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EFFECT OF ASYMMETRICAL LOADING AND WALKING TIME ON SURFACE EMG ACTIVITY OF THE LUMBAR PARASPINAL MUSCLES

By

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RESEARCH PROJECT

Submitted to the Physical Therapy Program at Grand Valley State University
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MASTER OF SCIENCE IN PHYSICAL THERAPY

1999
THE EFFECT OF ASYMMETRICAL LOADING AND WALKING TIME ON SURFACE EMG ACTIVITY OF THE LUMBAR PARASPINAL MUSCLES

ABSTRACT

BACKGROUND A high incidence of back pain is associated with carrying loads asymmetrically and is believed to be influenced by the amount of weight involved and the distance carried. PURPOSE (1) To study the effects of asymmetrical loading on lumbar paraspinal muscle activity. (2) To document ratings perceived exertion (RPE) for carrying an asymmetrical load. METHODS Electromyography (EMG) readings were obtained at the L2/L3 paraspinal level of 12 males and 12 females. All subjects completed three randomized 9-minute trials consisting of walking on a treadmill while carrying an asymmetrical load of either 0, 10 or 20% of their body weight. RESULTS Multifactorial ANOVA revealed that weight was a significant factor in influencing EMG activity on the ipsilateral side but not on the contralateral side (p=0.002 & p=0.085, respectively). Time was not a significant factor on EMG activity on either side. High correlations were found between overall RPE and low back RPE (r=0.859) as well as between the carried load and both overall and lowback RPE (r=0.665 and r=0.652, respectively). A low correlation was found between time and both overall RPE and low back RPE (r=0.351 and r=0.309, respectively). CONCLUSIONS Recommendations for load carriage should place more emphasis on the amount of weight carried rather than duration.
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DEFINITION OF TERMS

Artifact: False signals generated from another source other than muscle (e.g. electrodes, equipment, cabling, etc.).

Asymmetrical loading: Carrying a backpack on one shoulder with one strap.

Athletic bag: A bag carried on one shoulder with a single strap that typically hangs vertically to waist level.

Backpack: A soft canvas bag designed to be carried on the back with one strap over each shoulder.

Cadence: Step rate per minute.

Cross talk: The signals recorded by the EMG from muscles other than the muscles being tested.

Electromyography (EMG): A program or unit that records electrical muscle activity.

External loading: Weight that is carried outside the body (e.g. textbooks carried in a backpack).

Full-wave rectification: This process generates the absolute value of the raw EMG signal via leaving alone the positive raw EMG signal and multiplying the negative raw EMG signal by negative one.

Gait Cycle: A single sequence of events between two sequential initial contacts by the same limb.

Healthy: The absence of musculoskeletal conditions including leg length discrepancy, myofascial pain of shoulder and/or back and structural scoliosis as well as known cardiopulmonary pathology (i.e. exercise induced asthma, heart disease etc).

Heavy loads: Weight that is equal to or greater than 20% body weight.

Integration: In EMG, the calculation of a running total of rectified spikes and plotting them to produce a smooth curve.

Leg length discrepancy: Greater than than 1.3 cm difference between leg lengths.

Lumbar paraspinal muscles/Erector spinae: Superficial, longitudinal back muscles originating caudally from the lumbar vertebrae, the sacrum, and the ilium.

Metabolic cost: The amount of energy used to perform a task often measured by oxygen consumption or caloric usage.
**Muscle activity:** The electrical potential of a muscle that increases with a contraction and decreases with relaxation.

**Muscle fatigue:** A decrease in muscular tension demonstrated by an increase in EMG amplitude secondary to increased firing frequency and/or increased muscle recruitment.

**Muscle recruitment:** A change in the firing frequency and/or a change in the number of active motor units.

**Myofascial pain:** Pain and stiffness in soft tissues including muscles, tendons, and ligaments.

**Perceived exertion:** The act of detecting and interpreting sensations arising from the body during physical exercise.

**Preferred shoulder:** The shoulder/arm the subject chooses to carry a backpack on.

**Prolonged carrying:** Walking with a load for periods greater than five minutes.

**Raw EMG:** A gross indication of muscle activity levels.

**Short walking distances:** Walking with or without a load for less than five minutes for the purpose of eliminating fatigue.

**Surface electrodes:** The device placed on the surface of the skin to read electrical potentials of the muscle.

**Symmetrical loading:** Carrying a backpack with a strap over each shoulder.

**VO2 max/Oxygen consumption:** Maximal capacity to transport and utilize oxygen during exercise and is considered a measure of cardiovascular efficiency.
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CHAPTER 1

INTRODUCTION

Background to the Problem

Carrying and lifting loads is a common everyday activity that occurs in numerous contexts including (but not limited to) industrial jobs, academia, military exercises, activities of daily living, and recreational activities, including backpacking. Excessive loading or improper technique may predispose an individual to injury. Wells, Zipp, Schuette, and McElenny (1983) identified a high incidence of shoulder, neck, knee, and foot injuries in letter carriers with the highest incidence involving the low back. Letter carriers commonly carry heavy loads over one shoulder placing excessive stress on joints and associated structures. Karkoska, Franz, and Pascoe (1997) identified areas of physiological symptoms including low back pain associated with bookbag carriage in college students. Researchers demonstrate an immense interest in the effects of symmetrical loading, but asymmetrical loading has been studied very little.

Problem Statement

A high incidence of back pain is associated with asymmetrical loading and is influenced by the amount of weight and the distance it is carried. This suggests that populations other than letter carriers may be at risk, such as people who carry briefcases and students who commonly carry backpack loads over one shoulder. Wells et al. (1983) stated that musculoskeletal problems probably occur because of many factors including heavy weights and long walking distances. Previously, much of the literature on muscle activity due to carrying loads has focused on single lifts or carrying a load over a short
distance, thus eliminating muscle fatigue. Currently the effect of distance on muscle activity of the low back has not been investigated. Therefore, the focus of this study was to analyze the effect of asymmetrical loading on lumbar paraspinal muscle activity over timed periods greater than thirty seconds.

**Purpose**

The purpose of this study is two-fold: (1) to study the effects of asymmetrical loading on lumbar paraspinal muscle activity and (2) to document the relationship between the amount of weight and the subjects’ perceived exertion of carrying an asymmetrical load over the duration of nine minutes of walking at 1.3 meters/second.

**Significance of the Problem**

The results of this investigation will add to the body of knowledge concerning the effects of asymmetrical loading on the human body. Possible preventative measures may evolve as a result for people at risk of back pain when walking longer distances and carrying an asymmetrical load.

**Hypotheses**

The hypotheses that were tested include the following:

1. There will be no significant difference in muscle activity on the ipsilateral side among the 0, 10, and 20% body weight loads during the nine-minute walk.

2. There will be no significant difference in muscle activity on the ipsilateral side during the last thirty seconds of the first, third, sixth and ninth minute of the walk for each of the loads.

3. There will be a significant difference in muscle activity on the contralateral side during a nine-minute walk when carrying the 10 or 20% loads.
4. There will be a significant difference in muscle activity among the 0, 10, and 20% loads on the contralateral side during the last thirty seconds of the first, third, sixth and ninth minute of the walk.

5. There will be a high correlation in both overall and low back perceived exertion proportional to the carried load and over time.

6. Overall perceived exertion will increase more than perceived exertion of the low back proportional to the carried load.

Carrying and lifting loads asymmetrically is a common everyday activity in which there is an associated incidence of back injury. To date, the literature has focused solely on lifting and carrying loads over short distances. This study will contribute information regarding the added effects of prolonged carrying on the lumbar paraspinal muscles.
CHAPTER 2

REVIEW OF LITERATURE AND CONCEPTUAL FRAMEWORK

Review of Literature

The effects of external loading have been extensively reported in the literature. External loading can be separated into two basic types: (1) symmetrical, and (2) asymmetrical. The methods used to study the effects of these two basic types include analysis of metabolic cost, gait, posture, joint forces, ratings of perceived exertion (RPE), and electromyography (EMG). The following review will discuss what is currently known about these methods applied to loading, the results of these methods, and the advantages and disadvantages of each.

Metabolic Cost and Loading

Metabolic costs have been evaluated in a wide spectrum of carrying techniques ranging from modes used for subsistence in many of the world's more primitive cultures (Datta & Ramanathan, 1971; Soule, Pandolf, & Goldman, 1978) to military missions and leisure hiking (Bloom & Woodhull-McNeal, 1987; Johnson, Knapik, & Merullo, 1995; Kirk & Schneider, 1992; Knapik et al., 1997). Collectively, these studies have provided valuable insight into the most metabolically efficient modes of carriage, amount of weight to be carried and optimal speed at which to walk.

When comparing methods of carriage used traditionally in primitive cultures, a large deviation in metabolic cost has been found when walking 5.0 km/hr for a distance of 1 km. Datta and Ramanathan (1971) and Soule et al. (1978) concluded that expenditure is lowest when the loads are located as closely and as symmetrically to the
center of mass of the individual as possible. For example, carrying a double pack (weight distributed between the front and the back of the individual) or a load carried on an individual's head is more efficient when compared to a load carried in the hands or with a yoke over one shoulder. This phenomenon may be partially due to moving the load close to the individual's center of gravity thereby increasing stability and enhancing the use of large muscles (Legg, 1985).

Several researchers have investigated the effect of altered load position on metabolic cost. When similar modes of carriage such as symmetrical backpack loading with a variation in vertical load position were examined, no significant metabolic cost changes were evident (Bloom & Woodhull-McNeal, 1987; Johnson et al., 1995; Kirk & Schneider, 1992; Knapik et al., 1997). According to Johnson et al. (1995), the factors that were positively correlated with significant increases in metabolic cost were grade of incline (3%), weight of the load (47.6-61.2 kgs.), and/or distance walked (20 km).

Keren, Epstein, Magazanik, and Sohar (1981) determined 7.77 km/h to be the upper limit for economical walking with a load. Once a subject ambulates faster, running becomes more efficient compared to walking. Therefore, walking when carrying a load should be at a slower rate in order to conserve energy and reduce the risk of injury.

The recommended maximal weight that should be carried while hiking was determined to be 30 kg for 12 km hikes, 35 kg for 6 km (Shoenfeld et al., 1978) and 25 kg for 20 km (Shoenfeld, Shapiro, Portugeeze, Modan, & Sohar, 1977). These results are for healthy, young males without regard for height and weight.

In the previously discussed studies only whole body metabolic costs can be determined. Metabolic cost cannot determine the localized effect of loading on specific
muscles and the respective activity (Bobet & Norman, 1984). Measures of metabolic cost produce information about the amount of work being performed by the entire body in general but cannot identify the work or strain in specific muscle groups. An alternate method is needed to analyze the specific muscle groups.

Jorgensen (1985) concluded that the optimal work level in daily labor occupations, letter carriers and factory workers, should not exceed 35% of the individual's VO2 max in order to decrease the chance for injury. Oxygen consumption for the participants was found below 35% of VO2 max during occupational activities; however, it is possible that local fatigue of back muscles still can occur, which can promote poor coordination, awkward movements, and potential injury to various joints. Similarly, Kirk and Schneider (1992) evaluated perceived exertion, using the Borg scale, as well as metabolic cost and found that local fatigue increased over time in the legs, chest, and shoulders, but metabolic cost remained constant. The researchers concluded that the local fatigue was enough for the subjects to detect but not enough to alter energy cost. This evidence proves that it is possible to fatigue small groups of muscles without changing the overall energy expenditure. It is for this reason that more specific examination of localized muscle groups is necessary.

Legg, Ramsey, and Knowles (1992) evaluated metabolic cost in symmetrical versus asymmetrical loading and found a significant difference. The researchers hypothesized that increased metabolic cost was evident with asymmetrical loading because the muscles of the upper body were required to work harder in compensation for the lateral bending of the trunk. However, without a closer look at the muscles themselves, the true cause for the findings is impossible to infer. In order to determine
the effects of loading on specific muscles or areas of the body, a more localized measure is necessary.

**Effects of Asymmetrical Loading on Gait, Posture, and Joint Forces**

DeVita, Hong, and Hamill (1991) studied the effects of asymmetrical loading on joint forces at L5/S1 while walking. Five subjects walked 25m per trial at approximately 1.3m/s with 10 successful trials recorded for each subject per load condition. The load conditions consisted of 0, 10, and 20% body weight. The pack was carried for the subjects between trials for adequate rest, thus reducing fatigue. Frontal and sagittal plane film records were used in order to calculate lower extremity and L5/S1 moments of force. A significant increase of force was found at the L5/S1 joint at 20% body weight. As a result, the authors concluded the load should be carried symmetrically when the load is at least 20% body weight to decrease the risk of injury.

Noone, Mazumdar, Ghista, and Tansley (1993) hypothesized mathematically that only a fraction of an external asymmetrical load is supported by lateral bending of the spine, and the remainder is supported by the muscles. The authors stated that the human spine is better equipped to deal with asymmetrical load in a sagittal plane than the frontal plane because the erector spinae and intra-abdominal pressure provide better support with forward/backward motion. Low back forces are considerably increased with asymmetrical loading in the frontal plane. The authors concluded that people, especially school children, may laterally bend their spine to reduce these forces.

D. D. Pascoe, D. E. Pascoe, Wang, Shim, and Kim (1997) used kinematic film analysis and determined that a one-strap backpack or athletic bag promoted lateral spinal bending and shoulder elevation while the two-strap backpack significantly decreased
these bag-carrying stresses. The athletic bag promoted greater angular motion of head and trunk as compared to carrying books in a backpack. The authors concluded that the daily physical stresses associated with carrying book bags on one shoulder (e.g. one-strap backpack, athletic bag) significantly alters the posture and gait of youths. The authors anticipated the occurrence of postulated physical symptoms related to backpack use, such as muscle soreness, back pain, numbness, and shoulder pain.

Electromyography with Walking and Loading

EMG is commonly used to measure muscle activity and fatigue. Thorstensson, Carlson, Zonleffer, and Nilsson (1982) studied lumbar muscle activity in relation to trunk movements during walking. The treadmill speed ranged between 1.0-2.5 m/s. Recordings were made at the L4 level during 15-30 seconds of “steady state” ambulation at each speed. The authors found mean values for angular displacement range in the frontal plane of 3-7 degrees at a walking speed of 1.0-2.5 m/s, respectively. In relation to this displacement, an EMG burst on each side occurred during an angular displacement in the opposite direction. Hence, the paraspinal muscle resists motion in the frontal plane.

Several studies have analyzed symmetrical loading in the frontal plane by focusing on the effects of backpack loading on the erector spinae muscle activity (Bobet & Norman, 1984, Cook & Neumann, 1987). Cook and Neumann placed electrodes at the L2 level 4-5 cm from the midline. Bobet and Norman placed electrodes at the L4 level with 2 cm spacing between bipolar electrodes. The authors did not specify the distance from the midline. Carrying a 19.5 kg load, each of the 11 male subjects walked 90 m at a speed of 5.6 km/h. Both studies found slight decreases in erector spinae muscle activity during symmetrical backpack carriage as compared to unloaded walking. Bobet and
Norman explained theoretically that symmetrically loaded walking creates an extension moment, which partly offsets the flexion moment and decreases the activity of the erector spinae.

Cook and Neumann (1987) also analyzed asymmetrical loading over short walking distances in the same study. Each trial (total of 11 experimental conditions) consisted of two 15.3 m phases. Subjects walked at a pace of 1.3 m/s ± 10%. Cook and Neuman found significant increases in erector spinae muscle activity contralateral to the load carried asymmetrically in the frontal plane at 10% and 20% body weight as compared to no external load. There was also a significant difference between 10% and 20% body weight. The researchers also found a slight decrease in activity of the erector spinae muscle ipsilateral to the carried load at both 10% and 20%. The researchers did not, however, examine the effects long distance walking has on the muscles while carrying these loads. Research involving long distance walks and loading is an area that should be examined further.

Determining which activities require an increase in muscle activity can be beneficial in helping to decrease the number of injuries. Increased muscle activity as evidenced by EMG readings has been linked to a higher occurrence of low back pain (Lavender, Chen, Trafimow & Andersson, 1995). Through an epidemiologic investigation, the researchers also found a correlation between asymmetrical loading and an increase in lumbar paraspinal muscle activity.

Ratings of Perceived Exertion

The Borg scale of ratings of perceived exertion (RPE) is a valid tool used to subjectively measure exertion during exercise (Borg, 1982; Goslin and Rorke, 1986;
Holewijn and Lotens, 1992; Kirk and Schneider, 1992; Noble, Metz, Pandolf, Bell
Cafarelli and Sime, 1973; Pandolf, 1982). Noble and Robertson (1996) defined
perceived exertion as "the act of detecting and interpreting sensations arising from the
body during physical exercise" (p. 4). The most commonly used scale is the 15-graded
Borg scale of RPE (Borg, 1970); however, the Category Rating (CR) 10-scale is also
used (Borg, 1982). Borg (1982) suggested that the 15-grade scale is best applied for
simple studies of perceived exertion and medical rehabilitation when wishing to estimate
subjective intensity when metric properties of the scale are less important. The CR 10-
scale with ratio properties was suggested to be more suitable for determining subjective
symptoms such as breathing difficulties, aches, and pain. The 15-point Borg scale will be
used to record the subjects’ overall perceived exertion as well as that of their low back.
This information will be used as a supplement to the primary focus of the study.

The validity and reliability of RPE has been extensively studied. Borg (1970) and
Pandolf (1978) both established a positive linear relationship between RPE and heart rate
during cycling or treadmill locomotion. Skinner, Hustler, Bergsteinova, and Buskirk
(1973) studied the reliability and validity of the Borg 15-graded scale. Sixteen college-
aged university students cycled for two trials for each of two protocols. Protocol (1)
consisted of progressively increasing work loads to a self-imposed maximum. The initial
work load was 150 kg/min and increased 150 kg every two minutes. Protocol (2)
consisted of randomly assigned work loads. Heart rate and RPE were recorded during
the last twenty seconds of each work load in both protocols. There were no differences in
physiological and perceptual responses between the loads. No significant differences
were found in the physiological or perceptual variables studied when comparing
progressive to random protocols. Validity coefficients were high, ranging from 0.60 to 0.92 for all variables measured: respiratory rate (breaths/min), tidal volume (L/min and L/breath), oxygen intake (L/min, mL/Kg•min, and mL/Kg FFW•min), heart rate (beats/min), and RPE. Reliability coefficients were high ranging from 0.68 to 0.97 for all variables mentioned above with the exception of respiratory rate and tidal volume.

Stamford (1976) assessed the validity and reliability of the Borg 15-graded RPE scale. RPE and heart rate were compared during four different modes including cycle ergometry, walking, jogging, and bench stepping. Fourteen subjects were studied to determine the validity and reliability of RPE in these contexts. Three exercise protocols were established using the four modes of exercise. One protocol used a consistent workload, the second protocol consisted of oscillating workloads while the third consisted of progressive workloads. RPE measures were taken at either regular time intervals or at exercise termination. Heart rate was measured electrocardiographically every minute or every two minutes depending on the protocol. Reliability coefficients for all modes and protocols of exercise were high. Reliability coefficients were 0.90 for the progressive cycling test, 0.71 for the oscillating test, 0.76 for the bench stepping, and 0.76 for the submaximal walking. RPE ratings were not affected by the different types of work and were reliable both when taken periodically throughout the work session and when taken only at the termination of exercise.

Pandolf, Burse, and Goldman (1975) examined local factors (muscle and joint strain), central factors (cardiopulmonary strain), and over-all general RPE while walking or cycling. The first and second trials consisted of walking at 0% grade at 4.0 km/hr (2.5 mph) and 5.6 km/hr (3.5 mph) respectively. The following two trials were the same
except a 1.5 kg weight was strapped to each ankle. The final trial was performed on the
cycle ergometer for 6 min at 600 kpm/min. A minimum of 10 minutes separated each
trial to allow heart rate to return to baseline. Variables measured included heart rate and
oxygen consumption. RPE was obtained for joint and muscle strain (local), sensations in
the cardiopulmonary system (central), and over-all RPE to indicate overall, local, and
central exertion. There was no significant difference between local and central RPE
during treadmill walking, however there was a significant difference during cycling.
Local factors were determined to be the primary sensory inputs when rating over-all
exertion when riding a cycle ergometer and central factors were the primary sensory
inputs used when rating over-all exertion while walking on a treadmill.

Goslin and Rorke (1986) evaluated the factors that contribute to RPE when
carrying a backpack symmetrically at various loads (0, 20, and 40% body weight). They
found that RPE increased at a faster rate than the central responses (i.e. oxygen
consumption and heart rate). As soon as the external load was added, RPE increased 1.5
to 2 times that of central physiological responses with no significance. There were no
differences between the 20% and 40% loads. Goslin and Rorke suggested that central
systemic factors did not dominate the local factors. Rather, changes in RPE were
hypothesized to be due to increased levels of muscular tension, joint compression,
alterations in locomotor posture, kinesthetic sensations from skin, tendons and ligaments,
and/or the stretch receptor feedback. This observation has been supported by others
(Borg, 1982; Noble et al., 1973; Pandolf, 1978, 1982; Pandolf et al., 1975). Goslin and
Rorke believed a threshold effect in RPE was apparent and was demonstrated to occur at
lower levels of load and not to increase at higher levels of up to 40% body weight.
Although the 15-graded RPE scale is a valid and reliable subjective measuring tool, it was not intended to mirror heart rate and other vital measures. Borg (1982) stated that the 15-graded scale was developed to correspond closely with heart rate so that increasing values on the scale would correspond with a proportional increase in heart rate. However, Borg emphasized that “this close relationship was not intended to be taken too literally because the meaning of a certain heart rate value as an indicator of strain depends upon age, type of exercise, environment, anxiety, and other factors” (p. 379).

Summary and Implications for the Study

Numerous modes of equipment have been used to measure the effects of asymmetrical loading on the human body. These methods include metabolic cost, joint reaction studies, and EMG. To date, researchers have used metabolic cost to evaluate the effects of loading on the human body with significant factors including weight carried, level of incline, and walking speed. Significant increases of forces at L5/S1 joint with asymmetrical loads at 20% body weight have been described in joint reaction studies. However, metabolic cost and joint reaction studies are invalid measures for evaluation of individual muscle activity. If used appropriately, EMG is a valid measure of individual muscle activity. When asymmetrical loads at 10% and 20% body weight were compared to no load in EMG studies, significant increases in activity of the contralateral erector spinae were documented. Although specific muscles were examined, fatigue was eliminated in the EMG studies through the use of lift or a short distance walk. The present study will look at the effects on erector spinae muscle activity over three intervals of nine minutes of walking and asymmetrical loading using a backpack at no load, 10%
body weight, and 20% body weight. The results of this study added to the body of knowledge concerning the effects of asymmetrical loading on the human body. Possible preventative measures evolved as a result for people at risk for back pain when walking and carrying an asymmetrical load.
CHAPTER 3

METHODOLOGY

Study Design

This quasi-experimental study consisted of three trials (two experimental and one control). Each subject was randomly placed into one of six sequences using the three trials. The three trials consisted of no load (BW0), 10% body weight (BW10), and 20% body weight (BW20). EMG signals of the contralateral and ipsilateral erector spinae to the asymmetrical load were recorded. The recordings occurred during the final thirty seconds of the initial (T1), third (T2), sixth (T3), and ninth minutes (T4) while ambulating in each trial. Ratings of perceived exertion (RPE) were assessed and recorded at the same times. A pre-trial isometric contraction was taken to establish maximum voluntary effort (MVE). The dynamic EMG readings were normalized to the MVE. The design is noted in Figure 1.

<table>
<thead>
<tr>
<th>TIME</th>
<th>TRIAL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BW0</td>
</tr>
<tr>
<td>T1</td>
<td></td>
</tr>
<tr>
<td>T2</td>
<td></td>
</tr>
<tr>
<td>T3</td>
<td></td>
</tr>
<tr>
<td>T4</td>
<td></td>
</tr>
</tbody>
</table>

Figure 1. Study Design for Dynamic Electromyography (EMG) Values of the Contralateral & Ipsilateral Paraspinal Muscles, and Overall & Low Back Ratings of Perceived Exertion (RPE).
A disadvantage of this design involved each subject's endurance level. For example, subjects may have become fatigued after participating in two of the trials, such as BW10 and BW20. The fatigue level of these subjects may have affected the results of BW0. For this reason, subjects were allowed adequate rest time, a maximum of ten minutes or until heart rate returned to normal. Fatigue levels were also controlled for by placing subjects into randomized trials.

Advantages to this study design were numerous. Manipulation of the independent variable (load) in a controlled environment was one advantage to this design. Another advantage of this design was the randomization of the trial sequence. Each subject functioned as his or her own control. This design allowed data analysis of dynamic activity within each trial (changes in time) and across the trials (changes in load). Interaction analysis among subjects, gender, weight, and time was made possible through the design as well.

Subjects and Study Site

Subject Description

Subjects were recruited from the Grand Valley State University (GVSU) population on a volunteer basis. Volunteers had the opportunity to sign-up for designated times following a five-minute overview of the study. All subjects were healthy college aged students (12 males and 12 females) between the ages of 18 to 24 years of age. Before the experiment began, subjects were informed of risks, benefits, and procedures and signed an informed consent in compliance with the GVSU Research Review Committee (Appendix A).
Screening and Exclusion Criteria

A medical history and a physical screen were conducted pertaining to a checklist of conditions that may have interfered with the study and compromised the safety the participants (Appendix B). Subjects were excluded for the following reasons: various medical conditions, pharmacological restraints, cardiovascular, respiratory, and orthopedic disorders including leg length discrepancy greater than 1.3 cm, myofascial pain of the lumbar paraspinals or upper trapezius muscles, scoliosis, and obvious gait deviations. Resting heart rate and blood pressure were assessed during the physical screen as well. Body composition was estimated using the three-site method of Jackson and Pollock (1985). Subjects were familiarized with the treadmill and instructed on the proper technique of walking, exiting the treadmill, and the MVE. Subjects were instructed to refrain from smoking, alcohol, and caffeine (e.g. coffee, carbonated beverages, cappuccino, espresso, chocolate products, tea, etc) twelve hours before their scheduled trials and were instructed to eat a light breakfast to maintain efficient energy levels.

Study Site

The experiment occurred in the Human Performance Lab (HPL) at GVSU. The lab contained the necessary equipment: EMG (Noraxon USA, Inc., Scottsdale Arizona U.S.A.), polar heart rate monitor (Polar Electro, Inc., Port Washington New York U.S.A.), treadmill (Quinton Instrument Co., Seattle Washington U.S.A., model # 1860), and a Toledo scale (Toledo Scale Co., Toledo Ohio U.S.A., model # 2120).
**Equipment and Instruments**

The backpack used was the Eddie Bauer campus daypack (Eddie Bauer, Seattle Washington, U.S.A.). It was a 1,000-denier textured nylon and had adjustable padded shoulder straps designed for comfort. The large pouch was used to hold the weight.

The EMG software was supplied by the Noraxon System and contained the research program Myosoft for Windows (version 3.4). The program allowed the creation, process, and evaluation of EMG measurements. The EMG signals were visually monitored and recorded with great speed and accuracy. Raw and/or integrated data involving muscle recruitment, timing, amplitudes, endurance statistics, and mean calculations can be recorded which enables researchers to review, edit, and print results.

EMG measurements were recorded using 33 mm Blue Sensor disposable surface electrodes (Medicotest, Inc., Denmark) with a 15 mm recording surface containing silver/silver-chloride gel. These bipolar disc electrodes were placed at the L2/L3 level with the pull tab directed inferiorly. The discs were positioned parallel to and on the convexity of the paraspinal muscle as designated by an isometric contraction and palpation. An interelectrode distance of 18 mm was used. Prior to application, the skin was scrubbed with rubbing alcohol, shaved with a razor, and scrubbed again with rubbing alcohol to reduce input impedance in the amplifier.

Myosoft 3.4 uses a differential amplification with specific feedback algorithms built in. Impedance should be of low capacitance (less than or equal to 5 pico farad (pf)) which is accomplished through the skin preparation procedure. A bandwidth of 10-500 Hertz (Hz) was used with an actual gained range of 1000 Hz. This program achieves a full-wave rectification by leaving the positive values of the raw EMG signal alone,
multiplying the negative values of the raw EMG signal by negative 1, and adding both to calculate the integrated signal. Analysis of the integrated signal was performed by using the single marker exhaustive analysis.

Validity/Reliability

Validity of EMG has been demonstrated via the literature and depends on the type of recording device and instrumentation. Reliability of EMG depends on the time of day, size and type of electrodes, preparation of recording site, the interelectrode distance, location of the electrodes and standardization of those procedures, type of muscle action, and the velocity of movements tested (Alderink, 1997). In an attempt to control for these variables, a consistent procedure was conducted including preparation of the recording site, placement of the electrodes, and maintaining consistency of the interelectrode distance. All trials were conducted during the same range of time between the hours of 7 am and 1 pm. Location and placement of the bipolar electrodes and blood pressure readings for each subject was performed by the same researcher who demonstrated clinical proficiency. The lumbar paraspinals provided dynamic support for the lumbar spine when subjects carried the asymmetrical load.

Procedure

The experiment was conducted following the screening process. On the day of the experiment, subjects wore shorts or sweat pants, t-shirt and/or sports bra, socks, and athletic shoes. All subjects confirmed abstinence from smoking, alcohol, and caffeine for twelve hours prior to the trials. Resting heart rate and blood pressure were obtained after quietly sitting for ten minutes. Subjects identified their preferred carrying shoulder and their dominance.
Each subject had an area on his or her lower back, large enough for electrodes, scrubbed with alcohol, shaved with a razor, and scrubbed again with alcohol to reduce impedance of the EMG signal. The electrodes were placed at the L2 and L3 level with an interelectrode distance of 3.5 cm on the convexity of the paraspinal muscles as designated by an isometric contraction. The ground electrode was placed on the bony SI spinous process.

Verbatim instructions were verbally given to each subject regarding the procedure and safe ambulation on the treadmill (Appendix C). Following the instructions, each subject had the opportunity to ask questions. Each subject was also given verbal instructions (Appendix D) regarding the implementation of the RPE scale and was given the opportunity to ask questions about the rating procedure. No information was given to the subjects regarding the expected outcome of the perceptual ratings (Noble et al. 1973; Noble and Robertson, 1996).

Each subject was given a predetermined sequence of loads. For example, the first subject may have received a sequence of BW0, BW10, and BW20. The next subject may have received a sequence of BW20, BW0, and BW10. Each of these sequences was carried out by a total of four subjects, two males and two females. The backpack contained journals with the appropriate weight as designated by the trial.

The subject then was asked to lie prone on a padded table to complete the MVE. The MVE was performed by lifting his or her arms, legs, and head up off the mat as high as possible to get a maximal isometric contraction of the paraspinal muscles. The subject held this position for ten seconds. The final eight seconds of the contraction were
recorded. The recording of integrated EMG and raw EMG (I-EMG and R-EMG, respectively) was immediately saved to the hard drive.

Participants walked on a motorized treadmill (Quinton Instrument Co., Seattle Washington U.S.A., model 41860) as illustrated by Figure 2. Subjects walked nine minutes and maintained a velocity of 1.3 m/s, which is within the average human walking velocity range of 1.2 m/s to 1.5 m/s (Blessey, Hislop, Waters, and Antonelli, 1976). Each nine-minute trial began when the subject had comfortably removed his or her hands from the safety rails of the treadmill. I-EMG and R-EMG data of the lumbar paraspinal muscles were collected during the last thirty seconds of the initial (T1), third (T2), sixth (T3), and ninth minutes (T4) of each trial using the Myosoft research program. Subjects rated their perceived exertion at the same times from the Borg Scale that was presented directly in front of them. The values verbalized by the subjects were recorded on the data recording sheet (Appendix E). Heart rate response was assessed using a heart rate telemetry watch and was recorded each minute. The number of gait cycles was recorded between the fourth and fifth minute of each trial.

Figure 2. Experiment Setup
Immediately following each trial, an isometric contraction of the paraspinal muscles was performed for ten seconds. The final eight seconds was again recorded using EMG. The subject was then allowed to rest for a maximum of ten minutes or until heart rate returned to resting level before performing another pre-trial isometric contraction. Two more trials were performed and recorded in the same fashion using the other two loads.

**Data Analysis**

Fifteen gait cycles were used to standardize the EMG data. Cadence was used to determine the length of time to complete fifteen gait cycles. Single markers were placed at the beginning and end of this time period. A marker analysis was performed to calculate mean area of integrated EMG activity of the ipsilateral and contralateral sides. The mean area per second was calculated for each EMG value. Each subject's EMG values were normalized to his or her own MVE, and represented as percentages of the MVE. Mean and standard error were calculated for all percentages at the given times.

The software package, SPSS (version 8.0) was used to complete the data analysis. Data were analyzed using a repeated measure analysis of variance (ANOVA). Factors considered included individual, load (BW0, BW10, and BW20), and time (T1, T2, T3, and T4). Correlations of RPE, weight, and time were determined.
CHAPTER 4
RESULTS/DATA ANALYSIS

Techniques of Data Analysis

EMG data recorded during the trial was normalized and expressed as a percentage relative to the maximum voluntary effort (MVE) recorded at the beginning of the experiment. Data were recorded on both ipsilateral and contralateral lumbar paraspinals, and analyzed independently of one another. Multifactorial analysis of variance (ANOVA) with repeated measures was the appropriate statistical tool because of the number of independent variables (weight) and repeated measurements (time) (Portney & Watkins, 1993). Alpha levels were set at 0.05 for each analysis.

The Pearson product-moment coefficient of correlation was used to analyze ratings of perceived exertion (RPE) data. Borg (1982) defended the position that the 15-graded RPE scale has interval properties. This statistic is appropriate for use with variables with underlying normal distributions on the interval scale (Portney & Watkins, 1993).

Characteristics of Subjects

A total sample size of 24 subjects (n=24) from Grand Valley State University student population volunteered, 12 males and 12 females. Subject characteristics are listed under Table 1.
Table 1

Subject Characteristics

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>% Body Fat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>21.1 ± 1.7</td>
<td>180.8 ± 4.8</td>
<td>76.3 ± 7.7</td>
<td>9.6 ± 4.1</td>
</tr>
<tr>
<td>Female</td>
<td>19.7 ± 1.8</td>
<td>165.4 ± 3.8</td>
<td>63.9 ± 5.6</td>
<td>26.7 ± 4.5</td>
</tr>
<tr>
<td>Males &amp; Females</td>
<td>20.4 ± 1.9</td>
<td>173.1 ± 8.9</td>
<td>70.1 ± 9.2</td>
<td>18.5 ± 9.7</td>
</tr>
</tbody>
</table>

Note. Mean ± standard deviation.

One male subject showed to be an outlier, which significantly effected the statistical analysis. Hence, he was removed from the analysis. The result with the outlier may be viewed in appendix F. Complete results excluding the outlier can be viewed in appendix G.

Hypotheses/Research Questions

The means and standard deviations for integrated EMG data with the carried load and over time are listed in Table 2.

Interaction effects between individuals and weight were found significant (p<0.001) on the contralateral and ipsilateral sides. Time appeared not to be a significant factor in EMG activity on the contralateral or ipsilateral sides during the nine-minute walks (p=0.264 & 0.512, respectively). All results are contained in Table 3. See Figures 1 and 2 for illustration of the interaction effects.
Table 2

Mean and Standard Deviation of Normalized Electromyographic (EMG) Data with Carried Weight over Time (N=23).

<table>
<thead>
<tr>
<th></th>
<th>BW0</th>
<th>BW10</th>
<th>BW20</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>C</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>T1</td>
<td>55.7 ± 61.1</td>
<td>54.6 ± 74.0</td>
<td>42.2 ± 49.3</td>
</tr>
<tr>
<td>T2</td>
<td>56.0 ± 78.5</td>
<td>70.8 ± 91.2</td>
<td>40.1 ± 50.5</td>
</tr>
<tr>
<td>T3</td>
<td>57.5 ± 62.1</td>
<td>53.2 ± 70.2</td>
<td>42.7 ± 58.3</td>
</tr>
<tr>
<td>T4</td>
<td>46.0 ± 63.3</td>
<td>60.3 ± 74.7</td>
<td>29.6 ± 35.5</td>
</tr>
</tbody>
</table>

Note. Mean ± standard deviation. All values expressed as percentage of pre-trial maximal voluntary effort. C = contralateral. I = ipsilateral. BWO = carried load is 0% body weight. BW10 = carried load is 10% body weight. BW20 = carried load is 20% body weight. EMG data was recorded at T1 = first minute, T2 = third minute, T3 = sixth minute, and T4 = ninth minute.

Table 3

Analysis of Variance and Multiple Comparisons for Carried Weight, Time, and Individual (ID) of Integrated Electromyographic Activity (N=23)

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>Level of significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Contralateral</td>
</tr>
<tr>
<td>Between subjects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>2</td>
<td>0.085</td>
</tr>
<tr>
<td>Time</td>
<td>3</td>
<td>0.264</td>
</tr>
<tr>
<td>ID</td>
<td>22</td>
<td>0.000</td>
</tr>
<tr>
<td>Weight x ID</td>
<td>44</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Note. Values are significant at the p < .05 level. Weight = Carried Weight.
Figure 3. Interaction Effects of Electromyographic (EMG) Activity Between Carried Weight and Individuals on the Contralateral Side (N=23).

Figure 4. Interaction Effects of Electromyographic (EMG) Activity Between Carried Weight and Individuals on the Ipsilateral Side (N=23).
There was a high correlation between the carried load and both overall and low back RPE (r=0.665 and r=0.652, respectively). There was a low correlation between time and both overall and low back RRE (r=0.351 and r=0.309, respectively). There was a high correlation between overall RPE and low back RPE (r=0.859). Therefore as low back RPE increased, overall RPE increased proportionally. Results are presented in Table 4.

Table 4

Pearson Correlation of Ratings of Perceived Exertion (RPE), Carried Weight (Weight), and Time

<table>
<thead>
<tr>
<th>Source</th>
<th>r value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall RPE &amp; Low Back RPE</td>
<td>0.859</td>
</tr>
<tr>
<td>Overall RPE &amp; Weight</td>
<td>0.665</td>
</tr>
<tr>
<td>Overall RPE &amp; Time</td>
<td>0.351</td>
</tr>
<tr>
<td>Low Back RPE &amp; Weight</td>
<td>0.652</td>
</tr>
<tr>
<td>Low Back RPE &amp; Time</td>
<td>0.309</td>
</tr>
</tbody>
</table>

Note. Weight = Carried Weight.
CHAPTER 5

DISCUSSION AND IMPLICATIONS

Discussion of Findings

In the current study, there was a significant interaction effect found between carried weight and individual for both the ipsilateral and contralateral paraspinal muscles. Secondary to this interaction effect, conclusions cannot be drawn about these results regarding levels of significance. Cook and Neumann (1987) did not report any interaction effect and therefore were able to draw conclusions about the effect weight has on these muscles. In the current study, the subjects walked for periods of nine-minutes, which was significantly longer than the distance walked in the Cook and Neumann study. This longer distance may have influenced the posture in which the subjects walked and thereby altered the erector spinae muscle activity. Many other muscles function in trunk stability including internal obliques, transversus abdominus, and the multifidus. These muscles may fire more in response to the load to add to the stability of the trunk; thereby reducing the activity demands of the erector spinae muscles. Determining which muscles were aiding the erector spinae and the degree of assistance they gave is difficult because EMG activity was only recorded over the erector spinae muscles themselves. The pattern of muscle activity varied among the individuals as demonstrated by interaction effects, which is discussed below.

Weight appeared to be a factor on ipsilateral muscle activity. However, Cook and Neumann (1987) found no difference in ipsilateral muscle activity at any of the given loads. A reason for these differences may be related to the length of the walk. In this
study, subjects were allowed to readjust their backpacks during the trial, but not during any of the recordings. By readjusting the backpack, it is possible that they were able to find a position that allowed other trunk muscles to support the weight, therefore taking some of the load off of the erector spinae. The comfort from readjusting could possibly be demonstrated by alterations in muscle activity. It also may be hypothesized that the muscles on the same side of the load had to work harder to compensate for the added weight.

A major focus of this study was to examine the effect that walk time and asymmetrical load have on low back muscle activity, which has not been reported via EMG studies in the literature. The muscle activity contralateral and ipsilateral to the load carried did not change significantly during a nine-minute walk with any of the given loads. One possible reason for no significant difference is that nine minutes of walking may not be long enough to see any change in muscle activity. Other muscles may compensate over time to meet the demand of stress placed upon the body. During the trials, subjects were allowed to adjust the backpack. The adjustment may have prevented any significant changes in activity of the erector spinae muscle group.

The data analysis pointed to a strong interaction effect regarding the subjects. This indicated that there was a significant difference among the subjects. This difference resulted from very individual responses to the applied loads; therefore it resulted in a high level of significant interaction. For example, one subject may have had higher levels of muscle activity at BW10 load than at BW20 load whereas another individual may have had higher levels at BW20 load than at BW10 load. It is possible that at these higher loads other muscles could be activated to compensate for the increase strain these loads
place on the low back. When the strain becomes too much for the erector spinae muscles to manage other muscles such as the internal obliques may be activated to compensate. A pattern could not be determined as to which of the loads cause the highest level of muscle activity. Other reasons for the difference in responses include anatomical makeup and physiological responses. For example, one person may have stronger abdominal muscles, which can help support the low back when stresses are placed upon it, thereby reducing the amount of work the erector spinae has to perform. An individual’s fitness level may also make a difference in the amount of stress that the lower back is able to endure.

Both weight and time were positively correlated with increased RPE values for both low back and overall levels of exertion (Table 3). As weight and time increased, RPE values also increased. RPE values used for overall and low back were positively correlated to each other as well, as one increased the other also increased at a comparable rate. This was not expected. The hypothesis was for there to be a lower level of positive correlation where overall exertion would increase at a faster rate than the low back RPE. An inference was made that overall exertion might disguise the exertion of the low back; therefore leading to an increase risk for injury. This apparently does not hold true.

**Application to Practice**

Within the nine-minute trials of this study, time did not have a significant effect on muscle activity of the low back on the contralateral or ipsilateral sides (Table 2). Therefore, weight should be bigger concern as opposed to the length of time carried. In regards to occupations that require extensive carrying, further research should be conducted in order to draw conclusions regarding walks longer than nine minutes. Increasing the weight carried does demonstrate an asymmetrical distribution of forces on
the low back as shown by muscle response. The literature has shown that increased EMG activity is often a precursor to muscle strain and potentially pain (Lavender et al., 1995). In order to help decrease the incidence of these muscle strains, individuals who carry loads on a regular basis should be encouraged to carry the load as symmetrically as possible. This mode of carriage will not only keep the load closer to the center of gravity but also decrease overall exertion. It will also distribute the weight more evenly to both sides of the body (Datta & Ramanathan, 1971; Soule et al., 1978). In addition, the RPE scale is an effective measure of an individual’s actual level of exertion. The scale can be easily used by laypersons to express the amount of work they are being asked to do.

**Limitations**

A couple of factors may limit the generalizability of the study. First, this study took place in a non-natural setting. Subjects may have reacted differently than if they were in a natural setting, which may make it difficult to generalize the results. The treadmill also does not completely simulate walking on actual ground. Secondly, this study may not be generalizable to everyone based on the weight of the load and how the load is carried. People may, on average, carry more or less weight than was carried in this study. Lastly, the limited sample size included only the college-aged population and is not generalizable to other age groups, such as pediatric or geriatric populations. For example, school-aged children may not be able to generate the muscle activity needed to counter the forces generated by the asymmetrical loading. In addition, college students carry backpacks on a regular basis and may learn many compensatory mechanisms to adjust for increased loads. The limited sample size may also not adequately represent the whole population. The use of group averages may have overlooked individual change;
therefore, actual results may not be expressed. However, interaction effects among individuals can be analyzed.

There are some possible biomechanical and physiological limitations. Biomechanically, the load may be supported by other muscle groups, such as trapezius, transversus abdominus, internal oblique, and multifidus. In this study, only one muscle group was analyzed. Therefor, conclusions about these other muscles could not be drawn. Human subjects may have inherently altered the data collection. Changes in EMG signals may have occurred as a result of a learned response. As more trials were completed, subjects may have unconsciously performed more efficiently. Subjects were familiarized with walking on the treadmill and in the performance of isometric contractions prior to participating to reduce this learned response. The randomization of the trials also helped to decrease this.

An inherent limitation with the EMG machine is cross-talk. Cross-talk results when muscle activity, other than the muscle intended to be studied, is recorded by the EMG machine. Factors that may contribute to cross-talk include inappropriate electrode size, interelectrode distance, and inaccurate electrode placement. The paraspinal muscles are a relatively large muscle group; therefore, this may have reduced the effect of cross-talk. Electrode size and interelectrode distance were carefully standardized according to the literature. Artifact may have also altered the EMG signal. Artifact is additional signals measured by EMG from a non-biological source, such as the treadmill and computer. The electrode leads were cancelled out prior to each trial to demonstrate that there was no artifact influencing the EMG readings. Bipolar electrodes were used to help reduce artifact as well.
Beyond the fixed limitations, there were some additional limitations to the study. If a subject did not perform maximally during the isometric contraction, the data could not be an accurate predictor of muscle activity within the trials. The outlier may have performed in this manner.

The unexpectedly high correlation between low back and overall RPE may have been influenced by the subjects feeling that as overall RPE increased, low back RPE should also increase. Even though subjects were given explicit instructions regarding the individuality between overall and low back RPE this may have occurred.

**Suggestions for Further Research/Modifications**

Looking at internal obliques, transversus abdominus, and multifidi muscles with regards to asymmetrical loading may have further insight into the muscles that play an integral role in maintaining an upright posture. Perhaps different modes of carriage would make a difference in terms of muscle activity in the erector spinae over time and with various weights. For example, carrying an athletic bag or brief case may be different than carrying a backpack on one shoulder. There have been studies that have addressed this issue, but not in terms of long distance or duration. The effects of load carriage over long distances and times should still be studied further in order to examine fatigue levels in the muscles of the low back. The nine-minute trials may not have been sufficient time to allow for significant muscle activity changes to occur. Trials using longer distances could potentially demonstrate a more significant change in activity and also examine muscle fatigue levels.

Further research should be done regarding the relationship between low back pain and low back muscle activity. If a direct relationship can be determined, this may give
insight for the prevention of pain. The effect that age may have on low back muscle activity would be interesting to examine. Another possible study would be to examine the effect of carrying a backpack symmetrically (on both shoulders) has on the rectus abdominus, which may reciprocally inhibit the multifidi. The subjects in the present study were given a specific speed to walk. Subjects may perform differently if allowed to walk a self-selected speed. Research using video analysis could be done in conjunction with electromyography to identify possible moments of force and its relationship to muscle activity. Very little research has been published on the use of EMG for dynamic muscle activity. There needs to be a standard way to normalize readings so that they can be more readily compared to one another.

The difference between males and females also has not been considered. Secondary to the individuality of anatomical and physiological makeup between the two groups, it is possible that the muscle activity between two groups is very unique. More specified research in this area may develop recommendations unique to each of the groups for ideal modes of carriage as well as amount of load. Similarly, there may be a possible relationship between upper body strength and the effect load carriage has on the low back. These areas should also be examined more closely.

Conclusions/Summary

Carrying and lifting loads is a common everyday activity seen in recreation, work, and academia. This study found that time was not a significant factor in EMG muscle activity when carrying any load asymmetrically for nine minutes. Although, individuals responded uniquely to carrying loads, a general recommendation can be made that if heavy loads need to be carried they should be carried asymmetrically.
REFERENCES


APPENDIX A

Informed Consent Form

GRAND VALLEY STATE UNIVERSITY

PHYSICAL THERAPY DEPARTMENT

INFORMED CONSENT FOR RESEARCH INVOLVING HUMAN SUBJECTS

Title of Project  
Effect of Asymmetrical Loading and Walking Time on Surface EMG Activity of the Lumbar Paraspinal Muscles

Principal Investigators  
Michael Aenis, SPT  
Angela Bueche, SPT  
Brian Trembly, SPT

Purpose - You are being asked to participate in a research study that will require walking while carrying a backpack over one shoulder to examine the effects on low back muscle activity and perceived exertion.

Procedures and/or Compensation - If you decide to participate, you have been asked to come in 2 times. In the first visit, you will be asked a few questions regarding your general health. Then you will undergo a physical screening procedure by a physical therapy student. The physical screen includes assessment of resting heart rate and blood pressure, evaluation of walking pattern, presence or absence of scoliosis, differences in leg length, and physical pain. You will also be familiarized with walking on the treadmill and carrying loads. For the second visit, you will be required to refrain from caffeine, tobacco, and alcohol for the 12 hours prior to your scheduled trial. You should be dressed in athletic attire (e.g. comfortable walking shoes, socks, t-shirt, and shorts or sweat pants). Resting heart rate and blood pressure will also be obtained at this time. An area on the low back (large enough for electrode placement) will be prepared for testing by scrubbing with rubbing alcohol, shaving with a razor, and scrubbing again with rubbing alcohol prior to the application of the surface electrodes. Once the electromyography (EMG) is hooked up, you will be ask to lie on your stomach and tighten your back muscles by lifting arms and legs for a measurement. This process will be repeated before and after every trial. You will then walk three trials on a treadmill at 3.0 mph with a rest period of 10 minutes between the trials. Each trial will last approximately 9 minutes, and the load you will carry will change from trial to trial. The loads consist of walking with an empty backpack, a backpack containing 10% of your body weight, and a backpack containing 20% of your body weight. The order of the trials will be randomly and assigned to you prior to the start of the trials. The backpack
will be carried on your preferred shoulder. You will be asked to rate your discomfort, stress, and effort in your low back muscles at the beginning, at 3 minutes, at 6 minutes, and at the end of each trial. Heart rate will be monitored during each minute by a heart telemetry watch. The total time commitment for the second visit should take no longer than 1 1/2 hours.

*Risks and Discomfort* – As with all physical activity on a treadmill, there is a risk of falling. You will be given the opportunity to familiarize yourself with the treadmill, and there are siderails if you need to regain your balance. A researcher will always be present near the treadmill throughout the trials. There is always a risk of muscle strain and/or delayed onset muscle soreness with physical activity. The weight carried may cause mild discomfort. Skin irritation may occur under the shoulder strap of the backpack and/or under the electrodes, resulting from an allergic reaction. The backpack also has a remote potential to cause some nerve irritation and increased pressure in the eyeballs. The increased level of activity above resting could cause a stroke or heart attack. Although there is a remote possibility for injury, the activities you are being asked to do are performed everyday.

*Benefits and/or Compensation* – This study will provide information regarding the effect walking and carrying a load over one shoulder has on muscle activity of the low back. Information regarding your body composition will be available after you participate. You will also receive feedback on your physical screen as well as the opportunity to ask any questions you may have.

*Confidentiality* – The results of this study will be presented at campus and community presentations. This study may also be considered for publication in a health related journal. However, your name and any information that may identify you will remain confidential unless given with your permission or required by law. Only the principal investigators (Michael Aenis, Angela Bueche, and Brian Trembly) and committee members (Carol Weideman, Ph.D., John Peck, Ph.D., P.T., and Paul Stephenson, Ph.D.) will have access to the data.

*In the Event of Injury* – In the event of an injury as a result of this study, the principal investigators, committee members, and Grand Valley State University (GVSU) are not responsible. Medical attention may be sought at Health Services in the fieldhouse at GVSU at the participants' expense.

*Voluntary Participation* – Participation in this study is strictly voluntary, and you may withdraw at any time without any consequences from the researchers and GVSU.

*Offer to Answer Questions* – You will be given the opportunity to ask questions at any time regarding this study. Every attempt will be made to answer your questions to your satisfaction. You may take as much time as necessary to think this over. Further questions may be directed to Carol Weideman at 895-3259 or Paul Huizenga of the Internal Review Board at 895-2470.
AUTHORIZATION – "I acknowledge that I have read and understand the above information. I have been given an opportunity to ask questions, and I agree to participate in this study."

Date

Name of Subject (Please Print)

Signature of Subject

Signature of Witness

Signature of an Investigator

Photographs will be used in presentations and publications at GVSU and in the community. Do you authorize your photo being taken during the experiment and used in presentations.

Signature of Agreement
APPENDIX B

Health and Physical Screen

Subject Name: _____________________________ Subject #: ______

Age: ______ years Sex: (circle one): M F

Signed Consent Form? Y N

Personal Medical History:

Please check if you know you have any of the following:

( ) Neck problems   ( ) Shoulder problems
( ) Asthma          ( ) Back Problems
( ) Bleeding tendency ( ) Diabetes
( ) Heart problems  ( ) High Blood Pressure
( ) Rheumatoid arthritis ( ) Seizure Disorder
( ) Other - explain below

List any medications currently taking or taken within the last 3 months: ________________

How often do you exercise per week? ____________________________

For how long do you exercise? ____________________________

Specify exercise activities: ____________________________

Physical Screen Checklist

Ht: ______ cm  Wt: ______ kg

Leg length (ASIS to medial malleolus): R: ______ cm  L: ______ cm
Blood Pressure: ____ mm/Hg

Observational gait analysis (no obvious deviations): __

Scoliosis: Y  N

Myofascial pain of lumbar paraspinals and upper trapezius: Y  N

Subject notified of refraining from:

Alcohol: ___
Smoking: ___
Caffeine: ___

Body Composition

Thigh: ________________  Tricep: ________________
Chest: ________________  Suprailium: ________________
Subscapular: ________________  % body fat: ________________

Familiarization

Prep: ___  Isometrics: ___  Treadmill: ___  RPE: ___

NOTES: __________________________________________
_______________________________________________
_______________________________________________
APPENDIX C

Verbatim Instructions

"You have been evaluated to rule out any factors that may complicate this trial.
To begin with, two pairs of electrodes will be placed on your lower back by one of the researchers. In one trial, you will be given an empty backpack to carry on your preferred shoulder. In another trial, you will carry the backpack containing textbooks weighing 10% of your body weight. In yet another trial, you will carry the backpack containing textbooks weighing 20% of your body weight. The order of these trials will be random. Each of the three trials will be 9 minutes long with a rest period of 10 minutes between each trial. At rest, before and after each of these trials, you will lie on your stomach and be asked to tighten your low back muscles by lifting your arms and legs so that a reading of muscle activity can be taken. You will walk a total of 27 minutes and approximately 1½ miles. This is approximately the pace of a 20 minute mile. The treadmill will be started with your feet positioned on the side platforms. When you're comfortable, you may begin walking on the treadmill with both hands on the rails. You can leave your hands on the rail until you are comfortable taking your hands completely off the rail. The trial will begin at this point. You will walk as you normally do with a backpack. You may use your hand on the same side to grip the shoulder strap as necessary."

"EMG data and perceived exertion will be collected 4 times throughout each trial. Heart rate will be recorded every minute. While on the treadmill, please make the researchers aware if you are feeling any pain or discomfort or feel you cannot complete
the walk. A researcher will then stop the treadmill. Thank you for participating. Do you have any questions at this time?”
APPENDIX D

Verbatim Instructions for 15-Graded Borg Scale

“There is a scale in front of you that is numbered from 6 to 20. This scale is used to measure perceived exertion. There are no right or wrong numbers. Use any number you think is appropriate. The scale is a method used to determine the intensity of effort, stress, or discomfort that is felt during exercise. You will need to concentrate on your overall discomfort, stress, and effort as well as that in the muscles of your low back. These are two separate ratings. To get an idea of how to range the sensations you might feel in your back, think of the number 7 as the lowest exertion imaginable and the number 19 as the greatest exertion you can imagine. Try to rate lowest to highest in your mind with regard to the exercise you will be doing today which is to walk on a treadmill with backpack over one shoulder. When we ask you to rate your perceived exertion, you should respond with a number from the scale. Use the expressions next to the numbers to aid you in your selection of a number. Imagine that the numbers 6 through 20 each represent a category of sensation ordered according to intensity. For example, the number 7 should be reported when you feel your definition for category 6 is no longer met and the intensity has grown to the next possible level. Please feel free to ask any questions about what you have just been told.”
## APPENDIX E

**Data Recording Sheet**

**SUBJECT NUMBER:** _______

Confirmed abstinence from smoking, alcohol, caffeine: _____ (please check)

Resting Heart Rate: _____ beats/min  
Blood Pressure: _________ mmHg

Carrying shoulder (circle one): R  L  Dominance: R  L  A

**GAIT CYCLES:** (measured between 4th and 5th minutes of each trial)

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<th>20% BW</th>
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<td>Cycles/min</td>
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**HEART RATE** (beats/minute):

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<td>_______</td>
<td>_______</td>
<td>_______</td>
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<tr>
<td>3 min</td>
<td>_______</td>
<td>_______</td>
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<tr>
<td>4 min</td>
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<tr>
<td>8 min</td>
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<tr>
<td>9 min</td>
<td>_______</td>
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**PERCEIVED EXERTION**: (Overall/low back)

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<td>_______</td>
<td>_______</td>
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<tr>
<td>T2 (3rd min)</td>
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<td>T3 (6th min)</td>
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<tr>
<td>T4 (9th min)</td>
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**FOLLOW-UP**: (24-48 hours following)

Overall: __________________________________________________________

Low Back: _________________________________________________________

Shoulder: _________________________________________________________
APPENDIX F

Figures and Tables of Results Including Outlier

Estimated Marginal Means of CON

Figure G1

Scatterplot: Electromyographic Activity on Contralateral Side.

Estimated Marginal Means of IPS

Figure G2

Scatterplot: Electromyographic Activity on Ipsilateral Side.
Table G1

Effect of Carried Weight (Weight), Time, and Individual (ID) on Integrated Electromyographic Activity on the Contralateral Side (N=24).

Tests of Between-Subjects Effects

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<td>20211.854</td>
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</table>

a. MS(ID)
b. MS(Error)
c. MS(TIME*ID)

Table G2

Effect of Carried Weight (Weight), Time, and Individual (ID) on Integrated Electromyographic Activity on Ipsilateral Side (N=24).

Tests of Between-Subjects Effects

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a. MS(ID)
b. MS(Error)
c. MS(TIME*ID)
APPENDIX G

Tables of Results Excluding Outlier

Table H1

Effect of Carried Weight (Weight) and Time on Integrated Electromyographic Activity on the Contralateral Side (N=23)

Tests of Between-Subjects Effects

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a. MS(ID)
b. MS(WEIGHT * ID)
c. MS(Error)

Table H2

Effect of Carried Weight (Weight), Time, and Individual (ID) on Integrated Electromyographic Activity on the Ipsilateral Side (N=23)

Tests of Between-Subjects Effects

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a. MS(ID)
b. MS(WEIGHT * ID)
c. MS(Error)
Table H3

Pearson Correlation of Overall and Low Back (LB) Ratings of Perceived Exertion (RPE) with Carried Weight (Weight) and Time

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<td>288</td>
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<tr>
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</table>

**. Correlation is significant at the 0.01 level (2-tailed).