectiveness of an entire unit (Knapik & Reynolds, 1997). The following medical conditions are those most commonly suffered by servicemen in the field, combat, or training, as a result of load carriage with rucksacks.

1. Foot Problems

Our feet provide a stable foundation to keep our bodies upright, thus supporting the entire body frame. The feet also give us the ability to walk, run, and move about in any fashion we choose. For those in the military, the inability to travel by foot due to injury or extreme pain could yield many consequences, such as reduced personnel, unit effectiveness, and even mission failure (Knapik et al., 1992.)

a. Foot Blisters

Foot blisters are the most common load-carriage injury (Knapik et al., 1992). Blisters result from friction between the socks, skin, and boot. Heavy loads have been shown to increase blister incidence, possibly by increasing pressure on the skin and causing more movement between the foot and boot (Knapik et al., 1996). One of the major causes of foot blisters is excessive perspiration. The use of proper socks is critical in avoiding blisters, especially since it is unlikely for soldiers to make frequent stops in order to change them. Socks made from nylon and wool are known for their moisture absorbing qualities and when worn together, have proven to reduce the incidence of blisters.

b. Metatarsalgia

Metatarsalgia is a descriptive term for nonspecific painful overuse injury of the foot (Knapik et al., 1996). Excessive pressure from walking, running, and jumping directly affect this part of the foot. According to Durham (2010), a medical contributor to emedicine.com, the condition may be the result of an alteration in normal biomechanics that has caused an abnormal weight distribution among the metatarsal heads. Again, the importance of weight distribution on the human body is emphasized. Physical and occupational therapy are the first lines of treatment used for this injury. In serious cases, surgical treatment may be necessary to realign the metatarsal bones.

2. Knee Pain

Many instances of knee pain result from 1) an increase in road marching mileage or intensity and 2) from climbing hills, if service members have not been conditioned for such activities (Knapik & Reynolds, 1997).

3. Back Injuries

Back injuries, which normally occur over a period of time, affect a large number of infantrymen. In regards to backpacks, the total weight carried, duration and frequency of carriage, and the manner in which the weight is carried all affect the demands on the musculoskeletal system and may affect the incidence of musculoskeletal pain or discomfort (Mackie et al., 2003). As expected, heavier loads may pose an added risk for back injuries.

4. Rucksack Paralysis (Palsy)

Rucksack palsy is a disabling injury and has been reported in association with load carriage (Knapik & Reynolds, 1997). This injury causes trauma to the brachial plexus and has occurred in soldiers carrying rucksacks in road marches. The brachial plexus is a network of nerves that conducts signals from the spine to the shoulder, arm, and hand. Symptoms include numbness, paralysis, cramping and minor pain in the shoulder girdle, elbow flexors, and wrist extensors (Knapik & Reynolds, 1997). Bessen et al., (1987) conducted an examination of 18 soldiers in basic training who suffered from brachial plexus injuries. Fifteen of the soldiers were wearing the ALICE pack without a frame while three wore the ALICE with a frame. The majority (72%) of the injuries occurred during the long road marches (10-15 miles long). Soldiers commonly noted difficultly carrying their M-16 rifle during the march or doing pushups afterwards. Ultimately, only six soldiers were retained on active duty following a convalescence period (Bessen et al., 1987). The authors recommend the use of rucksacks with a frame since they appear to substantially decrease the risk of rucksack paralysis.

H. RATING OF PERCEIVED EXERTION

The Rating of Perceived Exertion (RPE) was developed by Gunnar Borg in 1970 to describe a person's perception of exertion during exercise. The RPE uses a 15-grade scale, which ranges from 6-20, where 6 is associated with no exertion at all and 20 is associated with maximal exertion (Appendix I). Ratings of perceived exertion or effort have been found to be an important psychological complement to physiological responses (Goslin & Rorke, 1986). Previous studies of perceived exertion have found high correlations with heart rates, blood lactate concentrations, and other physiological variables (Borg, 1990).

The objective of this research is to discover the various ways in which military personnel are affected by load distribution, identify the body regions which are affected during this task by use of the RBDD, and to verify that one load configuration may not be suitable for all individuals, especially when the activity is conducted on multiple gradients. Possible relationships between these factors were also explored.

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III. METHODS

A. OVERVIEW

This study was a with-in subjects, repeated measures design. The independent variables were gradient and pack placement. The dependent variables were heart rate, Regional Body Discomfort, and Perceived Exertion. Each of these dependent variables will be further explained in this section. The present study combines subjective, anthropometric, and physiological measures to analyze the effect of load placement and terrain gradient on load carriage.

Both subjective and physiological measures are important in the analysis of load carriage performance. This combined methodology has been widely used in similar studies on load carriage. For example, Legg (1985) found it beneficial to supplement physiological measurements (heart rate, oxygen consumption) with subjective opinion. Legg et al., (1987) also suggest that questionnaire techniques such as the subjective assessment of comfort or preference and some biomechanical factors (e.g., muscle electromyographic activity, joint angle changes, etc) will be more sensitive, useful, and appropriate for comparing load carriage systems. Likewise, the results from Bobet's and Norman's (1984) study showed that heart rate measures alone are not sufficient to evaluate the physiological demands of differences in load placement on the back during load carriage.

B. EXPERIMENTAL SUMMARY

Before any events were conducted, all test participants were administered a demographic questionnaire designed to elicit military history and service data, previous experience packing a rucksack, and general physical characteristics data. Participants were members of the USA, USN, USAF, USMC, and foreign military branches.

Data collection occurred at the Monterey Bay Athletic Club & Fitness Center located on the campus of the Naval Postgraduate School (NPS). Each participant was instructed to choose a comfortable, yet realistic pace that can be maintained for each gradient condition. The selected pace was measured by a member of the research team by regularly checking the speedometer on the treadmill.

Physiological measurements of individuals wearing loaded backpacks have included heart rate, electromyography (EMG), oxygen uptake, pulmonary ventilation, average and per unit mass energy cost, as well as relative work intensity (Quesada et al., 2000). This study includes one of the most common physiological measures of energy expenditure, heart rate variability (HRV).

The analysis of HRV is a powerful, noninvasive measure of neurocardiac function that reflects heart-brain interactions (McCraty et al., 2009). HRV was measured using the Polar S210 heart rate monitor. The monitor was worn around the chest of the subjects and was attached by a member of the research team. HRV readings were collected utilizing the Polar heart rate monitor after each trial.

The perceived regional discomfort for each participant was assessed after each trial for each of 24 body regions (12 front and 12 back) using a regional body diagram developed by Corlett and Bishop (1976), and a category scale rating method. The perceived regional discomfort diagram uses a common category scale, which refers to five different adjectives to describe discomfort levels: None, Slight, Moderate, Severe, and Extreme.

A subjective, post-test questionnaire was administered to participants after each trial. The questionnaire consisted of questions commonly used by researchers investigating load carriage characteristics and additional questions derived by the research team to address the effects of both load placement and terrain gradient.

C. DATA COLLECTION

1. Participants

Eight males (active duty military officers) volunteered to participate in the study. In accordance with the procedures approved the NPS Institutional Review Board, the participants were informed of the purpose, procedures and risks of the study and signed a statement of informed consent. Participants were graduate students recruited from NPS.

2. Road Marching

Participants were instructed to "simulate a road march" as opposed to being instructed to simply walk. The intent was to ensure that participants would walk at a rapid yet realistic pace.

3. Measures

a. Perceived Regional Body Discomfort Diagram

The perceived regional discomfort diagram uses a common category scale, which refers to five different adjectives to describe discomfort levels. The scale uses the following adjectives: None, Slight, Moderate, Severe, and Extreme, where extreme represents an extremely strong perceptual intensity. For the purpose of data analysis, the scale was converted to 1-5, with 1 being the lowest and 5 being the highest.

b. Rating of Perceived Exertion

The RPE is used in rehabilitation and for the prescription and regulation of exercise intensities or as a means to evaluate a certain training situation. In this research, the RPE was collected after each five-minute interval for a total of sixteen times over the course of two days.

c. Heart Rate Variability

Heart rate variability (HRV) is a measure of the naturally occurring beat-to-beat changes in heart rate. HRV was measured in this study by using the Polar S210 heart rate monitor. The HR monitor is a small digital recording device which can be worn as a watch or clipped onto a chest transmitter.

Figure 4. Polar S 210 Heart Rate Monitor

The monitor was worn around the chest of the Subjects. Readings were collected after each five-minute interval. The resting heart rate was collected prior to the first trial.

d. Heart Rate – RPE Relationship

Originally, RPE was designed to correspond closely to heart rate during exercise and thus provide a subjective means to estimate cardiovascular strain (Glass, Whaley, Wegner, 1991). For this reason, the RPE scale begins with 6 (and not zero), and the number range from 6–20 roughly corresponds to a heart rate range from 60-200 beats per minute in healthy people, about 30–40 years old, by using the equation Heart Rate = RPE x 10 (Borg, 2001).

e. Subjective Questionnaire

A subjective questionnaire was used to more fully examine subjective perceptual responses to varying load placements and gradients (Appendices G–H). A combination of multiple choice, Likert-scale, and open-ended questions were used to inquire about comfort, positive and negative responses to the load, and physical responses to load placement and gradient during the road march. Several questions were developed from the Harper et al., (1997) study on equipment compatibility and performance of men and women during heavy load carriage. The remaining questions were developed by the research team. Open-ended questions were used where applicable to allow participants to write a full explanation. The questionnaire was administered after each trial. A trial consisted of 20 minutes of road marching on the treadmill whilst wearing the pack in either one of the load distributions, high or low.

f. *Physical Activity Readiness Questionnaire (PAR-Q)*

The Physical Activity Readiness Questionnaire (PAR-Q) is a simple questionnaire that has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them (Appendix D). The PAR-Q was created by the British Columbia Ministry of Health and the Multidisciplinary Board of Exercise. This form was adopted directly from the American College of Sports Medicine Standards and Guidelines for Health and Fitness Facilities. The PAR-Q was administered to all participants prior to any physical activity, to ensure their ability to safely perform all physical tasks during the experiment.

g. *Anthropometric Measures*

The following anthropometric measures were taken:

- Stature
- Weight
- Shoulder breadth
- Sitting waist height (back length)

Stature, shoulder breadth and sitting waist height are relevant anthropometric measures to this research because they correspond closely to the areas of the body most affected by load carriage. Participant weight was measured, however, the mass of the loads were not varied among participants, thereby making this measure not pertinent. This thesis explored the possible relationship between the specified anthropometric measures and load distribution preference. Measuring instruments used are given in Appendix J.

4. Equipment

a. Treadmill

The Life Fitness motorized treadmill was used to collect data in this experiment. The treadmill is a commonly used piece of equipment to evaluate physical work capacity. Although it is expensive and immobile, the treadmill provides accuracy in speed, heart rate, gradient, and other variables depending on the machine. Additionally, when using a treadmill, data collection is not effected by weather or other external conditions. Photos of the Life Fitness treadmill can be seen in Figures 5 and 6. Additional tools used are noted in Appendix J.

D. PROCEDURES

The eight male participants were given instructions as to the conduct of the experiment. The heart rate monitor was secured around the chest, directly below the sternum. Participants were also reminded of the purpose and interpretation of the Rating of Perceived Exertion (RPE). The RPE was placed in front of participants on the treadmill, so that they could quickly refer to the scale and the description associated with it. The load placement of the rucksack was noted at the beginning of each trial and was randomly changed throughout the experiment. Free weights (three 4.53 kg and one 2.27kg) were used to load the rucksack. The rucksacks were loaded with thirty-five lbs. (15.87 kg), because it is the standard weight used for the Expert Infantryman's Badge (EIB). The EIB test measures an infantryman's skills and includes such tasks as a twelve mile road march which must be worn with a 35 lb rucksack and must be completed in less than three hours. Also, guidance from the Department of the Army on the physical fitness training policy asserts that during forced road marches, cadets will carry a 35 lb rucksack (Department of the Army, 2003).

A well-constructed cardboard box was used to create volume with essentially no weight. The dimensions of the box were 3440 cm x 2220 cm x 1250 cm. The rucksack was packed with either the weight on the bottom of the rucksack or flipped so that the weight was on top of the box (high or low).

After participants made all adjustments and felt comfortable with their load, they were instructed to step on the treadmill and prepare for a warm-up. Based on American College of Sports Medicine standards, warm-up and cool-down periods are necessary elements of any physical or fitness activity. All participants were given a two-minute warm-up, which allowed them to increase their heart rate and get acclimated to walking with the rucksack. Speed was increased from 1.7 m/s during the first minute to 2.0 m/s for the second minute. At the end of the warm-up period, participants were instructed to increase their speed until they reached a comfortable yet realistic road march speed that could be maintained for the subsequent trial. The treadmill was set with no gradient for this first session (two trials). For the next 15 minutes, participants ‘road marched’ on the treadmill. A three minute cool-down, where speed was decreased by 3.0 m/s per minute followed the march. The RPE was collected 4 times during the trial at times 5:00, 10:00, 15:00, and 20:00 minutes.

After participants doffed their rucksacks, they were instructed to sit down and complete the regional body discomfort diagram and subjective questionnaire. The regional body discomfort diagram and questionnaire were administered after every trial. If assessments were completed in less than 15 minutes, participants were told to rest for the remaining time. While participants were completing assessments, the placement of the load was switched and noted. Trial two consisted of all tasks previously described in trial one, with the exception of the placement of the load. At the end of trial two, participants were asked how they felt and were given a post-experiment medical sheet. The sheet contained medical contact information if anyone had a question or needed medical attention.

The second session was scheduled two days later in order to allow participants a recovery period. For the second session, the treadmill was set to an 11% positive incline. Again, the load was randomly switched every other trial between high and low. Three percent increments in grade were made every 30 seconds. By the end of the two minute warm-up, the 11% grade and final road march speed had been reached. The same measurements previously mentioned were collected during this session. After all assessments were collected, subjects were asked how they felt and were thanked for their participation.

Table 2 summarizes the experimental procedure and conditions of the present study. The table also identifies the independent and dependent variables. The participant's RPE and heart rate measures were collected at times: 5:00, 10:00, 15:00, and 20:00. The RBDD and questionnaire was administered twice per session.

Table 2. Summary of the experimental procedure and conditions:

	Gradient (I.V.)	Pack Placement (I.V.)	RPE (D.V.)	HR (D.V.)	RBDD (D.V.)	Questionnaire
Day 1	Level	High Low (Trial 1,2)	5 10 15 20	5 10 15 20	Twice	Twice
Day 2	Incline	High Low (Trial 1,2)	5 10 15 20	5 10 15 20	Twice	Twice

RPE = Rating of Perceived Exertion
HR = Heart Rate (beats/min)
RBDD = Regional Body Discomfort Diagram (scale of 6-20)
I.V. = Independent Variable
D.V. = Dependent Variable

Figure 5. Participant while on the treadmill

Figure 6. Participant while on treadmill with incline

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IV. RESULTS

A. DEMOGRAPHICS

The average participant age was 36.9 years. The average height and weight were 180.34cm and 89.47kg, respectively. Three of the eight (38%) participants never received any training on how to pack a rucksack. All three were members of the USN. Four of the participants (50%) received between 5–6 hours of sleep and the other four (50%) received between 7–8 hours of sleep prior to the first day of the experiment. A demographics summary table is given in Appendix A.

B. REGIONAL BODY DISCOMFORT DIAGRAM

The data from the Regional Body Discomfort Diagrams were first analyzed graphically in Excel. There did not appear to be any significant difference between the high and low load placements for both marching conditions. However, results consistently show that complaints were slightly higher for the low load placement than the high load placement. There were several exceptions where the participants experienced a higher degree of discomfort from the high load and three instances where they reported an equal amount of discomfort from both loads. As can be seen from Figures 7 and 8 (front of the body), all responses averaged between a value of 1-1.5 except for the shoulders and neck, which were expectedly higher.

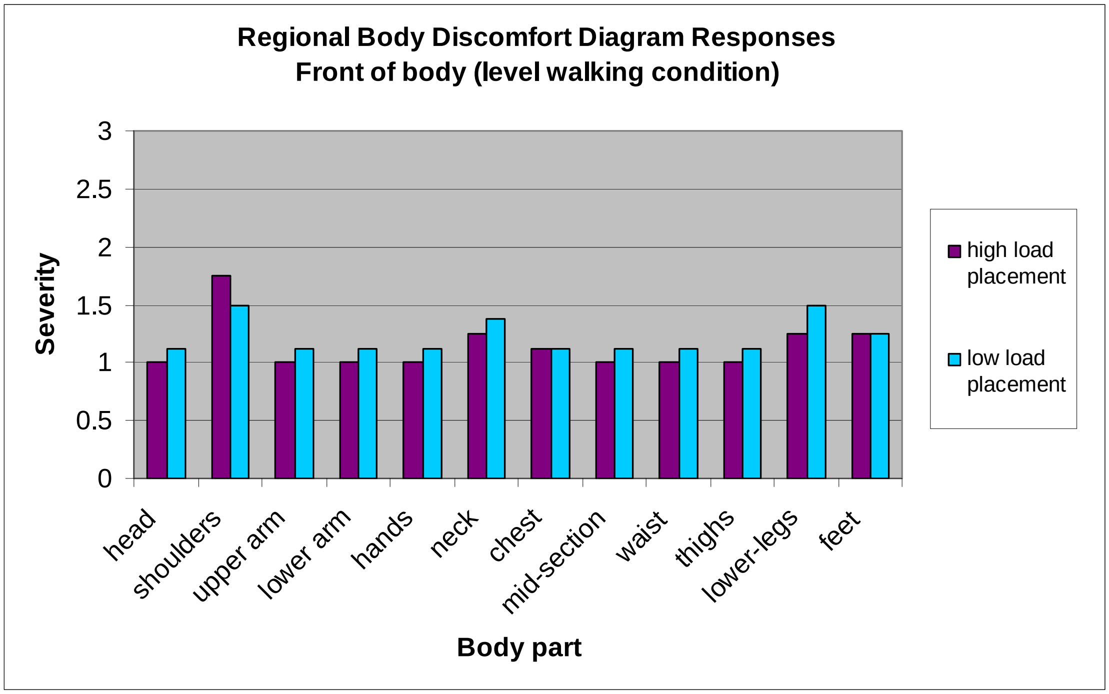

Figure 7. RBDD Responses Front of Body (level walking condition)

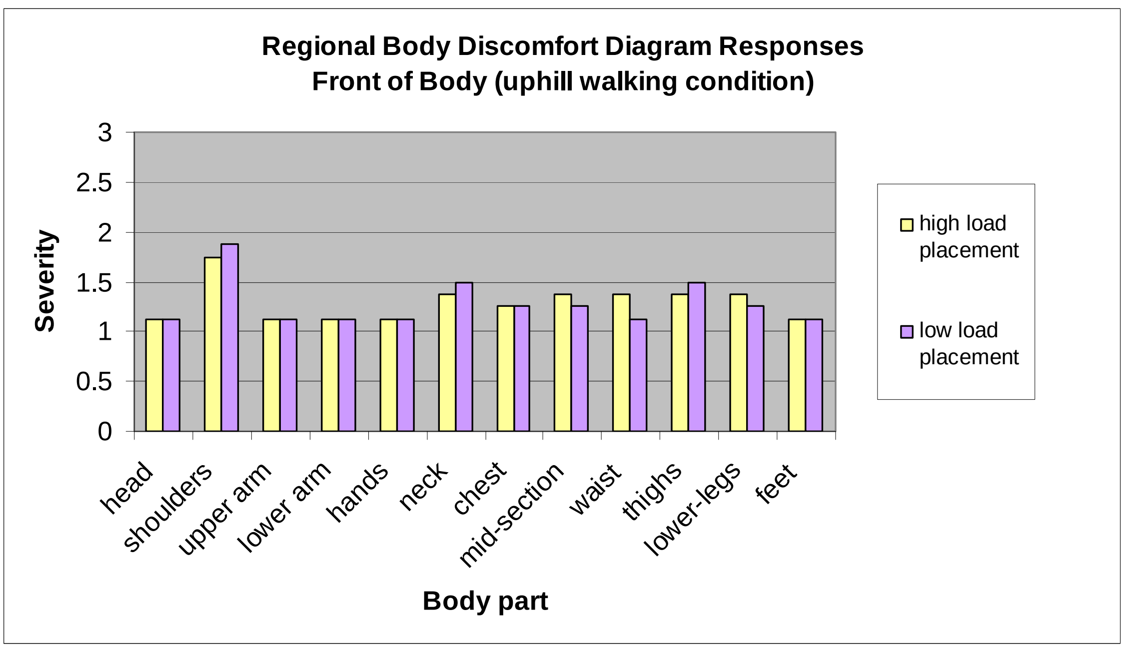

Figure 8. RBDD Responses Front of Body (uphill walking condition)

Figures 9 and 10 show similar trends for the back of the body. Values were slightly higher than those for the front of the body. Again, the shoulders and neck yielded the highest scores.

As can be seen from the overall results, respondents reported higher scores for the uphill condition than the level condition. Recall, the higher the score, the more discomfort was reported by the participant. In the majority of the cases, the difference is small. Additional statistical analyses were conducted to further investigate if these differences are significant.

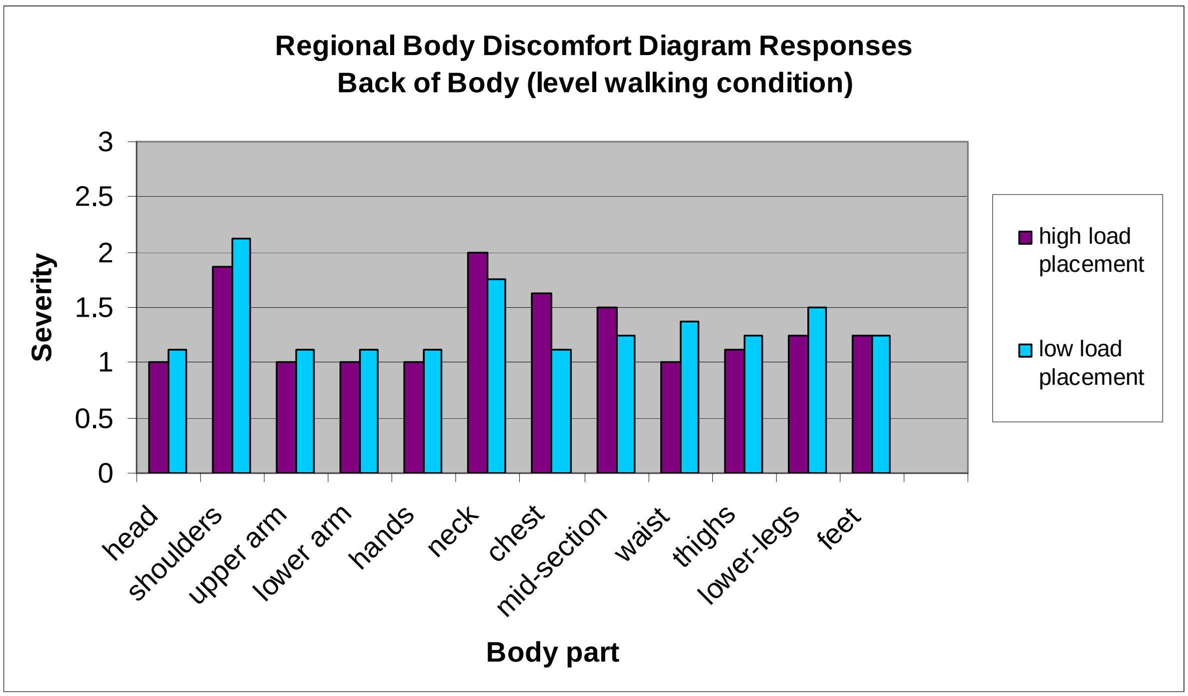

Figure 9. RBDD Responses Back of Body (level walking condition)

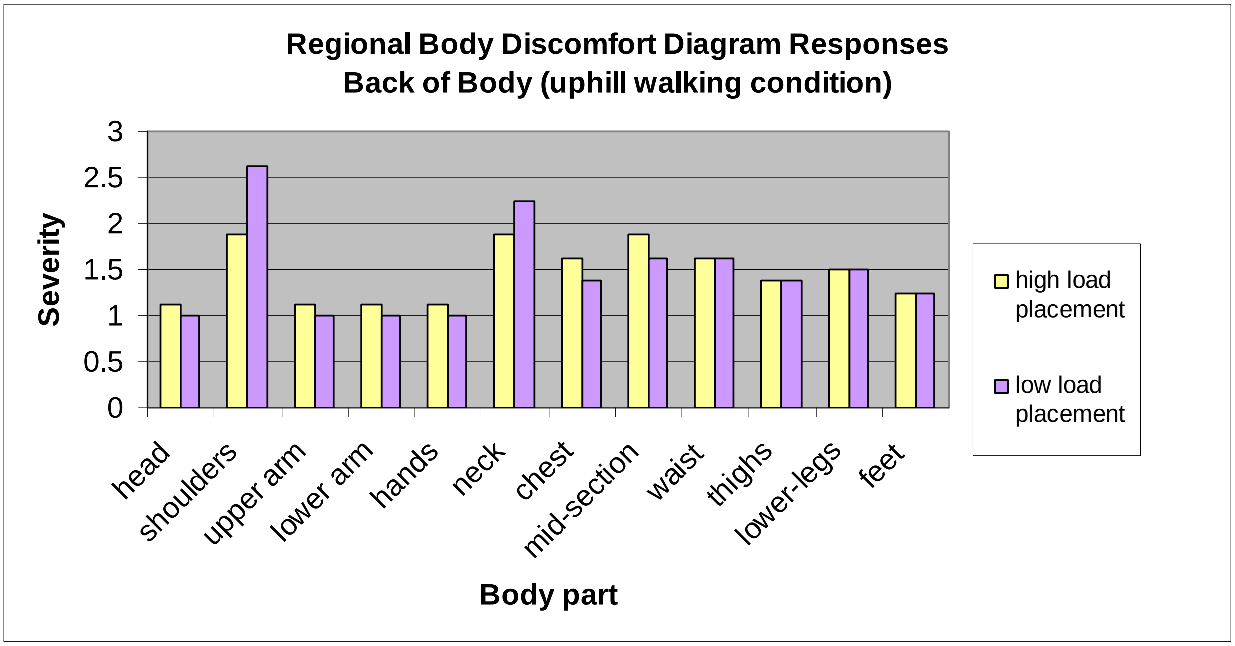

Figure 10. RBDD Responses Back of Body (uphill walking condition)

Due to the small sample size used in this study (n=8), it would be inadvisable to assume normality. In this case, it is sensible to further analyze the data by using non-parametric statistics, which make no assumption about the population other than it is continuous. The non-parametric test chosen was the Wilcoxon Signed Rank Test. This test is designed for use with repeated measures: that is when the Subjects are measured on two or more occasions, or under two or more different conditions. It is the non-parametric alternative to the repeated measures t-test, but instead of comparing means, the Wilcoxon converts scores to ranks and compares them at Time 1 and Time 2 (Pallant, 2001). The tests were performed using Statistical Package for Social Sciences (SPSS) v.11. Tables 3–6 show the results.

Table 3. Regional Body Discomfort Diagram Results (level, back of the body) Wilcoxon Signed Ranks Test

Ranks				
		N	Mean Rank	Sum of Ranks
LOWB - HIGHB	**Negative Ranks**	0(a)	.00	.00
	Positive Ranks	5(b)	3.00	15.00
	Ties	7(c)		
	Total	12		
a LOWB < HIGHB				
b LOWB > HIGHB				
c HIGHB = LOWB				

Test Statistics(b)	
	LOWB - HIGHB
Z	-2.032(a)
Asymp. Sig. (2-tailed)	**.042**
a Based on negative ranks.	
b Wilcoxon Signed Ranks Test	

Table 4. Regional Body Discomfort Diagram Results (level, front of the body) Wilcoxon Signed Rank Test

Ranks				
		N	Mean Rank	Sum of Ranks
LOWF - HIGHF	**Negative Ranks**	0(a)	.00	.00
	Positive Ranks	5(b)	3.00	15.00
	Ties	7(c)		
	Total	12		
a LOWF < HIGHF				
b LOWF > HIGHF				
c HIGHF = LOWF				

Test Statistics(b)	
	LOWF - HIGHF
Z	-2.041(a)
Asymp. Sig. (2-tailed)	**.041**
a Based on negative ranks.	
b Wilcoxon Signed Ranks Test	

Table 5. Regional Body Discomfort Diagram Results (uphill, back of the body) Wilcoxon Signed Rank Test

Ranks				
		N	**Mean Rank**	**Sum of Ranks**
LOWB - HIGHB	**Negative Ranks**	6(a)	3.50	21.00
	Positive Ranks	2(b)	7.50	15.00
	Ties	4(c)		
	Total	12		
a LOWB < HIGHB				
b LOWB > HIGHB				
c HIGHB = LOWB				

Test Statistics(b)	
	LOWB - HIGHB
Z	-.423(a)
Asymp. Sig. (2-tailed)	**.673**
a Based on positive ranks.	
b Wilcoxon Signed Ranks Test	

Table 6. Regional Body Discomfort Diagram Results (uphill, front of the body)
Wilcoxon Signed Rank Test

Ranks				
		N	**Mean Rank**	**Sum of Ranks**
LOWF - HIGHF	**Negative Ranks**	3(a)	7.00	21.00
	Positive Ranks	6(b)	4.00	24.00
	Ties	3(c)		
	Total	12		
a LOWF < HIGHF				
b LOWF > HIGHF				
c HIGHF = LOWF				

Test Statistics(b)	
	LOWF - HIGHF
Z	-.182(a)
Asymp. Sig. (2-tailed)	**.856**
a Based on negative ranks.	
b Wilcoxon Signed Ranks Test	

The first two tests compared high and low load conditions at a zero degree (level) angle. Table 3 shows a significance level of $p<.04$, meaning we can reject the null hypothesis and conclude the difference between the low and high load placements on the RBDD scores is statistically significant. Likewise, Table 4 also shows a statistically significant difference between the low and high load placements, at a significance level of $p <.05$. The next two tests compared load conditions at a thirty degree (uphill) angle. Tables 5 and 6 show significance levels of $p<.67$ and $p<.85$, respectively, on RBDD scores. Therefore, we can conclude that the difference between those scores is not statistically significant.

C. HEART RATE AND RATING OF PERCEIVED EXERTION

For all eight participants, heart rate was higher for the uphill condition than it was for the level condition. This result was expected, simply because more work is required to counteract the effect of gravity when on an incline. Table 7 summarizes the heart rate and RPE data for all eight participants.

Table 7. Heart Rate and RPE Data

Participant	Gradient	HR	RPE		HR		Participant	Gradient	HR	RPE		HR
#			Low	High			#			Low	High	
1	level	74	9	9	85		5	level	103	13	12	108
		84	10	8	81				108	14	12	111
		84	9	8	86				112	13	13	116
		76	8	8	73				99	13	13	112
	uphill	108	13	9	105			uphill	161	15	13	149
		107	11	9	118				177	16	14	160
		111	10	9	118				181	16	13	169
		102	10	8	110				150	16	13	141
2	level	141	13	12	134		6	level	89	11	12	85
		139	13	13	138				90	11	13	81
		137	13	13	138				85	11	13	77
		120	11	13	127				82	11	13	76
	uphill	139	12	13	160			uphill	112	12	12	114
		151	13	14	166				117	13	12	119
		159	14	15	166				123	14	13	129
		135	14	15	139				91	13	12	95
3	level	95	8	8	91		7	level	125	6	6	115
		92	10	8	93				123	6	6	122
		98	11	9	93				127	6	6	121
		88	11	9	93				113	6	6	113
	uphill	150	11	11	159			uphill	164	6	7	173
		162	13	15	169				165	7	11	175
		167	15	16	176				173	8	13	180
		125	14	13	130				134	7	7	134
4	level	110	10	10	108		8	level	91	8	8	94
		109	12	10	109				99	9	9	95
		114	13	12	108				93	9	9	95
		105	14	13	102				86	9	9	86
	uphill	144	13	12	134			uphill	124	11	10	129
		149	14	13	141				132	12	11	129
		151	14	14	150				133	12	11	129
		125	13	13	122				110	9	10	99

In another observation, participants four and six were the only two with consistently lower heart rate readings for the low load (no gradient).

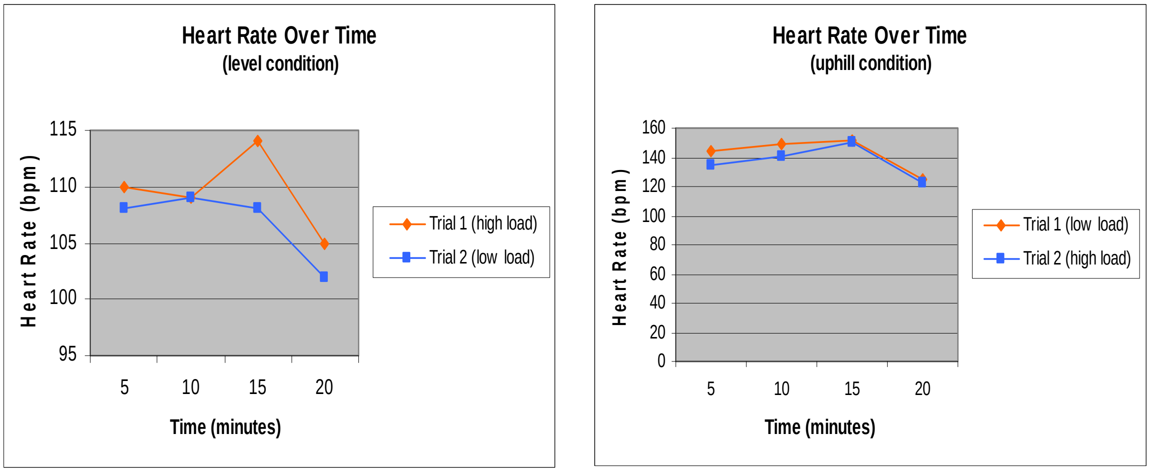

Figure 11. Participant No. Four - Heart rate over time

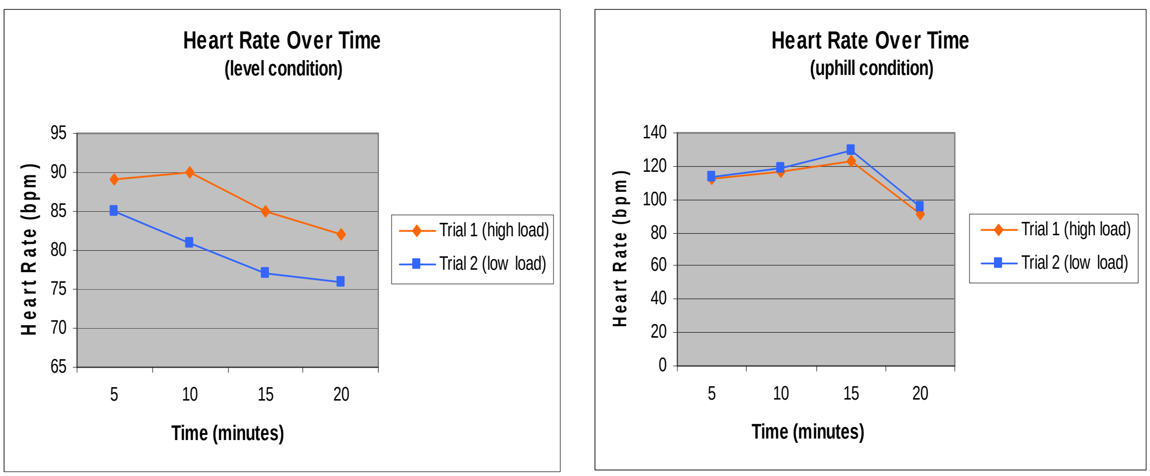

Figure 12. Participant No. Six - Heart rate over time

Participant number four also reported that he did not have to work as hard during the march for the low load condition based on his RPE scores. Consequently, participant number six did feel as though his work load increased based on higher RPE scores.

Additionally, these two participants both preferred the low load according to their questionnaire responses. The remaining six participants preferred the pack with the high load.

As previously mentioned, RPE was designed to correspond closely to heart rate during exercise, and thus provides a subjective means to estimate cardiovascular strain. For almost every participant, the graphs illustrate a linear relationship, in which the values are very close. Therefore, we can conclude that the participants were able to accurately report how hard they were working. Graphs illustrating heart rate vs. RPE for all participants are given in Appendix K.

D. ANTHROPOMETRIC MEASURES

In an effort to determine if a relationship between specified anthropometric measures and load placement exists, the researchers took the following anthropometric measures from participants: height, weight, shoulder breadth, and sitting waist height (back length). Participant measurements are given in Appendix A. Questionnaire responses to questions related to load distribution preference were then compared against the anthropometric measures by conducting a one-way analysis of variance (ANOVA) in SPSS, where load distribution preference was the factor.

The results in Table 8 show that there is not a statistically significant result and we fail to reject the null hypothesis (stature = $p<.96$, weight = $p<.61$, shoulder breadth = $p<.168$, and back length = $p<.634$). We can conclude that a relationship between the measures and load distribution preference does not exist.

Table 8. One-Way ANOVA of Anthropometric Measures by Load Distribution Preference

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Stature	Between Groups	.042	1	.042	.003	.961
	Within Groups	95.333	6	15.889		
	Total	95.375	7			
Weight	Between Groups	52.156	1	52.156	.294	.607
	Within Groups	1064.083	6	177.347		
	Total	1116.239	7			
Shoulderbrdth	Between Groups	4.950	1	4.950	2.455	.168
	Within Groups	12.098	6	2.016		
	Total	17.049	7			
Backlength	Between Groups	5.320	1	5.320	.252	.634
	Within Groups	126.8	6	21.148		
	Total	132.209	7			

E. QUESTIONNAIRES

The post-test subjective questionnaires were divided into three sections to simplify data analysis.

The questionnaire given to participants can be seen in Appendices G-H.

The questions were grouped as follows:

- Group 1: yes and no questions (questions 1-6, 10)
- Group 2: Likert scale of 1 to 5 (questions 7-9, 11-13)
- Group 3: questions comparing the high vs. low load placement (questions 14-16)

This questionnaire was administered for both sessions (day 1 – level gradient, day 2 – uphill gradient). Additionally, all participants' comments were recorded. A summary of the results for the first session **(level gradient)** are as follows:

Q1: ***Were you able to move your arms normally?***

One participant reported not being able to move his arms normally for the high load and two for the low load.

Q2: ***Were you able to maintain a normal walking position?***

Participants complained of a forward bending motion.

Q3: ***Did the pack move around excessively while you were performing the march?***

None of the participants reported the pack moved around excessively for the high load placement and one for the low load.

Q4: ***Did the pack dig into your body?***

Two participants reported that the pack dug into their body for the high load and one for the low load. One participant stated that the pack felt better closer toward the base of his spine and between shoulder blades.

Q5: ***Did the straps dig into your body?***

Three participants complained that the straps dug into their body for the high load and two for the low load. The main complaint was that the majority of the weight rested on the shoulders. Also, after his road march with the high load placement, participant number three stated "carrying less load on my shoulders made the straps far more comfortable." This statement is particularly interesting because both loads remained the same throughout the experiment. One can infer that the low load felt heavier than the high load to participant number three.

Q6: ***Did your load feel well balanced during the march?***

Only one participant for both the high and low loads felt that the load did not feel well balanced. Some comments include "felt like it was dragging me back" and "I wish the load could have been raised higher across my shoulders."

Q10: ***Did the rucksack restrict your breathing in any way?***

Only one participant for both the high and low load placements reported that the pack did restrict his breathing in some way. He stated that "breathing slowed during this trial (low)."

The results for the second section (**level gradient**) are as follows:

Questions 7, 8, 11, 12, and 13 were rated on a likert scale of 1-5, with 1 being the lowest and 5 being the highest. The **mode** was reported for each question.

Q7: ***Please rate your overall comfort while performing the march.***

The mode response for comfort during the march was a 4 for the high load and a 3 for the low load. Hence, participants felt that the high load placement was slightly more comfortable than the low load.

Q8: ***Please rate your ability to maintain your balance while performing the march.***

The participants rated their ability to maintain their balance a 5 for both load placements.

Q9: ***What was the first part of your body to experience fatigue while carrying the rucksack?***

The participants reported that the upper back/shoulders were the first part of their bodies to experience fatigue for both load conditions. This result is logical when considering the majority of the weight of a rucksack is displaced over the back and shoulders.

Q11: ***Please rate the extent to which you felt out of breath.***

Participants did not feel out of breath while carrying either load.

Q12: ***Please rate your overall mobility while performing the march.***

Participants rated their mobility a 4 for both load conditions.

Q13: ***Please rate your ability to maintain your pace.***

Participants did not experience any difficulty maintaining their pace. The mode response was 5.

The results for the third section **(level gradient)** are as follows:

Q14: ***Which load placement did you prefer? Why?***

Participant preference was evenly distributed between both load conditions. Four participants preferred the high load and the other four preferred the low load.

Comments: Didn’t feel like it was pulling me back (low load).

The packed seemed to distribute the weight better and kept my balance from being thrown off (high load).

The pack felt as if it was pressing against my back rather than hanging from my shoulders (high load).

I felt I had better support (low load).

More stable of the two (high load).

Less back pain (low load).

Less pull on the shoulders (low load).

Q15: ***Which of the loads had an effect on your coordination?***

The majority of the participants (6) stated that neither load had an effect on their coordination. There was one response for both loads and one for the low load.

Q16: ***Did one load feel heavier than the other? If yes, which one?***

Five participants responded that neither load felt heavier than the other. Conversely, three participants responded that one load did feel heavier than the other. Participant number three reported that the low load felt heavier. Participants four and six thought that the high load felt heavier.

The results for the second session **(uphill gradient)** are as follows:

Q1: ***Were you able to move your arms normally?***

All participants were able to move their arms normally. One participant stated he felt a little constrained due to the incline.

Q2: ***Were you able to maintain a normal walking position?***

The results for both the high and low load conditions were the same: five participants reported being able to maintain a normal walking position while three reported they were unable to maintain a normal walking position. Two participants claimed they had to bend forward in order to maintain their balance.

Q3: ***Did the pack move around excessively while you were performing the march?***

None of the participants reported that the pack moved around excessively during the march on either load placement.

Q4: ***Did the pack dig into your body?***

During the high load condition, the majority (6) of participants felt that the pack did not dig into their bodies, while two felt the pack did dig into their bodies. One participant responded, “my shoulders carried more of the load than during the level trial.” For the low load, five participants responded no and three responded yes.

Q5: ***Did the straps dig into your body?***

Fifty percent of the participants felt as though the straps were digging into their bodies and 50% did not for the high load condition. For the low load, there were three yes responses, and five no responses. There were also complaints of pulling on the shoulders.

Q6: ***Did your load feel well balanced during the march?***

One participant reported that his load did not feel well balanced for the high load and two participants reported the same for the low load. Some of the comments were, “my equilibrium wasn't very good”, “it was a little off”, and “I had to stay hunched forward.”

Q10: ***Did the rucksack restrict your breathing in any way?***

Five participants did not have any problems breathing while three reported that the rucksack did restrict their breathing in some way for both load conditions. The comments included, “as my level of exertion increased, my chest pressed against the straps and breathing required a bit more effort”, “the straps limited my breathing”, and “hunching forward still made it somewhat difficult to breathe in comparison to normal walking.” Any complaint of restrictive breathing should be a cause for concern and should be further examined.

The results for the second section **(uphill gradient)** are as follows:

Questions 7, 8, 11, 12, and 13 were rated on a likert scale of 1–5, with 1 being the lowest and 5 being the highest. The **mode** was reported for each question.

Q7: ***Please rate your overall comfort while performing the march.***

The mode comfort was a 5 for the high load and a 3 for the low load. This means that participants felt that the high load placement was significantly more comfortable (60%) than the low load.

Q8: ***Please rate your ability to maintain your balance while performing the march.***

The participants rated their ability to maintain their balance a 5 for both load placements.

Q9: ***What was the first part of your body to experience fatigue while carrying the rucksack?***

The participants reported that the upper back/shoulders were the first part of their bodies to experience fatigue for the low load condition.

Comments: I felt better as the march progressed.

Q11: ***Please rate the extent to which you felt out of breath.***

Participants did not feel out breath during the high load placement (mode response was 1), but did feel highly out of breath during the low load placement (mode response was 4).

Q12: ***Please rate your overall mobility while performing the march.***

Participants rated their mode mobility a 5 for the high load condition and a 4 for the low load condition.

Q13: ***Please rate your ability to maintain your pace.***

Participants did not experience any difficulty maintaining their pace. The mode response was 5.

The results for the third section **(uphill gradient)** are as follows:

Q14: ***Which load placement did you prefer? Why?***

The majority (6) of participants preferred the high load condition when it came to the incline. Only two participants preferred the low load.

Comments: The low placement felt wrong. I felt like I had it sitting on my pelvis for the whole march (low load).

I felt more comfortable and had better equilibrium (high load).

Felt more stable (high load).

Better balanced (high load).

Easier on the shoulders (low load).

When the load was high, my lower back bothered me more (high load).

Less pull on the shoulders (low load).

Q15: ***Which of the loads had an effect on your coordination?***

The majority of the participants (5) stated that neither load had an effect on their coordination. There were two responses for both loads and one for the low load.

Q16: ***Did one load feel heavier than the other? If yes, which one?***

5 participants responded that neither load felt heavier than the other. Conversely, 3 participants responded that one load did feel heavier than the other. Participant 1 reported that the low load felt heavier. Participants 4 and 7 thought that the high load felt heavier.

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V. CONCLUSIONS AND RECOMMENDATIONS

A. DISCUSSION

In this study, researchers examined the ways in which military personnel are affected by load carriage placement, attempted to identify different body parts which were affected during this task, and determined that one load configuration may not be suitable for all individuals, especially when the activity is conducted on different terrain gradients. An analysis of each dependent variable: heart rate, Regional Body Discomfort Diagram, and Rating of Perceived Exertion, showed that the majority of participants preferred the high backpack load condition and that they experienced more discomfort while walking uphill. The Wilcoxon signed rank test showed that the difference between the two loads was statistically significant. The participants clearly experienced more discomfort from the low pack placement while marching on the level gradient. Researchers are unsure as to why participants did not experience similar results for the incline gradient. However, a simple explanation could be that it may be more difficult to ascertain the source of one's pain while in the midst of performing an already arduous task. Additionally, RBDD results showed that the shoulders, neck, upper back, and lower legs of participants were subjected to the most pain. The waist and chest areas of several participants also sustained a notable amount of discomfort during the study. Questionnaire responses matched the results from the Wilcoxon signed rank test, in that participants preferred the high load distribution. Another common complaint amongst participants was that the majority of the weight rested on the shoulders. Finally, graphical results from the heart rate vs. RPE showed that there was a definite relationship between the two. The two measures were closely related for most of the participants, making it sensible to conclude that heart rate is an accurate objective indicator of physical work and that RPE is a reliable subjective indicator physical work.

As a secondary research area, this thesis attempted to determine if a relationship between specified anthropometric measures and load placement preference exists. Researchers took the following anthropometric measures from participants: height, weight, shoulder breadth, and sitting waist height (back length). Questionnaire responses to questions related to load preference were then compared against the anthropometric measures by conducting a one-way ANOVA. The results indicate that there was not a significant result (stature = $p<.96$, weight = $p<.61$, shoulder breadth = $p<.168$, and back length = $p<.634$). Researchers concluded that there is not a relationship between the measures and load distribution preference. A larger sample size would provide some insight on the possibility of a relationship between the two.

Although most (80%) of the participants preferred the higher load placement, this finding should not imply that other 20% should pack their backpacks in the same manner if it does not suit their physical and mission needs.

Military personnel should be mindful that their backpacks should be packed based not only on military guidelines and personal preference, but the gradient in which they will be traversing and which pack placement will yield the least amount of fatigue, injury, and discomfort over time. The activity of road marching for training purposes as well as combat operations will continue to be an integral part of military operations. Optimistically, by use of after action reports, soldier interviews, and further research, the military, medical and research communities can continue to gain more insight regarding characteristics of the soldier’s load (e.g., weight, load configuration, load placement), with the intentions of reducing stress, fatigue and injuries to our servicemen.

B. HSI CONSIDERATIONS

From an HSI perspective, the findings of this thesis identified several areas that would benefit from further research and exploration. HFE, system safety, and training issues were identified in this thesis. Mission and user requirements need to be better taken into consideration when designing future pack variants to make them more efficient for the user. Safety should continue to be a primary concern for military personnel in regards to reducing injury and strain, to include using equipment within the specified weight limitations. Training, especially for inexperienced personnel, should continue to be updated and inclusive of all potential risks and hazards.

C. RECOMMENDATIONS AND FURTHER RESEARCH

For future research on this topic, a larger sample size would definitely be beneficial. Also, a more diverse group of participants, particularly regarding age might have an impact on results. Finally, additional questions for participants related to fitness routines, back and core strengthening routines, and past injuries may also be relevant further exploration of this topic.

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APPENDIX A. DEMOGRAPHIC AND ANTHROPOMETRIC DATA

Demographics Summary Table

Age (yr)	Stature (in)	Weight (kg)	Resting Heart Rate (bpm)	Shoulder Breadth (cm)	Sitting Waist Height (cm)	Branch of Service	Have you ever received any training on how to pack a rucksack?	When was the last time you ate?	When was the last time you worked out or participated in a physical activity?	How many hours of sleep did you get last night?
42	65	67.59	71	39.5	56	USMC	Yes	Over 3 hours	Over 2 days	5-6
35	75	100.7	79	39.9	61.4	USN	No	30-60 minutes	2 days ago	5-6
34	75	91.63	58	39.3	64.4	USN	No	1-2 hours	Over 2 days	5-6
41	69.5	83.01	89	38.5	65.4	AF *	Yes	1-2 hours	2 days ago	7-8
34	71.5	90.26	78	41.3	54.2	USN	No	1-2 hours	2 days ago	7-8
40	74.25	98.43	86	41	66	ARMY *	Yes	2-3 hours	2 days ago	7-8
34	67.25	78.47	76	38	61.6	USMC	Yes	2-3 hours	Yesterday	7-8
35	70.5	105.69	65	42.8	63.7	USA	Yes	1-2 hours	Yesterday	5-6
Note: * denotes foreign military										

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APPENDIX B. PARTICIPANT CONSENT FORM

Naval Postgraduate School Participant Consent Form & Minimal Risk Statement

Introduction. You are invited to participate in a study entitled The Effect of Load Distribution and Gradient on Load Carriage being conducted by the Naval Postgraduate School Human Systems Integration Program, Operations Research Department.

Procedures. If I agree to participate in this study, I understand I will be provided with an explanation of the purposes of the research, a description of the procedures to be used, identification of any experimental procedures, and the expected duration of my participation. *Synopsis*: There will be two sessions: (day 1) 1 ½ hour with high and low load placements on a level treadmill (day 2) 1 ½ hour with high and low load placements on an inclined treadmill. During both sessions you will be expected to complete 3 different assessments (2 questionnaires and one body discomfort diagram). Additionally, body measurements such as height and weight and physiological measures of heart rate will also be collected.

Risks and Benefits. I understand that this project does not involve greater than minimal risk and involves no known reasonably foreseeable risks or hazards greater than those encountered in everyday life. I have also been informed of any benefits to myself or to others that may reasonably be expected as a result of this research.

Compensation. I understand that no tangible reward will be given. I understand that a copy of the research results will be available at the conclusion of the experiment.

Confidentiality & Privacy Act. I understand that all records of this study will be kept confidential and that my privacy will be safeguarded. No information will be publicly accessible which could identify me as a participant, and I will be identified only as a code number on all research forms. I understand that records of my participation will be maintained by NPS for five years, after which they will be destroyed.

Voluntary Nature of the Study. I understand that my participation is strictly voluntary, and if I agree to participate, I am free to withdraw at any time without prejudice.

Points of Contact. I understand that if I have any questions or comments regarding this project upon the completion of my participation, I should contact the Principal Investigator, Shanell Colclough, (831) 402-2135, slcolclo@nps.edu. Any medical questions should be addressed to LTC Eric Morgan, MC, USA, (CO, POM Medical Clinic), (831) 242-7550, eric.morgan@nw.amedd.army.mil.

Statement of Consent. I have read and understand the above information. I have asked all questions and have had my questions answered. I agree to participate in this study. I will be provided with a copy of this form for my records.

__________________________________ ____________________
Participant's Signature Date

__________________________________ ____________________
Researcher's Signature Date

APPENDIX C. PARTICIPANT INFORMATION SHEET

The Effect of Load Distribution and Gradient on Load Carriage – Participant Information Sheet

Participant I.D.____________ Age_______

Height__________ Weight__________ Resting Heart Rate________

Shoulder breadth__________ Sitting waist height__________

Branch of Service: MOS:____________

a) Air Force
b) Army
c) Marine Corp
d) Navy

Are you aware of any medical condition that you have that could affect your safety while participating in this experiment? Yes/ No. If yes, please inform the researcher.   INITIAL HERE ________

1. Have you ever received any training on how to pack a rucksack?
   a) Yes
   b) No

2. When was the last time you ate?
   a) 30-60 minutes ago

b) 1-2 hours ago
c) 2-3 hours ago
d) over 3 hours ago

3. When was the last time you worked out or participated in a physical activity (sports)?
a) earlier today
b) yesterday
c) 2 days ago
d) over 2 days ago

4. How many of hours of sleep did you get last night?
a) 8+
b) 7-8
c) 5-6
d) less than 5 hours

APPENDIX D. PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

NASM
NATIONAL ACADEMY OF SPORTS MEDICINE

Data Collection Sheet

NAME:____ DATE:________________

HEIGHT:_________in. WEIGHT:___________lbs. AGE:__________

PHYSICIANS NAME:____________________________ PHONE:_____________

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)

	Questions	Yes	No
1	Has your doctor ever said that you have a heart condition and that you should only perform physical activity recommended by a doctor?		
2	Do you feel pain in your chest when you perform physical activity?		
3	In the past month, have you had chest pain when you were not performing any physical activity?		
4	Do you lose your balance because of dizziness or do you ever lose consciousness?		
5	Do you have a bone or joint problem that could be made worse by a change in your physical activity?		
6	Is your doctor currently prescribing any medication for your blood pressure or for a heart condition?		
7	Do you know of <u>any</u> other reason why you should not engage in physical activity?		

If you have answered "Yes" to one or more of the above questions, consult your physician <u>before</u> engaging in physical activity. Tell your physician which questions you answered "Yes" to. After a medical evaluation, seek advice from your physician on what type of activity is suitable for your current condition.

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APPENDIX E. DATA COLLECTION CHECKLIST

Subject I.D.________

DATA COLLECTION CHECKLIST

Trial 1

_____ Consent Form
_____ PAR-Q
_____ Participant Info Sheet
_____ Put on heart rate monitor
_____ Height, weight, anthro measurements, resting HR
_____ Explanation of RPE and reminder of informed consent
_____ Note load placement and don pack
_____ 2 min warm-up (begin at 1.0, after 30sec: 1.3; 60sec: 1.5; 90sec: 1.7)
_____ Begin testing for the next 15 min at whatever speed participant chooses **Note speed. It must be the same for trial 2.
_____ Collect RPE and heart rate 4 times (times 15, 10, 5, 0 on the treadmill timer)
_____ 3 min cool-down (reduce speed)
_____ Collect Heart Rate
_____ Doff pack. Have participant complete: Regional Body Discomfort Diagram, Subjective Questionnaire

Trial 2

_____ Switch Load (note load placement and don pack)
_____ 2 min warm-up (begin at 1.0, after 30sec: 1.3; 60sec: 1.5; 90sec: 1.7)
_____ Begin testing for the next 15 min at previous speed
_____ Collect RPE and heart rate 4 times (times: 15, 10, 5, 0 on the treadmill timer)
_____ 3 min cool-down (reduce speed)
_____ Collect Heart Rate
_____ Doff pack. Have participant complete: Regional Body Discomfort Diagram, Subjective Questionnaire
_____ Give participant the Post-Experiment Form and thank them for their participation

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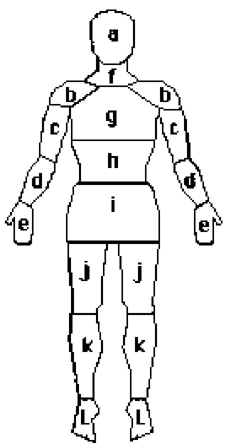
APPENDIX F. REGIONAL BODY DISCOMFORT DIAGRAM

REGIONAL BODY DISCOMFORT DIAGRAM FOR “THE EFFECT OF LOAD DISTRIBUTION & GRADIENT ON LOAD CARRIAGE”

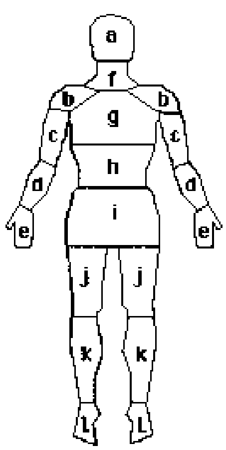
Volunteer Number: __________ Date: __________ Test Condition: __________

1. Rate the degree of SORENESS, PAIN, or DISCOMFORT that you are currently feeling for Body Parts A through L. Do so for the FRONT and the BACK of the body.



FRONT of Body

	a	b	c	d	e	f	g	h	i	j	k	L
NONE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SLIGHT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODERATE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SEVERE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EXTREME	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐



BACK of Body

	a	b	c	d	e	f	g	h	i	j	k	L
NONE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SLIGHT	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
MODERATE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
SEVERE	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
EXTREME	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

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APPENDIX G. POST-TEST QUESTIONNAIRE (TRIAL 1)

(A)

Participant I.D.__________

The Effect of Load Distribution & Gradient on Load Carriage: Post-test Questionnaire

Please circle your answer to each question below and provide comments as appropriate.

1. Were you able to move your arms normally?
   a) Yes
   b) No
   Comments:____
   ____

2. Were you able to maintain a normal walking position?
   a) Yes
   b) No
   Comments:____
   ____

3. Did the pack move around excessively while you were performing the march?
   a) Yes
   b) No
   Comments:____
   ____

4. Did the pack dig into your body?
   a) Yes
   b) No
   Comments:____
   ____

5. Did the straps dig into your body?
   a) Yes
   b) No
   Comments:____
   ____

6. Did your load feel well balanced during the march?
   a) Yes

b) No

Comments:____

____

7. Please rate your overall comfort while performing the march. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

8. Please rate your ability to maintain your balance while performing the march. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

9. What was the **first** part of your body to experience fatigue while carrying the rucksack?
   a) upper back/ shoulders
   b) lower/mid back
   c) legs/thighs
   d) other ______________________

10. Did the rucksack restrict your breathing in any way?
   a) Yes
   b) No

Comments____

____

11. Please rate the extent to which you felt out of breath. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

12. Please rate your overall mobility while performing the march. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

13. Please rate your ability to maintain your pace. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

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APPENDIX H. POST-TEST QUESTIONNAIRE (TRIAL 2)

(B)

Participant I.D.__________

The Effect of Load Distribution & Gradient on Load Carriage: Post-test Questionnaire

Please circle your answer to each question below and provide comments as appropriate.

1. Were you able to move your arms normally?
   c) Yes
   d) No
   Comments:____
   ____

2. Were you able to maintain a normal walking position?
   c) Yes
   d) No
   Comments:____
   ____

3. Did the pack move around excessively while you were performing the march?
   a) Yes
   b) No
   Comments:____
   ____

4. Did the pack dig into your body?
   a) Yes
   b) No
   Comments:____
   ____

5. Did the straps dig into your body?
   a) Yes
   b) No
   Comments:____
   ____

6. Did your load feel well balanced during the march?
   a) Yes

b) No
Comments:____
____

7. Please rate your overall comfort while performing the march. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

8. Please rate your ability to maintain your balance while performing the march. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

9. What was the **first** part of your body to experience fatigue while carrying the rucksack?
a) upper back/ shoulders
b) lower/mid back
c) legs/thighs
d) other ______________________

10. Did the rucksack restrict your breathing in any way?
a) Yes
b) No
Comments____
____

11. Please rate the extent to which you felt out of breath. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

12. Please rate your overall mobility while performing the march. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

13. Please rate your ability to maintain your pace. Circle your answer on a 5-point scale, where 1 is the lowest and 5 is the highest.

1	2	3	4	5
Low				High

14. Which load placement did you prefer?
    a) High
    b) Low
    Why?____
    ____

15. Which of the loads had an effect on your coordination?
    a) High
    b) Low
    c) both
    d) neither

16. Did one load feel heavier than the other?
    a) Yes
    b) No
    If Yes, which one: High / Low (please circle)

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APPENDIX I. RATING OF PERCEIVED EXERTION CHART

THE RATING OF PERCEIVED EXERTION (RPE) MEASURING SCALE*

Use this quantitative scale at the end of each resistance exercise and your whole workout to assess how much exertion they took to complete.

Rating	Subjective Feeling
0	Nothing at all (no intensity)
0.3	
0.5	Extremely weak (just noticeable)
0.7	
1	Very Weak
1.5	
2	Weak (light intensity)
2.5	
3	Moderate
4	
5	Strong (heavy intensity)
6	
7	Very strong
8	
9	
10	Extremely strong (strongest intensity)
11	
•	Absolute maximum (highest possible intensity)

Instructions for use: "During the exercise we want you to pay close attention to how hard you feel the exercise work rate is. This feeling should reflect your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. Don't concern yourself with any one factor such as leg pain, shortness of breath or exercise intensity, but try to concentrate on your total, inner feeling of exertion. Try not to underestimate or overestimate your feelings of exertion; be as accurate as you can."

* From; Gunnar Borg, *G. Borg's Perceived Exertion and Pain Scales (Champaign, IL: Human Kinetics, 1998).* Reproduced with the permission of the author.

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APPENDIX J. ADDITIONAL EQUIPMENT USED

- An anthropometer was used to measure the acromial sitting height or back length. This measurement is the vertical distance between a sitting surface and the acromian landmark on the tip of the right shoulder.

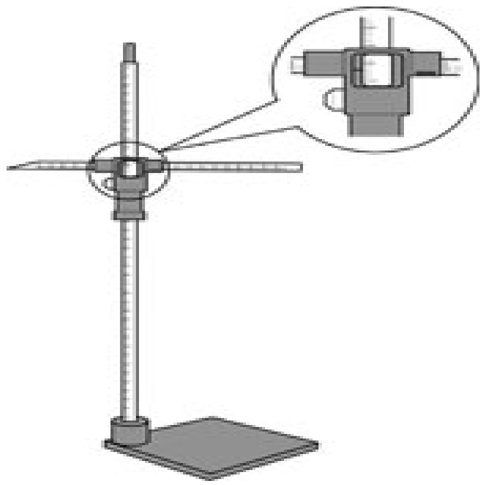

Figure 13. Anthropometer

- A Sliding caliper was used to measure the biacromial breadth (shoulder breadth). This measurement is the distance between the right and left acromion landmarks at the tips of the shoulders.

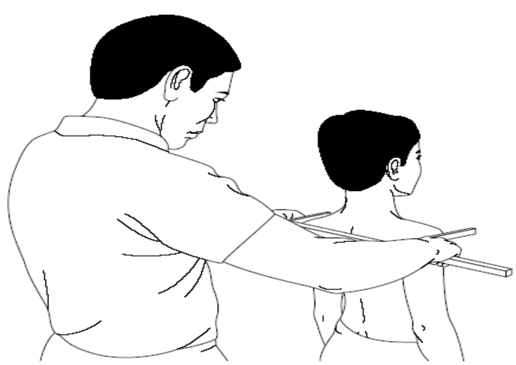

Figure 14. Sliding caliper used to measure shoulder breadth

- A stadiometer with a sliding headpiece was used to measure stature.

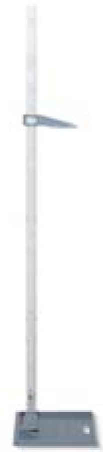

Figure 15. Stadiometer with sliding headpiece

- Participants carried a load using the Camelbak BFM (Basic Fighter Maneuvers) rucksack. The rucksack weighs 2.53 kg (5.57 lbs) and can hold a capacity of 2.83 kg. The dimensions of the rucksack are 533 mm x 330 mm x 254 mm (21 in x 13 in x 10 in).

APPENDIX K. HEART RATE VS. RATING OF PERCEIVED EXERTION

Figures 16–23 graphically illustrate Heart Rate vs. RPE relationship for all eight participants.

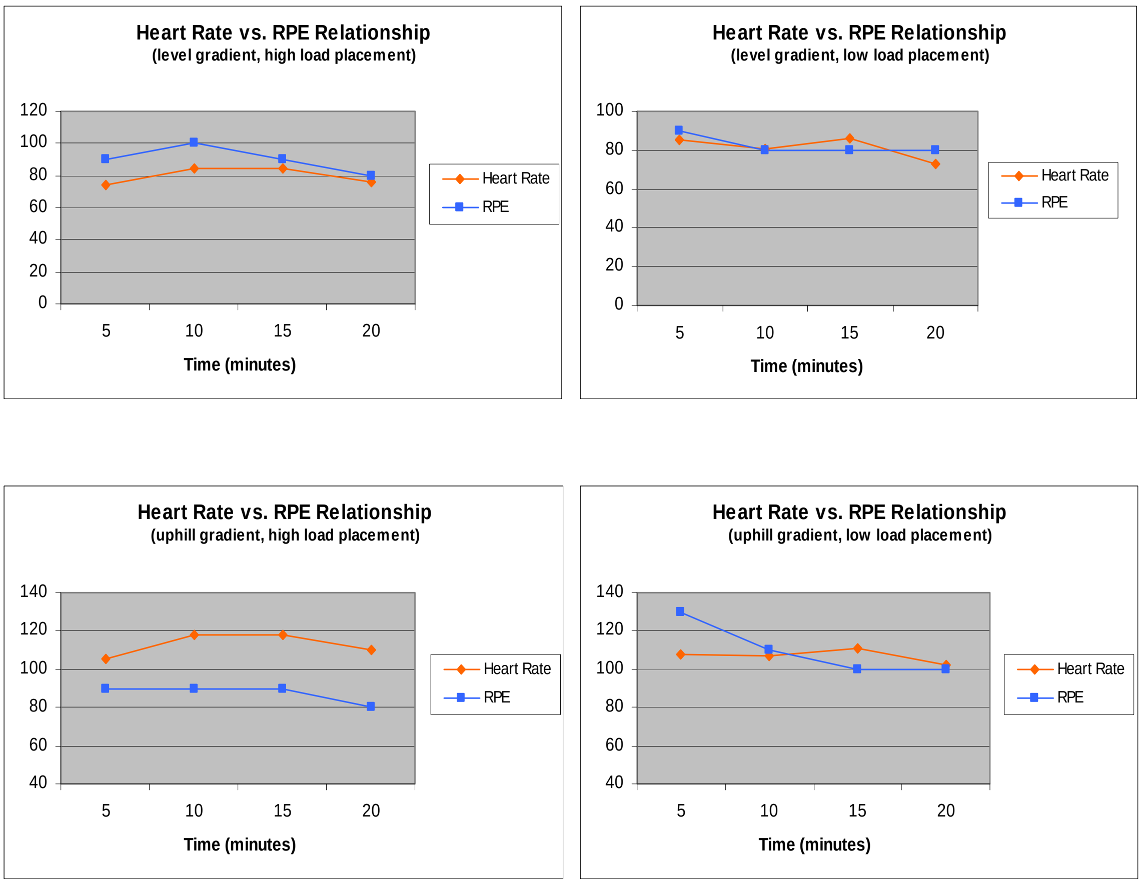

Figure 16. Participant 1: Heart Rate vs. RPE

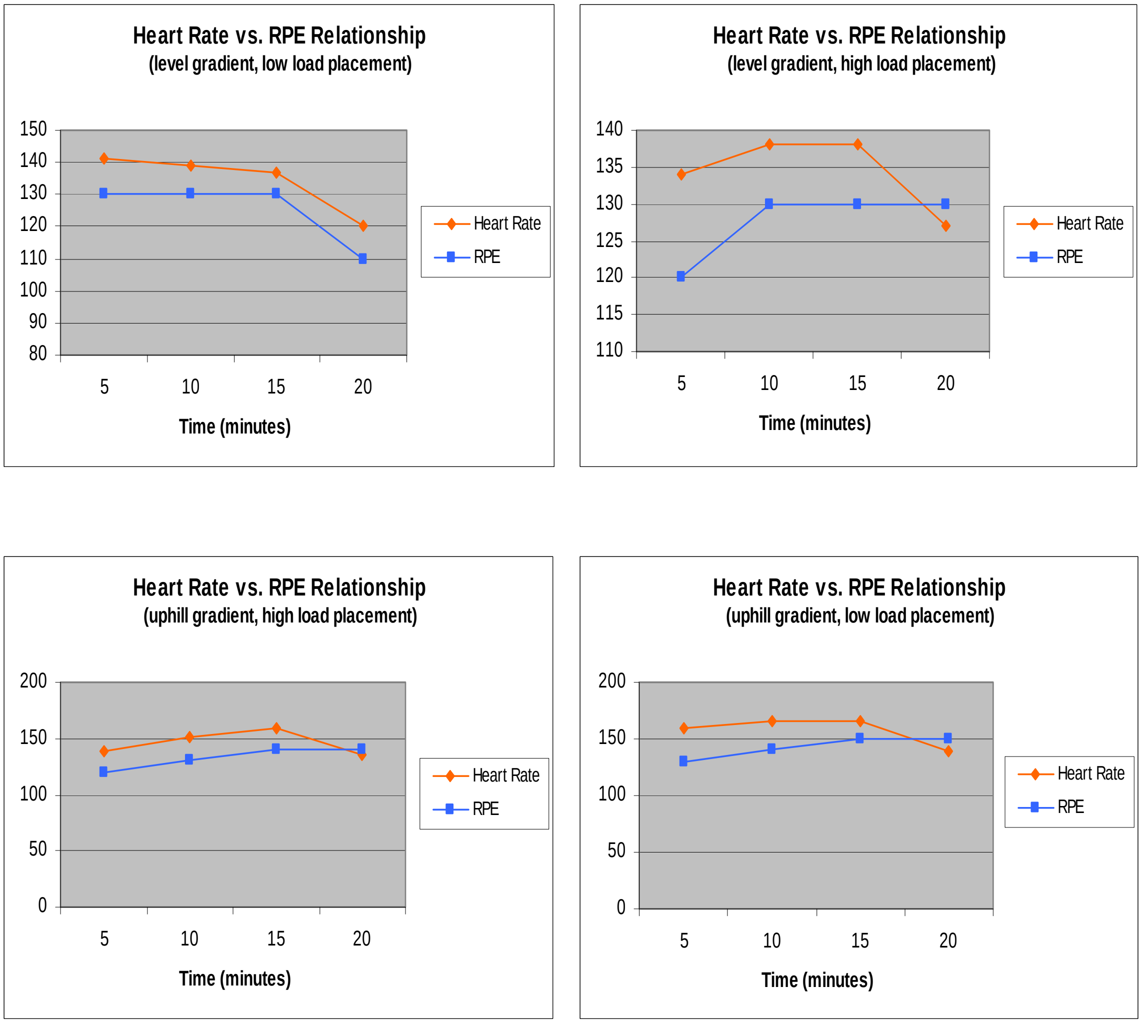

Figure 17. Participant 2: Heart Rate vs. RPE

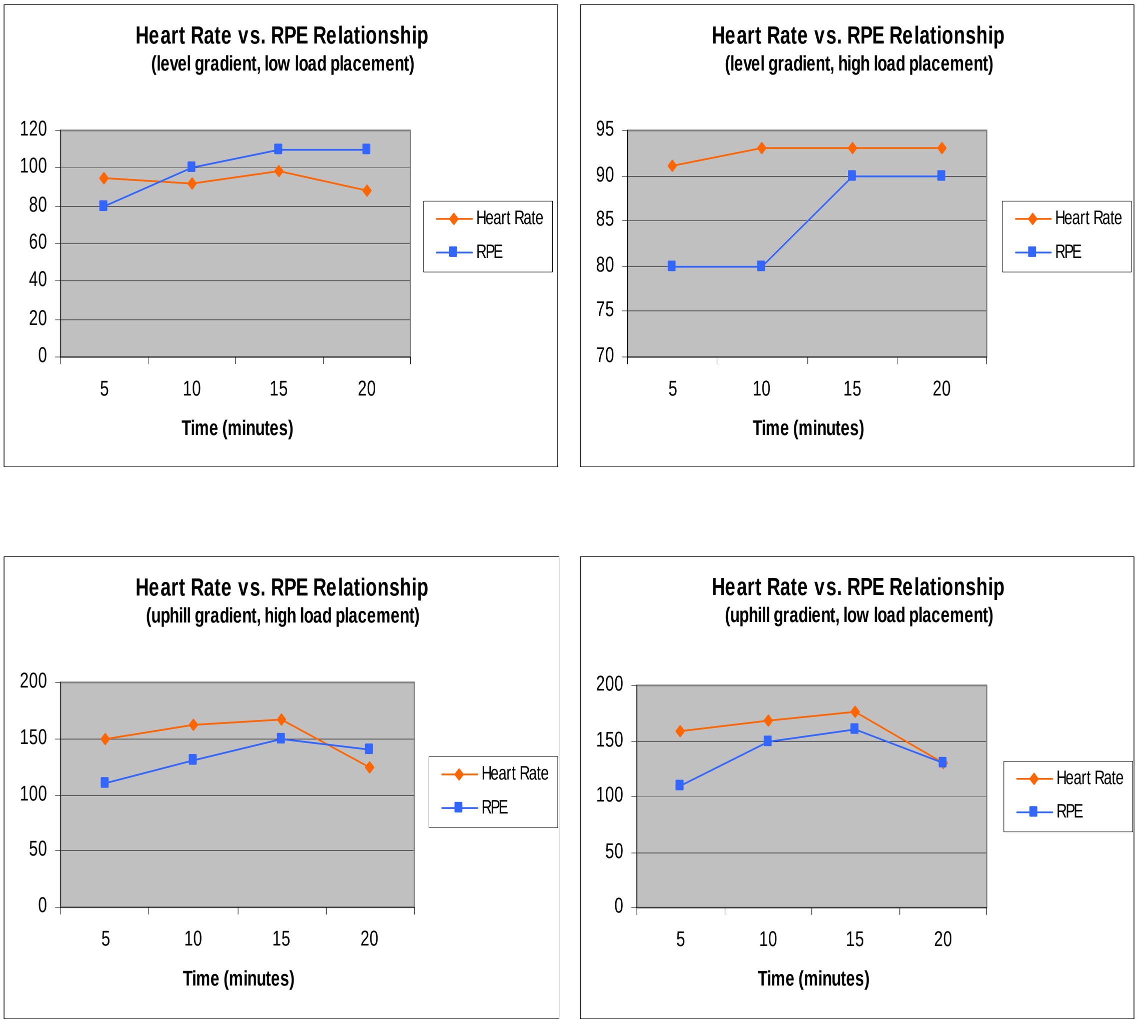

Figure 18. Participant 3: Heart Rate vs. RPE

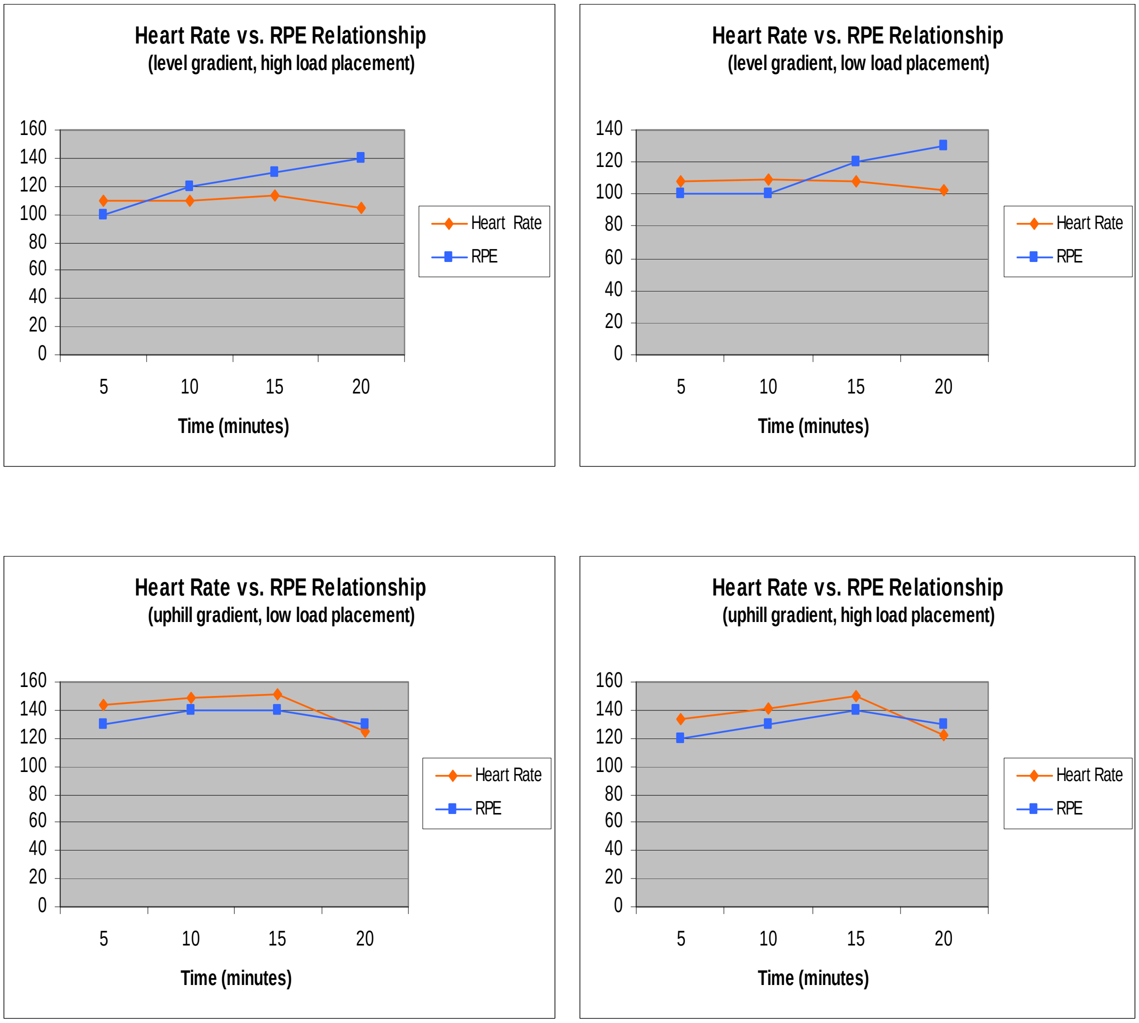

Figure 19. Participant 4: Heart Rate vs. RPE

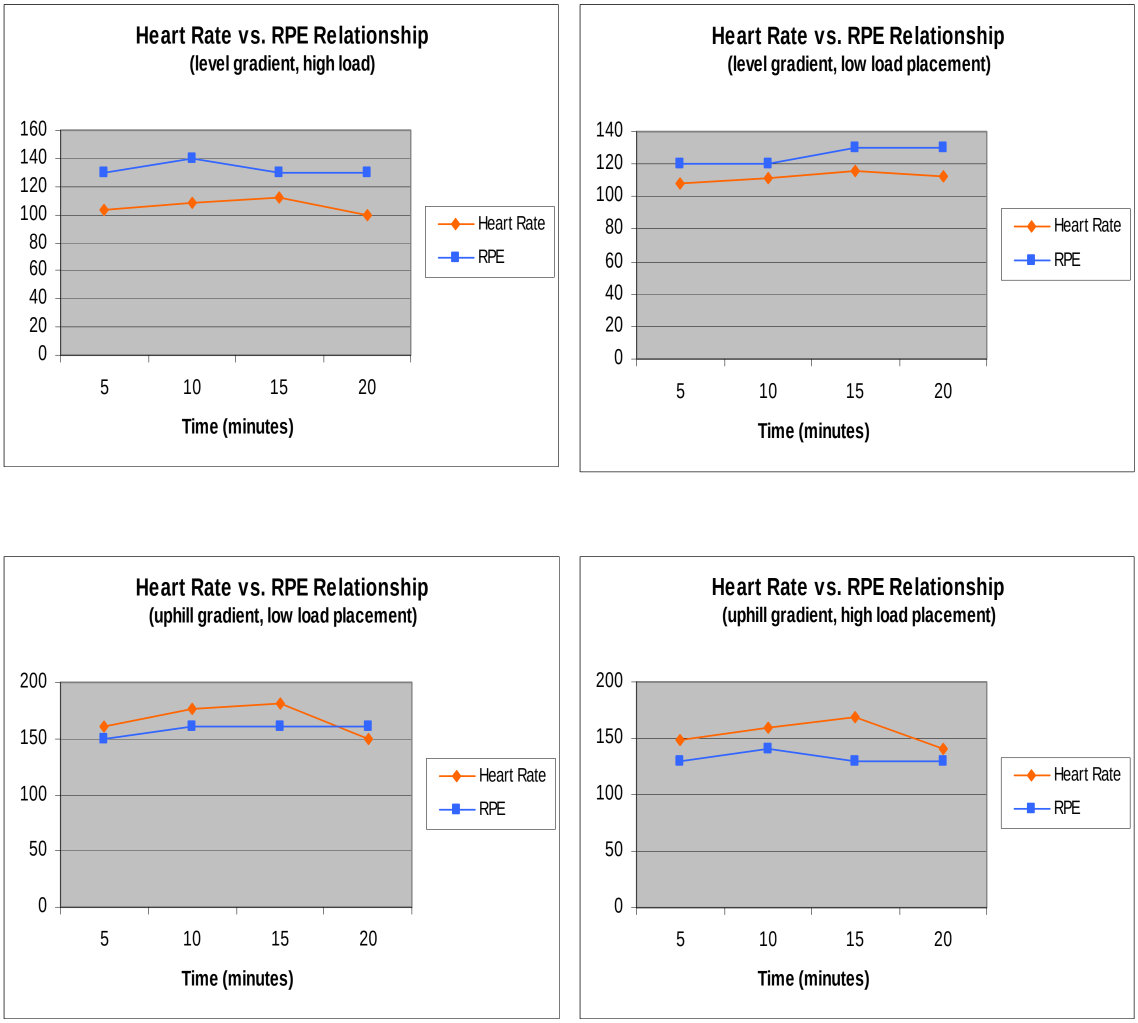

Figure 20. Participant 5: Heart Rate vs. RPE

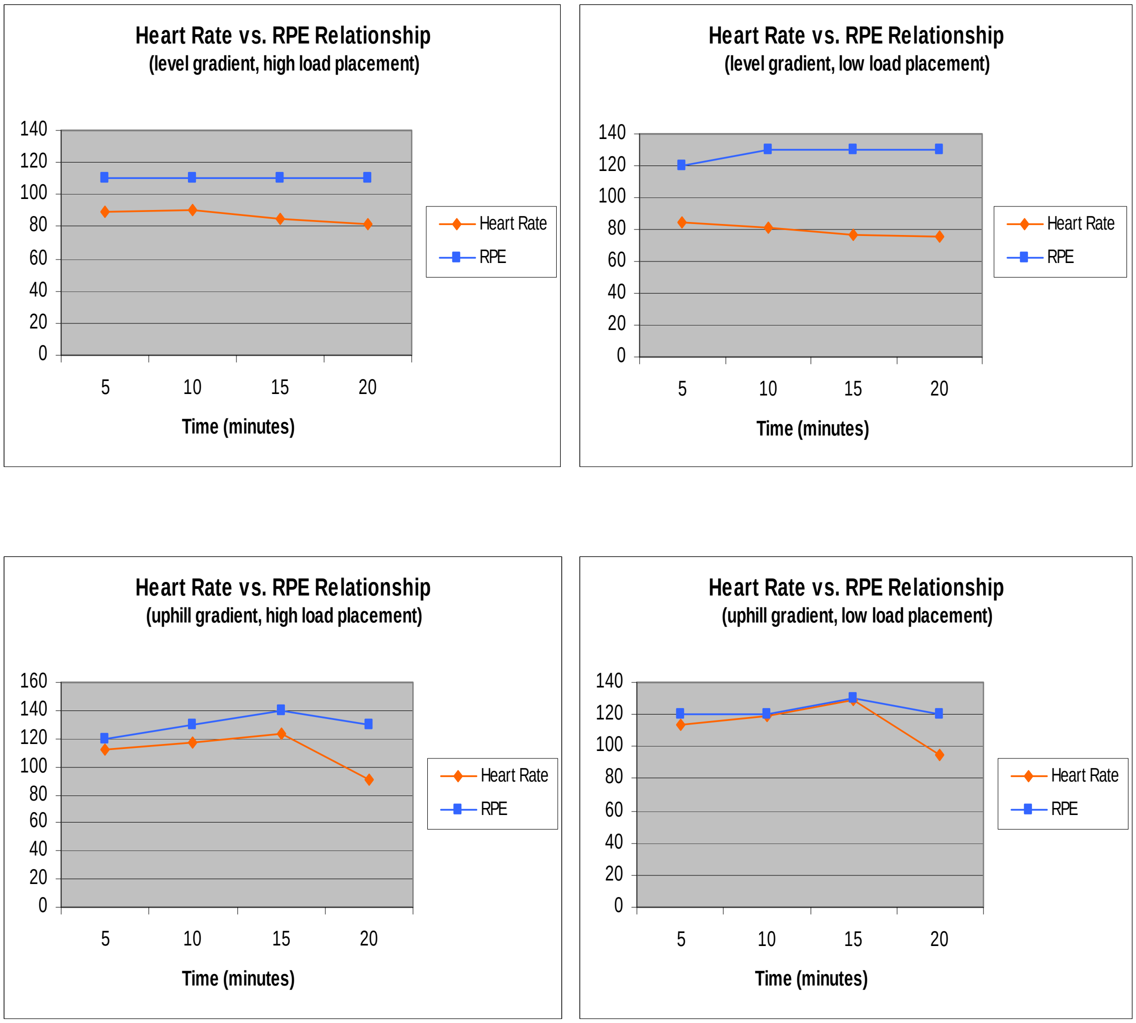

Figure 21. Participant 6: Heart Rate vs. RPE

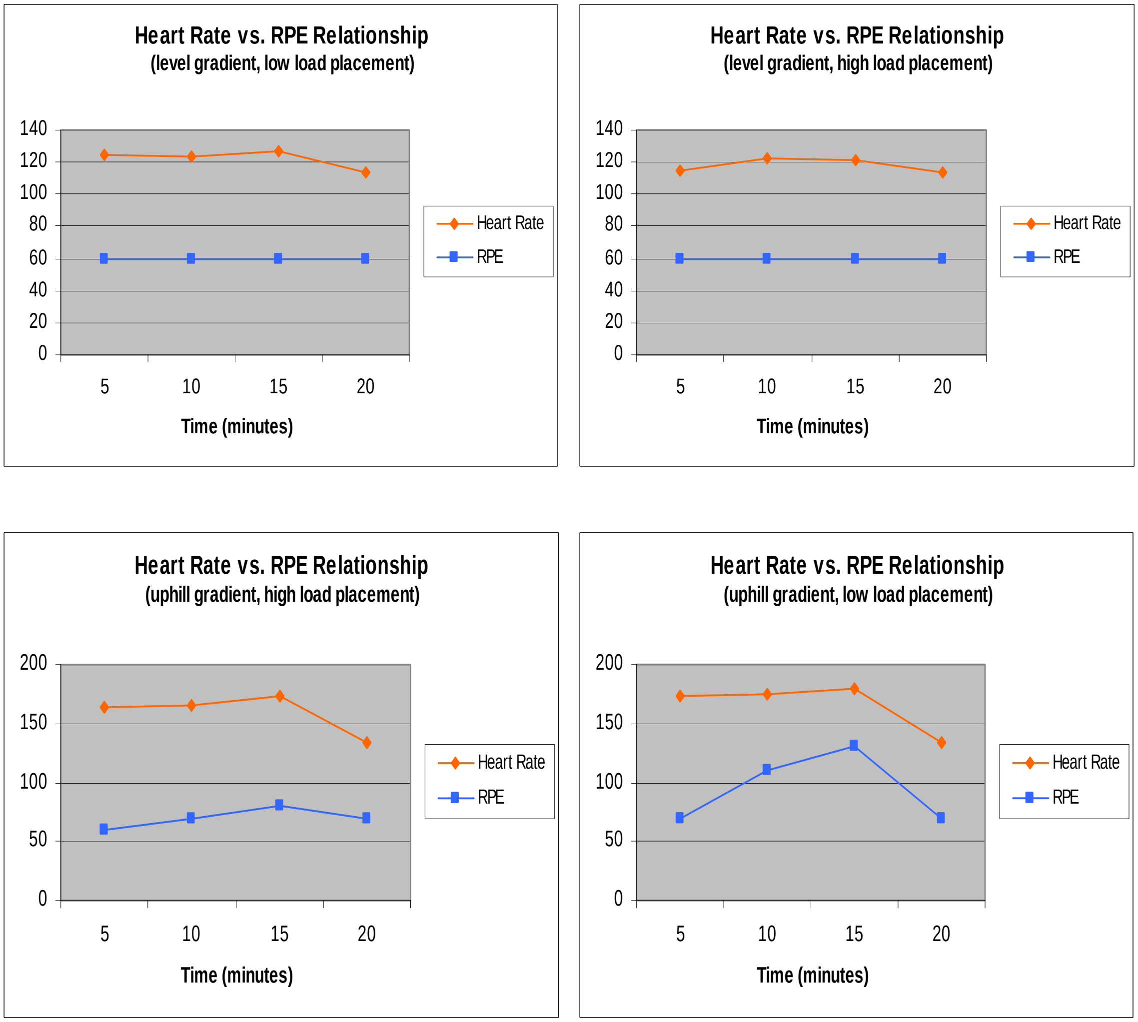

Figure 22. Participant 7: Heart Rate vs. RPE

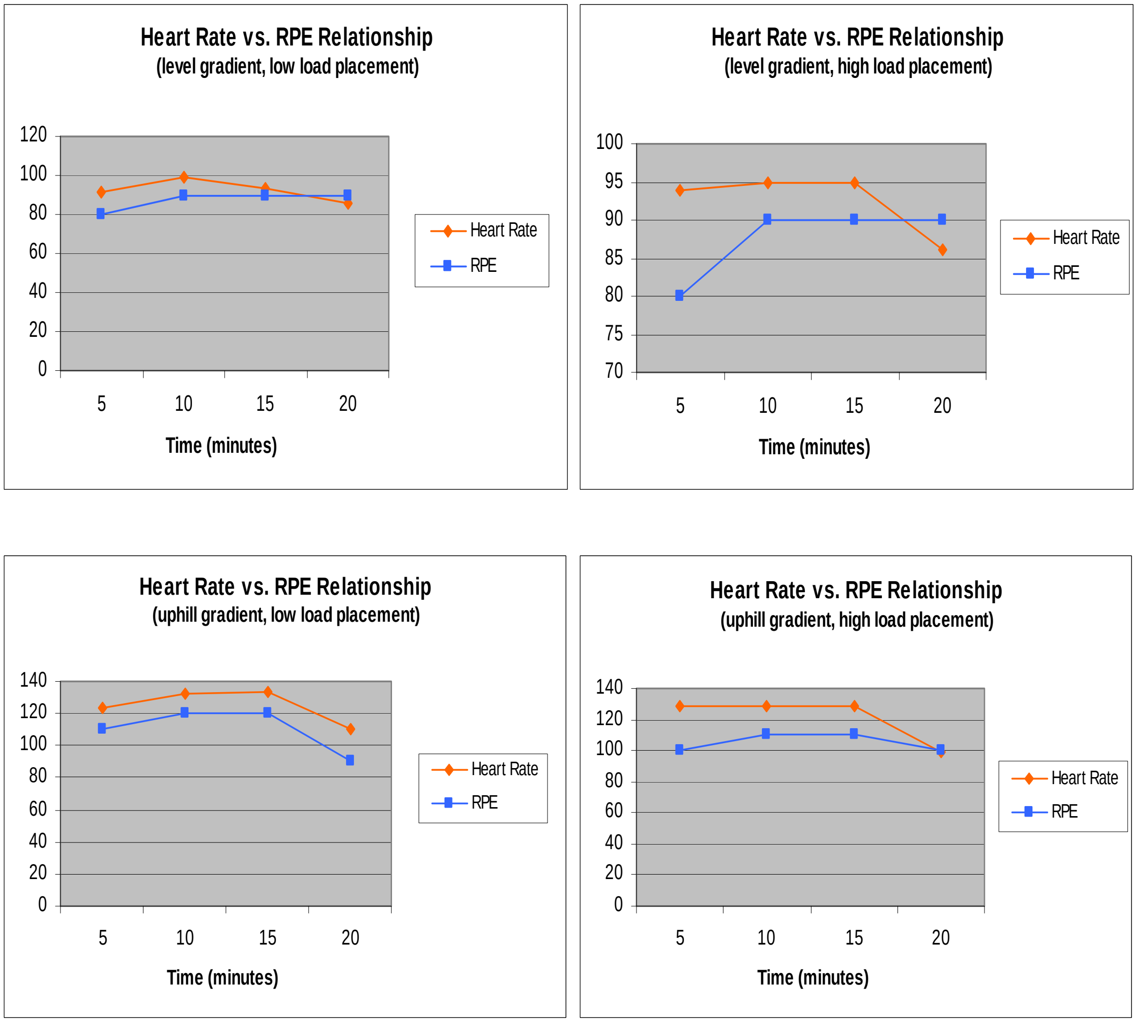

Figure 23. Participant 8: Heart Rate vs. RPE

APPENDIX L. POST-EXPERIMENT MEDICAL FORM

Post-Experiment Form

If you have any medical concerns, please do not hesitate to contact one of the following:

Medical contact info:

> Emergency medical contact information: Presidio of Monterey (POM), Doctor on call: (831) 648-2177
> CHOMP Emergency Room: (831) 625-4900
> If non-emergency, POM Clinic: (831) 242-7550

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