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Energy expenditure while back-packing with carriers of different design

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WITH CARRIERS OF DIFFERENT DESIGN

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CHAPTER I

THE PROBLEM AND RELATED LITERATURE

The Problem[1]

Statement of the Problem

The purpose of this study was to compare the energy expenditures of subjects while they were back-packing with three different types of pack carriers which were equally loaded.

Significance of the Study

United States Forest Service personnel frequently have to transport food and supplies within remote mountainous areas. Even though other transportation techniques have been attempted, back-packing is still the only method that can be used for transporting such a load in many of these areas. These packs frequently have to be transported considerable distances which places tremendous work stress upon the individual. Consequently, any new method of pack carrying which might reduce this work stress for a given load would be of considerable value. In this study, the work stress imposed upon subjects by a pack carrier which is now conventionally used was compared to that imposed upon them by two other pack carriers. Energy expenditure and heart rate were used as

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[1]This study was completed under a cooperative agreement between the Montana State University Department of Health, Physical Education, and Athletics and the Missoula Equipment Development Center of the United States Forest Service, Department of Agriculture.

measures of this work stress.

Basic Assumptions

The following assumptions were made for this study.

1. It was assumed that during the experimental work period, the subjects maintained a steady state of metabolism.
2. When calculating energy expenditure, it was assumed that the number of kilocalories used depended only upon the fat metabolism and carbohydrate metabolism.[2]
3. A caloric equivalent of five kilocalories per liter of oxygen consumed was assumed for the purpose of computing the energy expenditure.
4. It was assumed that there were no interacting effects on the subject's energy expenditure due to working under a given experimental condition on a given day.

Definition of Terms

Pack Carrier. A pack carrier is a specially built frame which can be strapped onto an individual's back to enable him to carry objects. The pack load is tied to this frame.

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[2] C. Frank Consolazio, et. al., Physiological Measurements of Metabolic Functions in Man, (New York: McGraw-Hill Book Company, Inc., 1963), p. 11.

Load. In this study, the load was considered to be the weight of the pack carrier plus the weight of the pack.

Pack Load. The weight of the load minus the weight of the pack carrier was used as the pack load.

Energy Expenditure. Energy expenditure was expressed as the number of kilocalories of energy expended by an individual while resting and while working.

Resting Metabolic Rate. The resting metabolic rate was the energy expenditure of the subjects during a rest period taken prior to the beginning of experimental work. Its purpose was to provide a base-line to determine the change in metabolic rate due to pack carrying.

Work Metabolic Rate. The work metabolic rate was the energy expenditure of the subjects during the experimental work period.

Limitations of the Study

1. Each of the ten subjects was observed only once under each experimental condition. The day to day work metabolic rate variances of each subject under a specific experimental condition were not determined. However, the metabolic variability of subjects under the resting condition was determined.
2. Only the energy expenditure and heart rate changes were analyzed for each experimental condition. Of the many physiological adjustments that the body makes to exercise, these are the two most commonly

used to evaluate work stress in studies of this type.

Related Literature

Most of the studies of energy expenditure while back-packing have been done by the Armed Forces. Several studies have been completed in which the energy expenditure of subjects was compared while they carried high back-packs and low back-packs. The findings from these studies have generally shown no significant differences between the energy expenditures of subjects while back-packing with the different load positions. These studies are reviewed in the following paragraphs.

Martorano et. al.[3] compared the energy expenditure of subjects when they carried loads of 30, 50, and 70 pounds on a "Hip-Pack," on a packboard, or in a Haversack. The subjects walked at the rate of 3.5 miles per hour for 30 minutes on a treadmill set at a 1.5 percent grade. The results from these experiments showed that the energy expenditures of the subjects were not significantly different when they carried equal loads on a "Hip-Pack," on a packboard, or in a Haversack.

Daniels et. al.[4] compared the energy costs of subjects while they back-packed loads weighing from 27-76 pounds. The

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[3] J.J. Martorano, et. al., "A Comparison of Energy Expenditure when Carrying Different Weights with 'Hip-Pack' and Conventional Load-Carrying Systems," Bureau of Medicine and Surgery, Navy Department MR005.12-7010.1.15 Naval Medical Field Research Laboratory Volume XIII, No. 7, May, 1963.

[4] F. Daniels Jr., et. al., "Energy Cost of Carrying Three Load Distributions on a Treadmill," Physiology of Load Carrying I, EPB Report No. 203, OQMG, March, 1953.

subjects walked with a pack for 30 minutes at a rate of 3.5 miles per hour on a treadmill. Comparisons were made between energy expenditures from data collected under experimental conditions during which the packs were distributed in three different positions--high on a packboard, low on a packboard, and around the waist in "saddle bags." The high-back load distribution had an estimated center of gravity located about 5 inches posterior to the fourth thoracic vertebrae. The low-back load distribution had a center of gravity estimated to be about 4 inches posterior to the second lumbar vertebrae. The average metabolic rates of subjects while they carried the high pack ranged from 1154 cubic centimeters of oxygen per minute when carrying a load of 31 pounds to 1565 cubic centimeters of oxygen per minute when carrying a load of 76 pounds. The range of average metabolic rates while carrying the low pack was from 1139 cubic centimeters of oxygen per minute while carrying a load of 31 pounds to 1478 cubic centimeters of oxygen per minute while carrying a load of 76 pounds. No significant differences were found between the energy expenditures of subjects when they carried a given load either high or low on the back.

The addition of a load upon an individual's back causes the body to lean forward. This forward lean is called the angle of inclination. Hale _et_. _al_.[5] determined the angle of

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[5] C.J. Hale, _et_. _al_., "Trunk Inclination in Carrying Low and High Packs of Various Weight," _Physiology of Load-Carrying V_, EPB Report No. 216, OQMG, July, 1953.

inclination caused by back-packing loads of 0, 20, 40, 60, and 80 pounds. Each load was carried once high on a packboard and once low on a packboard. There was no significant difference between the angle of trunk inclination when the same load was carried high or low on the packboard. The effect of increase in pack weight on trunk inclination was significantly greater for both the high pack carry and the low pack carry.

The pressure exerted on a person by the straps of a back-pack may cause a great deal of discomfort. Karpovich and Hale[6] studied the differences between strap pressures while carrying loads in high and low positions on a packboard. While walking on a descending grade, the strap pressure exerted by a low-back carry was significantly lower then the strap pressure exerted by a high-back carry. There was no difference between the strap pressures due to the two placements of the load when walking on an ascending grade. Of the five different types of combat packs, the packboard was shown to exert the most strap pressure.

T. Eng-Hauw et. al.[7] measured performance times and energy expenditures of subjects while they were: (1) running 25 yards, (2) executing six consecutive five-foot standing

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[6]P.V. Karpovich and C.J. Hale, "Pressure Exerted by Pack Straps, as Related to Load Carried and Chest Dimensions," Physiology of Load Carrying IV, EPB Report No. 213, OQMG, June, 1953.

[7]T. Eng-Hauw, et. al., "Evaluation of Army Combat Packs by Measuring Energy Costs and Speed of Movement," The Physiology of Load Carrying XIV, EPB Report No. P-71, OQMG, October, 1957.

broad jumps, (3) falling and getting up four times, (4) creeping ten yards, (5) rolling sidewise five times, and (6) ascending 12½ feet. Each of these events were executed while the subjects carried a pack high on the back and then again while they carried a pack low on the back. Neither the performance times nor the energy expenditures of the subjects, while carrying either a high pack or a low pack, were significantly different.

CHAPTER II

PROCEDURE OF THE STUDY

Subjects

Ten students from Montana State University volunteered to be subjects. Prior to the collection of data, steps were taken to assure that each subject was acquainted with the testing equipment and the testing procedures. The physical characteristics of the subjects are shown in Appendix A. Their average age was 18 years, their mean height was 180 centimeters, and their mean weight was 88 kilograms.

Equipment and Apparatus

Pack Carriers

Pack carriers are designed so that an individual can carry a heavy load on his back. The standard procedure has been for the person to carry the weight of the load high upon the back since the pack frame is attached to him by straps going over the shoulders and under the arms. Recently, it has been suggested that the pelvis is better suited to support the load.[1] The pack frames tested in this study included two frames of the standard design and a new type of frame which was designed to place the weight of the load upon the pelvis. The load was 72 pounds, which included the weight

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[1]C.H. Kenerson, "Hip Pack," Director of Marketing, Bell Aerosystems Company, Division of Bell Aerospace Corporation, Buffalo, New York, 1963.

of the pack and the weight of the pack frame.

Pack Carrier I (Figure 1) was the standard pack now used by the Forest Service and the Armed Forces. It was constructed so that the pack load could be tied to the hard fibrous frame (A). This frame was then attached to a man with two web straps (B) which passed over the shoulders and under the arms. The fibrous frame rested on the man via a tight canvas sheet (C) which distributed the load evenly and high on the back over the space between the shoulders.

Pack Carrier II (Figure 2) was similar to Pack Carrier I with two exceptions: (1) it was made of fiber-glass material (A), and (2) the lower attachments of the shoulder straps (B) to the pack frame were slightly higher on the frame. The load was distributed evenly and high on the man's back over the space between the shoulders.

Pack Carrier III (Figure 3) was originally designed to provide supports for a rocket mechanism which enables military men to clear obstacles and obstructions which are too high or too wide to overcome by conventional means. When this carrier was properly worn, the weight of the load was distributed entirely upon the pelvis. This carrier, as shown in Figure 4, could be adjusted to fit the body contour of each individual in terms of shoulder width (A), vertical distance between the shoulders and the pelvic girdle (B), and the pelvic width (C).

Figure 1. Pack Carrier I. A, fibrous frame; B, web straps; C, canvas sheet.

Figure 2. Pack Carrier II. A, fiber-glass frame; B, lower attachments of shoulder straps.

Figure 3. Pack Carrier III.

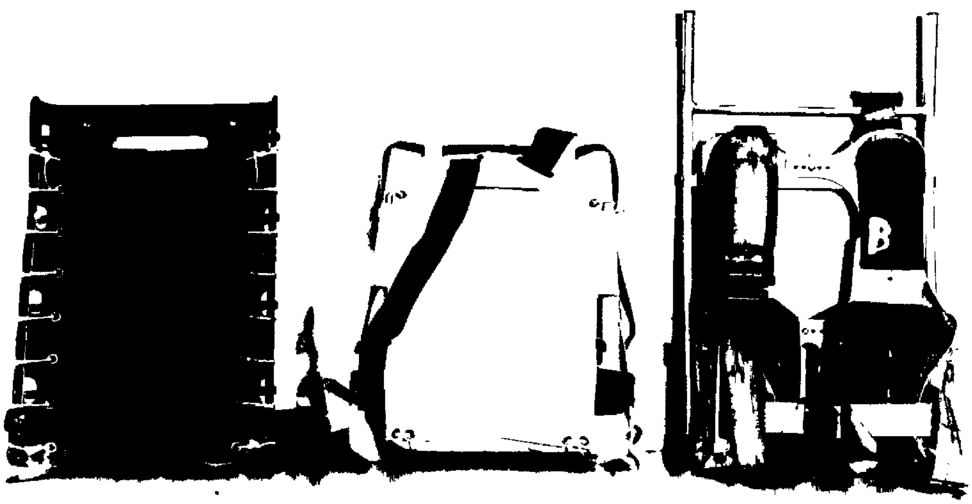

Figure 4. Pack Carrier I, Pack Carrier II, and Pack Carrier III. Adjustments on Carrier III are for: A, shoulder width; B, distance between shoulders and pelvis; C, pelvic width.

Treadmill

The walking surface of the treadmill was a continuous belt eight feet long and three feet wide. It was made of Goodyear wedge grip rubber and revolved on two 8.5 inch end rollers with forty-two 1.9 inch bed rollers between them. The smaller rollers furnished support for the walking surface.

The speed and elevation of the treadmill were manually controlled. The speed was held at a constant rate of three miles per hour. The angle of inclination was set by a hand-cranked winch located at the front of the machine. A dial located on the side of the treadmill indicated the percent of grade.

Air Collection and Sampling Equipment

The gasometer.

A 600 liter chain-compensated gasometer was used to collect the expired air. A three-way manual valve regulated the flow of the air into the gasometer bell. A meter stick attached to the gasometer indicated the height that the gasometer bell rose while the expired air was being collected. The volume of the expired air was obtained by multiplying the number of centimeters the bell rose times a conversion factor which was 5.158 liters per centimeter. Prior to taking a sample, the expired air was mixed by an electric fan located within the gasometer bell. The temperature of the expired air was obtained from a thermometer which was also located within the gasometer bell.

Sampling equipment

The expired air samples were collected over mercury into 125 or 250 milliliter sampling tubes and then labelled. The gas analysis was performed within eight hours after the collection of the sample.

Circuits for collection

The open circuit method for the collection of expired air was used because of its accuracy and adaptability to the problem. The basic equipment used for the collection of expired air is shown in Figure 5. Different circuits were used during the resting period than were used during the working period.

Resting period

During the resting period, the subjects inhaled and exhaled through a mouthpiece (M). Rubber tubing R_1 connected the expiratory circuit (E_1) of the mouthpiece to the three-way manual valve (V_1). From this valve, the expired air was directed into the gasometer (G) via connecting tubing (C_1) and another three-way manual valve (V_2). Nasal breathing was prevented by sealing the nasal passages with a nose-clip (N).

Working period

When walking on the treadmill, the subjects wore a facemask (F). A one-way respiratory valve (RV), attached to the facemask automatically controlled the flow of inspiratory and expiratory air so that the subjects inhaled room air while their expired air was directed toward the gasometer. This valve permitted the subjects to inhale and exhale large volumes of air without appreciable resistance. From the expiratory side (E_2) of the respiratory valve (RV), the expired air was directed into the gasometer (G) via a connecting tubing (R_2), the three-way manual valve (V_1), connecting tubing (C_1), and the three-way manual valve (V_2).

Gas Analysis Equipment

The Scholander method of gas analysis was used to determine the percentages of oxygen and carbon dioxide in the expired air samples. The principle of this method was reported by Scholander.[2]

> A gas sample is introduced into a reaction chamber connected to a micrometer burette and is balanced by means of an indicator drop in a capillary against a compensating chamber. Absorbing fluids for carbon dioxide and oxygen can be tilted into the reaction chamber without causing any change in the total liquid content of the system. During absorption of gas, mercury is delivered into the reaction chamber from the micrometer burette so as to maintain the balance of the gas against the compensating chamber. Volumes are read in terms of micrometer divisions. The rinsing fluids and absorbents are accurately adjusted to have the same vapor tension.

The techniques for gas analysis described by Scholander[3] were used with the exception of the transfer of the air samples from the sampling tube into the analyzer. This was

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[2]P.F. Scholander, "Analyzer for Accurate Estimation of Respiratory Gases in One-Half Cubic Centimeter Samples," _The Journal of Biological Chemistry_, 167:5-7, January, 1947.

[3]_Ibid_.

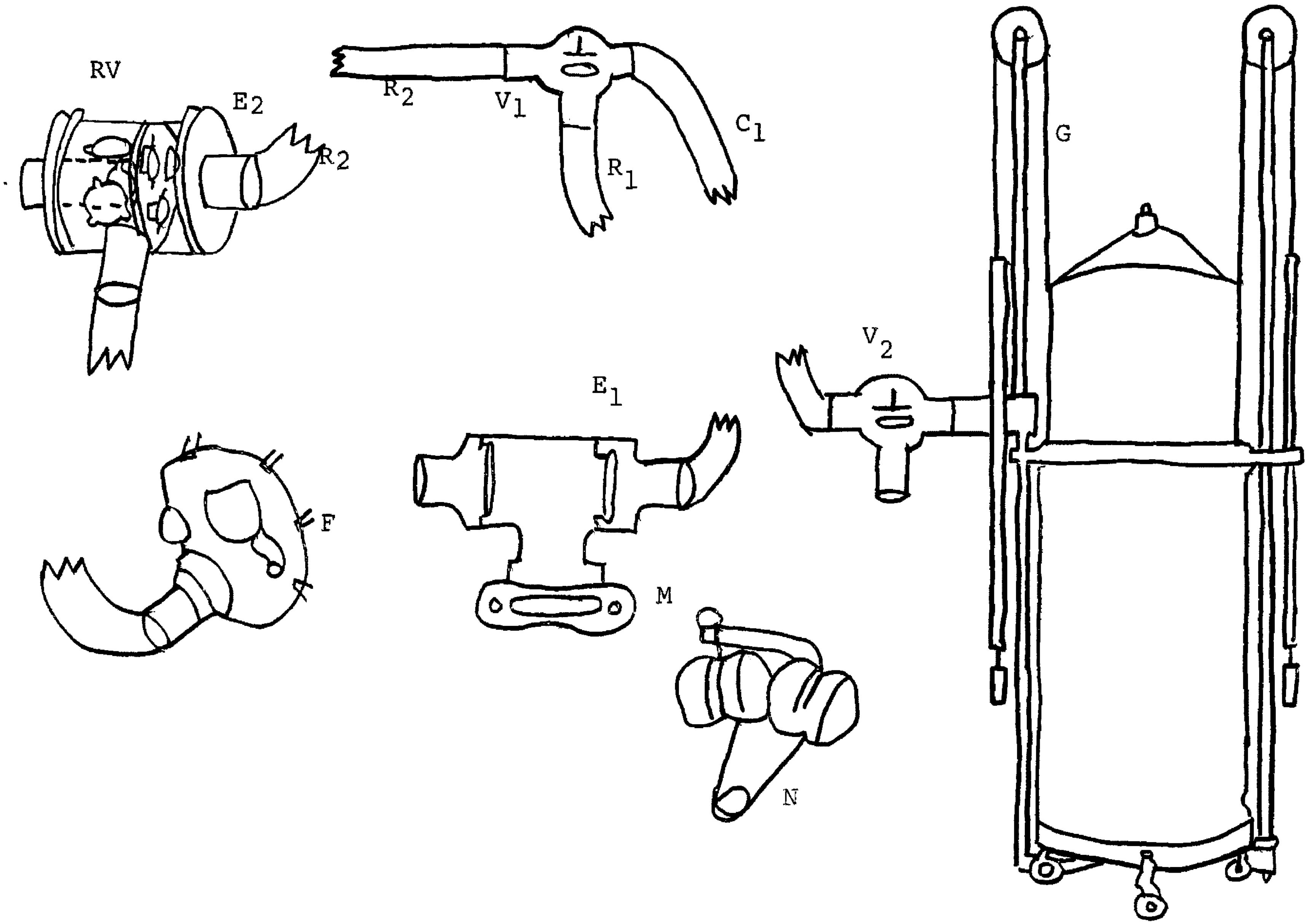

Figure 4. Circuits for Collection of Expired Air. M, mouthpiece; R_1, rubber tubing; E_1, expiratory circuit; V_1, three-way manual valve; G, gasometer; C_1, connecting tubing; V_2, three-way manual valve; N, noseclip; F, facemask; RV, respiratory valve; E_2, expiratory circuit; R_2, connecting tubing.

done by a technique described by Nusbaum.[4] The precautions Scholander described were observed to insure the accuracy of the results.[5] His formulae for computing the percent of carbon dioxide and oxygen in the air sample were followed. These were:[6]

$$\frac{M_1 - M_2}{M_1} = \text{percent of carbon dioxide}$$

$$\frac{M_2 - M_3}{M_1} = \text{percent of oxygen}$$

M_1 = volume of the air sample

M_2 = volume of the air sample after absorption of carbon dioxide

M_3 = volume of the air sample after absorption of carbon dioxide and oxygen

<u>Standards for acceptance</u>

To assure the accuracy of the gas analysis, certain standards were set. The first requirement was that the micrometer burette had to come within plus or minus .005 micrometer divisions of the machine zero at the end of the analysis. Scholander set up this deviation to allow for the elasticity of rubber stoppers in the side arms of the

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[4]Galen Nusbaum, "A Study to Investigate the Energy Expenditure of Subjects While They were Operating Mechanical Trenchers of Different Design," (unpublished Master's thesis, Montana State University, Missoula, 1963), p. 13.

[5]Scholander, *op. cit.* p. 10.

[6]*Ibid.*

analyzer. Variations greater than this would indicate inconsistency of operation. Secondly, the percents of carbon dioxide and oxygen on two successive analyses had to be within plus or minus .05 percent of each other for the analysis to be acceptable.

Computation of Energy Expenditure

Procedure

The formulae used to compute energy expenditure were those provided by Consolazio, Johnson, and Pecora.[7] Energy expenditure was expressed as the number of kilocalories per minute. The procedure for computation is outlined below:

1. The volume of the collected gas was converted to Standard Temperature and Pressure Dry (STPD) by multiplying the measured volume times a correction factor. This factor was based on the temperature of the gas sample and the barometric pressure at the time it was collected. The barometric pressure in millimeters of mercury was recorded from an aneroid barometer located within the laboratory.
2. The percent of nitrogen in the sample was obtained by adding the percent of carbon dioxide and oxygen and then subtracting from 100 percent.

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[7]C. Frank Consolazio, et. al., Physiological Measurements of Metabolic Functions in Man, (New York: McGraw-Hill Book Company, Inc., 1963), p. 9.

3. The true oxygen consumption was next determined. This was computed according to the formula:

   true oxygen = % nitrogen in expired air x 0.265 - % oxygen in expired air

4. The volume of air expired per minute was computed according to the formula:

   $$\dot{V}\ \text{air/min.} = \frac{\text{Volume collected (corrected to STPD)}}{\text{Collection time}}$$

5. The volume of oxygen consumed per minute was determined by the formula:

   $$\dot{V}O_2/\text{min.} = \frac{\text{Vol. exp. air/min.}}{100} \times \text{true oxygen}$$

6. The number of kilocalories used per minute was determined by the formula:

   $$\text{Kcal/min.} = \dot{V}_{O_2}/\text{min.} \times 5$$

Experimental Procedure

Each subject was oriented to the objectives of the study and told of the importance of their cooperation. This orientation was accomplished by providing each subject with a hand-out sheet (Appendix B) which described the experiment and presented certain restrictions which subjects were to observe. After each subject had read the hand-out sheet, a verbal explanation was given to re-emphasize the importance of their cooperation. On the orientation day, it was emphasized that each subject would be required to report to the laboratory for six testing periods when the collection of data began. Prior to the collection of data, each subject was required to participate in two practice trials. During these trials all the procedures of an experimental trial were performed.

A testing period lasted for one hour. Each subject reported to the laboratory for only one testing period in a day. The time of day that each subject reported was the same on each of the six days.

Application of Experimental Conditions

The sequences of grade of walking were determined from a table of randon numbers provided by Dixon and Massey.[8] Even numbers were taken to represent walking on the level while odd numbers were taken to represent walking on the 5 percent grade. The sequence in which the pack carrier was used was determined by: (1) letting the numbers 1,2, and 3 represent Pack Carrier I; (2) letting the numbers 4,5, and 6 represent Pack Carrier II; and (3) letting the numbers 7,8, and 9 represent Pack Carrier III in the table of random numbers. Table I shows the sequential combination for each subject.

[8]W.J. Dixon and F.J. Massey, Jr., Introduction to Statistical Analysis, (New York: McGraw-Hill Book Company, Inc., 1957), p. 366-370.

TABLE I

COMBINED SEQUENCES

Subjects	1st. day	2nd. day	3rd. day	4th. day	5th. day	6th. day
T. Bi.	5&I*	5&II	5&III	0&I	0&II	0&III
D. Du.	5&II	0&I	0&III	0&II	5&I	5&III
R. Ga.	0&I	5&III	5&I	5&II	0&III	0&II
W. Hi.	0&I	0&II	5&II	5&I	0&III	5&III
G. Tr.	5&II	5&I	5&III	0&I	0&III	0&II
J. Li.	0&I	5&I	0&II	5&II	0&III	5&III
D. Mo.	5&II	0&II	0&I	5&I	5&III	0&III
R. Re.	5&I	5&II	0&I	0&II	5&III	0&III
J. Sa.	5&I	0&III	0&II	5&II	5&III	0&I
T. Be.	5&II	0&III	5&I	5&III	0&II	0&I

* 0 = Walking on level   5 = Walking on 5 percent grade
* I = Pack Carrier I   II = Pack Carrier II
III = Pack Carrier III

Conduct of Experimental Trials

The testing period consisted of four phases. Phase I was the period prior to the resting period, Phase II was the resting period, Phase III was the exercise period, and Phase IV was the post-exercise period. The subjects began each testing period with Phase I and ended each testing period with Phase IV.

Phase I. The Pre-Rest Period

1. The subjects filled out a checklist (Appendix C) on which they described their activities during the 24 hours prior to entering the laboratory and the schedule they anticipated following during the

remainder of the day.

2. A series of strength tests were then given.[9] These were completed within ten minutes.

Phase II. The Rest Period

1. After finishing the strength tests, the subjects laid down on a padded table and were connected to the gas collection apparatus. They then rested for a 15 minute period.
2. The gasometer was flushed three times with the subject's expired air prior to the collection of the air sample.
3. An expired air sample was collected from each subject during the last five minutes of this period.
4. The resting heart rates of the subjects were taken. They were recorded when the rate was the same on two successive 15 second readings taken during the last five minutes.

Phase III. The Exercise Period

1. The total weight of the load to be moved by the subject was measured with a balance scale on each testing day. This load included the weight of the facemask as well as the subject's body weight and the weight of the back-pack.

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[9]A study of the strength decrement incurred in selected muscle groups while back-packing was conducted by another investigator using the same subjects at the same time.

2. The treadmill speed was checked and the percent grade was set immediately after the subject had been weighed.
3. After the adjustments on the treadmill were completed, the subjects began a 30 minute walk.
   a. The gasometer was flushed three times as during the resting period.
   b. The expired air sample for the work period was collected in the gasometer from the 15th to the 17th minutes of the 30 minute work period.
   c. The exercise pulse rates of the subjects were taken during the air collection period and were recorded when two successive 15 second readings were the same.
   d. The facemask was removed after the expired air sample had been collected, but the subjects continued walking until the 30 minute period was over.

Phase IV. The Post-Exercise Period

1. After the 30 minute walk, the subjects removed the back-pack and immediately reported for the post-exercise strength tests.

CHAPTER III

ANALYSIS AND DISCUSSION OF RESULTS

Analysis of Results

Treatment of Data

The data which was collected from the subjects while walking on the level is shown in Appendix D, while that collected from the subjects while walking on the 5 percent grade is shown in Appendix E. The metabolic rates are expressed in kilocalories per minute, and the heart rates are expressed in beats per minute. The data for subject T. Be. while walking on the 5 percent grade with Pack Carrier I is not shown because of an error made in measuring the volume of the expired air.

The two measurements which were considered indicative of work stress were net energy expenditure and net heart rate. These were computed according to the following formulae:

1. Net Energy Expenditure = exercise metabolic rate - resting metabolic rate

2. Net Heart Rate = exercise heart rate - resting heart rate

Resting Rates

Resting metabolic rates

The resting metabolic rates of the subjects under all experimental conditions were felt to be within acceptable limits and therefore adequate for use as a base-line for comparative purposes. Consolazio et. al.[1] states that the energy expenditure of the average male while lying quietly is .019 kilocalories per kilogram of body weight per minute. The average resting energy expenditure of the subjects in this study was .021 kilocalories per kilogram of body weight per minute.

The mean resting metabolic rates of subjects under each experimental condition ranged from 1.84 kilocalories per minute to 1.97 kilocalories per minute. The reliability of the resting metabolic rates was checked by using the one-way analysis of variance to test the hypothesis of equal resting mean metabolic rates under each experimental condition (Table II). The differences between resting mean metabolic rates under each experimental condition were not significant. Therefore, it may be concluded that the base-lines established under all experimental conditions were the same.

TABLE II

ANALYSIS OF VARIANCE TABLE FOR RESTING METABOLIC RATES

Source	Sum of Squares	Degrees of Freedom	Mean Squares	F ratio
Means	.101	5	.022	.31
Within	3.785	54	.071	
Total	3.886	59	$F_{.95(5,54)} = 2.40$	

[1]F. Consolazio, et. al., Physiological Measurements of Metabolic Functions in Man, (New York: McGraw-Hill Book Company, Inc., 1963), p. 330.

Resting heart rates

The resting heart rates of the subjects prior to all experimental trials were also found to be within acceptable limits and could therefore be used as a base-line for comparative purposes. The resting heart rate means of the subjects under the six experimental conditions ranged from 64 beats per minute to 67 beats per minute. This average is slightly higher than that given by Karpovich,[2] but it is in agreement with the values given by Morehouse and Miller.[3] The one-way analysis of variance was used to test the hypothesis of equal resting heart rate means under all experimental conditions (Table III. The differences between the mean resting heart rates were not significant. Therefore, the base-lines established for all experimental conditions were concluded to be the same.

TABLE III

ANALYSIS OF VARIANCE TABLE FOR RESTING HEART RATES

Source	Sum of Squares	Degrees of Freedom	Mean Squares	F ratio
Means	250707.1	5	13.46	.251
Within	250774.4	54	53.54	
Total	501481.5	59	$F_{.95(5,54)} = 2.40$	

[2]P.V. Karpovich, Physiology of Muscular Activity (Philadelphia: W.B. Saunders Company, 1959), p. 190.

[3]L.E. Morehouse and A.T. Miller, Physiology of Exercise (St. Louis: C.V. Mosby Company, 1959), p. 110.

Method of Analysis

The date was analysed by the one-way analysis of variance. The hypotheses tested were:

1. There were no differences among net energy expenditure means while back-packing with each pack carrier on the level.
2. There were no differences among net heart rate means while back-packing with each pack carrier on the level.
3. There were no differences among net energy expenditure means while back-packing with each pack carrier on the 5 percent grade.
4. There were no differences among net heart rate means while back-packing with each pack carrier on the 5 percent grade.

It was assumed that the differences between walking on the level and walking on the 5 percent grade were significant, but this significance was of no concern to this study.

Comparison of Pack Carriers

Walking on level

The mean net energy expenditures and the mean net heart rates of the subjects while back-packing with each of the three pack carriers on the level are shown in Table IV. The metabolic rates are expressed in kilocalories per minute, and the heart rates are expressed in beats per minute. No significant

F ratio was shown for the differences between the net metabolic means (Table V). The same procedure was utilized to analyze the net heart rates while back-packing with each of the three pack carriers. The differences between the mean net heart rates were not significant either (Table VI). Therefore it was concluded that the amount of work stress imposed upon the subjects while back-packing on the level was the same while using each pack carrier.

TABLE IV

NET ENERGY EXPENDITURE MEANS AND NET HEART RATE MEANS WHILE WALKING ON THE LEVEL

	Pack Carrier I	Pack Carrier II	Pack Carrier III
MR	6.13	6.18	5.97
HR	46.10	52.20	49.80

TABLE V

ANALYSIS OF VARIANCE TABLE FOR NET METABOLIC RATES WHILE WALKING ON THE LEVEL

Source	Sum of Squares	Degrees of Freedom	Mean Squares	F ratio
Means	.2338	2	.1169	.17
Within	18.5267	27	.6862	
Total	18.7605	29	F .95(2,27) = 3.36	

TABLE VI

ANALYSIS OF VARIANCE TABLE FOR NET HEART RATES WHILE WALKING ON THE LEVEL

Source	Sum of Squares	Degrees of Freedom	Mean Squares	F ratio
Means	188.9	2	94.45	.69
Within	3700.1	27	137.04	
Total	3889.0	29	F .95(2,27) = 3.36	

Walking on 5 percent grade

The mean net energy expenditures and the mean net heart rates of the subjects while back-packing with each of the three pack carriers on the 5 percent grade are shown in Table VII. The metabolic rates are again expressed in kilocalories per minute, and the heart rates are again expressed in beats per minute.

TABLE VII

NET ENERGY EXPENDITURE MEANS AND NET HEART RATE MEANS WHILE WALKING ON THE 5 PERCENT GRADE

	Pack Carrier I	Pack Carrier II	Pack Carrier III
MR	9.40	9.75	9.67
HR	74.90	79.20	77.60

No significant F ratio was shown for the differences between the net metabolic means (Table VIII). The same procedure was utilized to analyze the net heart rates while back-packing with each of the three pack carriers. The differences between the mean net heart rates were not significant either (Table IX). Therefore, it was concluded that the amount of work stress imposed upon the subjects while back-packing on the 5 percent grade was the same while using each pack carrier.

TABLE VIII

ANALYSIS OF VARIANCE TABLE FOR NET METABOLIC RATES WHILE WALKING ON THE 5 PERCENT GRADE

Source	Sum of Squares	Degrees of Freedom	Mean Squares	F ratio
Means	.6116	2	.3058	.20
Within	39.5822	26	1.5224	
Total	40.1938	28	$F_{.95}(2,26) = 3.38$	

TABLE IX

ANALYSIS OF VARIANCE TABLE FOR NET HEART RATES WHILE WALKING ON THE 5 PERCENT GRADE

Source	Sum of Squares	Degrees of Freedom	Mean Squares	F ratio
Means	89.3	2	44.65	.25
Within	4584.9	26	176.30	
Total	4674.2	28	$F_{.95}(2,26) = 3.38$	

Subjective Analysis of Pack Carriers

After each subject had finished his sixth experimental trial, he was asked which pack carrier he preferred. Eight of the ten subjects preferred Pack Carrier III, one subject preferred Pack Carrier II, and one subject preferred either Pack Carrier I or Pack Carrier III. Some of the subjects complained that Pack Carrier II caused their arms and fingers to become numb, This condition of numbness may have been caused by the manner in which the shoulder straps passed over the shoulders. These straps on Pack Carrier II did not pass directly over the shoulders as they did with Pack Carrier I because the lower attachments were anchored higher on the frame of Pack Carrier II than they were on Pack Carrier I.

Discussion of Results

The net energy expenditures of subjects while back-packing with Pack Carrier I, Pack Carrier II and Pack Carrier III were comparable while walking on the level and also while walking on the 5 percent grade. This was also true of the net heart rates of the subjects while back-packing under the same experimental conditions. These results are in agreement with those reported in the previously discussed studies completed by Martorano[4] and his co-workers, and

[4]J.J. Martorano, et. al., "A Comparison of Energy Expenditure when Carrying Different Weights with 'Hip-Pack' and Conventional Load-Carrying Systems," Bureau of Medicine and Surgery, Navy Department MR005.12-7010.1.15 Naval Medical Field Research Laboratory Volume XIII, No. 7, May, 1963.

Daniels[5] and his co-workers.

[5] F. Daniels, Jr., *et. al.*, "Energy Cost of Carrying Three Load Distributions on a Treadmill," *Physiology of Load Carrying I*, EPB Report No. 203, OQMG, March, 1953.

CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The net energy expenditures and the net heart rates of subjects were determined while they were back-packing with three different types of pack carriers. The net rates were considered to be the differences between the resting rates and the exercise rates. The pack carriers were designated as Pack Carrier I, Pack Carrier II, and Pack Carrier III. Pack Carrier I was the standard pack used by the United States Army and the United States Forest Service. Pack Carrier II is similar to it, but is constructed of a fiber-glass material. Pack Carrier III was originally designed as a frame for a rocket mechanism that military men use to lift themselves over obstacles and obstructions which are unsurpassable by conventional means. When Pack Carrier III was properly worn, the weight of the load was distributed upon the pelvis.

Ten male subjects, who were students at Montana State University, were assigned at random to the sequences of grade walking and pack carrier use. Each subject was tested with each pack carrier while walking once on the level and once on a 5 percent grade. Prior to the working period, the resting metabolic rates and the resting heart rates of the subjects were measured during the last five minutes of a 15 minute resting period. The exercise metabolic rates and the exercise heart rates of the subjects were determined from data gathered during the time interval between the fifteenth and the seventeenth minutes of a 30 minute walk on the treadmill. The expired air was collected in a chain-compensated gasometer. Air samples were taken from the gasometer over mercury into 125 or 250 milliliter sampling tubes and later analyzed with a Micro-Scholander Gas Analyzer.

The data collected from the subjects while they walked on the level was treated separately from the data collected while they walked on the 5 percent grade. A one-way analysis of variance test was used to determine whether the net energy expenditure means of the subjects while they back-packed with each pack carrier on a given grade were equal. The same statistical procedure was followed for the comparison of the net heart rate means. The significance level chosen was .05. No significant differences were found.

Conclusions

While walking on the level and while walking on the 5 percent grade, no significant differences were found between the net energy expenditure means of subjects while back-packing with each pack carrier. Also the net heart rate means of subjects while back-packing with each of the pack carriers were not significantly different. The superiority of any of the three pack carriers, with reference to the prevention of work stress, was not shown in this study.

Recommendations

In view of the findings of this study and the problems encountered during its completion, the following recommendations have been made.

1. Further research should be conducted under field conditions. Variations in terrain and weather conditions might affect the experimental results.
2. The number of experimental trials with each pack carrier should be increased in order to obtain a more precise exercise rate.

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APPENDIX

APPENDIX A

PHYSICAL CHARACTERISTICS OF SUBJECTS

Subjects	height in centimeters	weight in kilograms	surface area in square meters	age in years
J. Sa.	182.5	90.3	2.14	18
W. Hi.	177.5	82.1	2.02	19
R. Re.	182.5	89.8	2.14	18
D. Mo.	180.0	83.0	2.06	18
D. Du.	181.3	81.2	2.04	18
J. Li.	176.3	85.3	2.04	19
T. Bi.	182.5	91.2	2.16	18
G. Tr.	177.5	108.4	2.28	19
T. Be.	177.5	81.6	2.02	18
R. Ga.	182.5	90.3	2.14	18
MEANS	180.01	88.32	2.104	18.3

APPENDIX B

INSTRUCTIONS FOR THE SUBJECTS

You are participating in a research project being conducted in cooperation with the United States Forest Service. Three types of pack Carriers are being compared. For two of the pack carriers, the load is distributed high upon the back and for the third pack carrier, the load is distributed upon the pelvis. During the experimental period, you are being requested to carry out the instructions given to you to the best of your ability. Your cooperation is the key to the success of the experiment. Please strive to lead a uniform and ordinary daily activity program during the 24 hours prior to the testing period. The instructions you are being asked to follow are:

1. No food or liquid, except water, should be taken in the three hours prior to the testing period.
2. Your last meal before the test period should be composed of exactly the same menu.
3. Go to bed the night prior to the test, at the same hour designated for all test days.
4. Do not attend a party the night before the test.
5. Do not smoke for at least two hours prior to the test.
6. After you enter the laboratory do the following things:
   a. Fill out the checklist which will be provided.
   b. Weigh yourself.
   c. Report for the strength tests.
   d. After the strength tests, lie down on the padded table for the rest period.
   e. After the rest period, put on the assigned back-pack, weigh yourself with the load, and then begin the 30 minute walk.
   f. After the walk on the treadmill, remove the pack and report for the post-exercise strength tests.

APPENDIX C

CHECKLIST

Date: ________

NAME: Last____________ First____________

1. Hours of sleep last night ___________
   a. State the condition of your sleep: Well( ); Other ( )

2. Number of hours spent in physical work yesterday _______

3. Schedule of last night:
   a. Dance or party ( )
   b. Preparation for an exam. ( )
   c. Homework ( )
   d. Reading ( )
   e. Otherwise disturbed ( )

4. Last meal:
   a. Hour you had your last meal _______
   b. Describe what you ate:
      1.
      2.
      3.
      4.

5. Schedule this morning:
   a. Physical work ( )
   b. Examination ( )
   c. Describe activity the last two hours prior to coming to the laboratory:

6. Schedule after the experiment:
   a. Will you have an examination? ( )
   b. Will you have other worries? ( ) Describe:

7. How do you feel at the present?
   a. Ready for the experiment ( )
   b. Not ready for the experiment ( )
   c. Worried ( )
   d. Feeling pain ( ) Where:

APPENDIX D

RAW DATA FOR WALKING ON THE LEVEL

	Pack Carrier I				Pack Carrier II				Pack Carrier III			
Subjects	RMR*	EMR*	RHR*	EHR*	RMR	EMR	RHR	EMR	RMR	EMR	RHR	EHR
J. Sa.	2.02	7.89	68	112	1.98	8.23	64	108	2.03	8.36	68	112
W. Hi.	2.15	6.52	64	120	1.89	7.25	64	120	1.62	7.06	56	112
R Re.	2.09	7.70	62	96	2.09	8.18	64	124	2.20	7.29	56	112
D Mo.	1.18	7.35	60	92	1.71	6.94	64	100	.97	8.16	58	108
D Du.	2.19	7.62	72	115	2.08	7.50	64	120	2.34	7.90	72	116
J Li.	1.61	7.31	68	100	1.87	7.95	68	108	1.59	7.18	68	112
T. Bi.	2.01	9.99	80	132	1.90	8.68	60	104	1.88	6.74	64	108
G. Tr.	1.93	7.89	72	130	2.02	8.98	72	120	2.03	8.74	76	124
T. Be.	1.85	8.99	60	120	1.82	8.12	56	122	1.73	7.67	60	112
R. Ga.	1.84	8.86	52	112	1.78	9.05	64	136	2.03	9.01	68	128
MEANS	1.89	8.01	65.8	112.9	1.91	8.09	64	116.2	1.84	7.81	64.6	114.4

* RMR = Resting Metabolic Rate in Kcal/min. EMR = Exercise Metabolic Rate in Kcal/min.
* RHR = Resting Heart Rate in beats/min. EHR = Exercise Heart Rate in beats/min.

APPENDIX E

RAW DATA FOR WALKING ON THE 5 PERCENT GRADE

Subjects	Pack Carrier I				Pack Carrier II				Pack Carrier III			
	RMR*	EMR*	RHR*	EHR*	RMR	EMR	RHR	EHR	RMR	EMR	RHR	EHR
J. Sa.	1.91	11.85	72	144	1.99	11.95	68	136	1.90	11.92	72	140
W. Hi.	1.64	10.70	56	136	2.16	11.39	60	124	2.10	10.87	56	132
R. Re.	2.34	10.55	60	124	1.99	11.63	56	140	2.29	11.67	64	140
D. Mo.	1.59	11.55	60	124	1.57	11.29	60	140	1.51	10.45	56	132
D. Du.	2.29	10.74	76	148	1.99	11.11	76	156	1.83	10.53	64	144
J. Li.	1.65	11.12	64	132	1.92	10.97	72	132	1.90	11.27	68	132
T. Bi.	1.83	8.07	72	132	1.98	12.04	72	148	1.68	11.30	68	140
G. Tr.	1.92	13.84	78	164	2.10	11.93	80	176	1.96	13.04	76	164
T. Be.					1.74	10.86	56	136	1.54	10.51	60	132
R. Ga.	1.91	13.30	56	164	2.27	14.04	68	172	1.91	13.78	56	160
MEANS	1.90	11.30	66	140.9	1.97	11.72	67	146.0	1.86	11.53	64	141.6

* RMR = Resting Metabolic Rate in Kcal/min. EMR = Exercise Metabolic Rate in Kcal/min.
* RHR = Resting Heart Rate in beats/min. EHR = Exercise Heart Rate in beats/min.