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# A study to investigate the strength decrement of selected muscle groups during treadmill walking at different grade levels while back-packing a prescribed load

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# A STUDY TO INVESTIGATE THE STRENGTH DECREMENT OF SELECTED MUSCLE GROUPS DURING TREADMILL WALKING AT DIFFERENT GRADE LEVELS WHILE BACK-PACKING A PRESCRIBED LOAD

by

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# CHAPTER I

# THE PROBLEM AND RELATED LITERATURE[1]

## THE PROBLEM

### Statement of the Problem

The purpose of this study was to investigate the strength decrement of selected muscle groups during treadmill walking at different slopes while back-packing a prescribed load.

### Significance of the Study

Despite modern mechanical advances, back-packing is still an important method used by the United States Forest Service Personnel to transport equipment in wilderness areas. Objective evaluation of back-packing should help the equipment designer develop equipment modifications which not only ease the worker's burden but also lead to increased efficiency.

It is realized that field conditions cannot be duplicated in the laboratory. However, since certain factors which would normally vary,

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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.

can be held constant under laboratory conditions, much useful information can be gained in this manner.

This study seeks to analyze back-packing under variations of grade. It is hoped that the knowledge gained herein will give better insight into the functioning of specific muscle groups while back-packing, and that this knowledge may later be made applicable to field conditions.

## Basic Assumptions

The assumption was made that muscles under physical stress may weaken, and this serves as an index of the fatigue. Clarke demonstrated the validity of this assumption in another study.[1] Subjects exercised their elbow flexor muscles on an ergograph with a load resistance equal to three-eighths of the elbow flexor strength. The mean loss in strength was approximately thirty-two percent after cessation of exercise, and strength recovery was not complete three-fourths of an hour later.

## Definitions

Strength Decrement- the difference in strength of a given muscle group before exercise and after exercise.

Strength Decrement Index- the proportion of pre-exercise strength lost during physical exertion.[2]

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[1]H. Harrison Clarke, "Strength Decrement Effects of Exhaustive Efforts of the Elbow Flexor Muscles," Archives of Physical Medicine and Rehabilitation, 35:560, September, 1954.

[2]H. Harrison Clarke and David H. Clarke, Developmental and Adapted Physical Education (Englewood Cliffs, N. J. : Prentice Hall, Inc., 1963), pp. 79-96.

$$SDI = \frac{Si - Sf}{Si} \times 100$$

Si = initial strength, taken before exercise.

Sf = final strength, taken after exercise.

SDI = Strength Decrement Index.

Knee Extension: a movement occurring at the knee joint where the angle between the anterior aspect of the thigh and the anterior aspect of the leg becomes larger.

Knee Flexion: a movement occuring at the knee joint where the angle between the anterior aspect of the thigh and anterior aspect of the leg becomes smaller.

Hip Flexion: a movement occurring at the hip joint where the angle between the anterior aspect of the thigh and the anterior aspect of the trunk becomes smaller.

Hip Extension: a movement occurring at the hip joint where the angle between the anterior aspect of the thigh and the anterior aspect of the trunk becomes larger.

Trunk Extension: a movement at the vertebral column that results in an increase in the angulation in the aspects of this column. This movement bends the trunk posteriorly.

Trunk Flexion: a movement at the vertebral column that results in a decrease in the angulation in the anterior aspect of this column. It involves bending the trunk anteriorly.

Shoulder Flexion: a decrease in the angle between the anterior aspect of the humerus and an imaginary coronal (frontal) plane extending through this joint. This involves an upward and forward movement of

the humerus from the anatomical position.

Percent Grade: the tangent of the angle of inclination at which the treadmill was run during test marches.

Back-pack: a standard pack used by the United States Forest Service. For the purposes of this study, the pack was loaded to a weight of sixty-two pounds with regularly carried equipment.

## Limitations of the Study

The following factors must be taken into consideration in the application of the conclusions of this study.

1. The number of subjects was restricted to ten male students enrolled in physical education service courses at Montana State University during the spring quarter, 1963.
2. Variables not taken into consideration in this study were age, weight, and height.
3. Gravitational pull was not considered when the lower extremities were tested for strength.
4. Although there are many muscle groups involved in supporting a back-pack while walking, the knee extensors, knee flexors, hip extensors, hip flexors, trunk extensors, trunk flexors, and the shoulder flexors were the only muscle groups tested for strength decrement since these were the ones which showed statistically

significant decrements in Clarke's[1] work.

5. The preceding seven muscle groups were tested on only the right side of the body. Martin's[2] study, which agrees with Kellogg's, indicated that both sides of the body may be assumed to be equally strong.

## Review of Related Literature

Clarke[3] studied strength decrement and strength decrement indices of muscles involved in carrying various packs on military marches of seven and one-half miles. Thirty Springfield College male students majoring in physical education carried the Quartermaster experimental pack, the combat pack, and the rucksack on their backs at different positions and with varying weight. Each march was made over moderately rough terrain at the rate of two and one-half miles every fifty minutes. Muscle groups tested were those which were felt to be under direct stress in supporting the packs, those involved in stabilizing the body in relation to the pack, those primarily activated in marching, and those affected by interference with circulation due to pressure from pack straps. The muscle groups showing greatest strength losses for the nine marches in the two series were: trunk extensors in eight marches, hip extensors in seven marches, and knee flexors in six

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[1]H. Harrison Clarke, "Strength Decrements from Carrying Various Army Packs on Military Marches," Research Quarterly, 26:257, October, 1955.

[2]E. G. Martin, "Muscular Strength and Muscular Symmetry in Human Beings," The American Journal of Physiology, May, 1918, p. 70.

[3]Clarke, loc. cit., pp. 253-265.

marches. The ankle plantar flexors were only tested in the first six marches, but they showed significant strength decrement in all six. The trunk flexors and the hip flexors showed strength losses in five marches while the shoulder elevators and knee extensors showed strength loss in only four marches. The Quartermaster experimental pack caused the least amount of decrement, followed by the combat pack and the rucksack. The physical condition of the subjects improved considerably as a result of repeated pack carrying marches.

Winbigler[1] studied the strength decrement of fourteen muscle groups. These were the trunk flexors, trunk extensors, hip flexors, hip extensors, hip abductors, hip adductors, hip inward rotators, hip outward rotators, knee flexors, knee extensors, ankle dorsi flexors, ankle plantar flexors, ankle inverters, and ankle everters. Seventeen University of Oregon male students selected from non-professional physical education classes were tested twice for muscle strength. The first test was given after a one minute warm-up run, and the second was given one minute after they had run on the treadmill for ten minutes at a speed of seven miles per hour. The treadmill was set at zero grade (flat). Although these conditions were sub-maximal, it allowed the subjects to finish the run in what the author termed "a

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[1]Thomas Duane Winbigler, "Strength Decrement Effects on the Muscles of the Trunk and Lower Extremities from Sub-Maximal Treadmill Running," (microcarded Masters thesis, University of Oregon, Eugene, 1956), pp. 1-31.

relatively high state of fatigue."[1] Only the hip outward rotators and the trunk flexors showed a significant strength decrement.

Clarke[2] conducted a study showing strength decrement on the muscles of the lower leg and ankle resulting from wearing the following types of Army footwear: combat boot, rubber insulated boot, and the quarter cut shoe. Twenty-nine Springfield College students majoring in physical education acted as subjects, each completing three marches wearing a different boot or shoe on every march. A combat pack weighing forty-one pounds was carried on every march. The actual marching distance was seven and one-half miles over moderately rough terrain at a rate of two and one-half miles in fifty minutes with a ten minute stop at the end of each two and one-half miles permitting time to test for strength. Military marches with the combat boot resulted in the least decrement; the rubber insulated boots were next best; and the strength decrement was the greatest with the quarter cut shoe. The ankle everters were the muscle groups most affected by strength decrement in the three marches. These were followed by the ankle plantar flexors, the ankle inverters, and the ankle dorsi flexors.

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[1] Ibid., p. 24.

[2] H. Harrison Clarke, "Strength Decrements from Wearing Various Army Boots and Shoes on Military Marches," Research Quarterly, 26:266-273, October, 1955.

# CHAPTER II

# PROCEDURES

## Strength Decrement Index

The strength decrement effect of pack carrying while walking on a treadmill was calculated from the strength losses of seven selected muscle groups. Clarke[1] showed that when a muscle group is exercised against resistance, it loses its ability to apply tension. He called this loss strength decrement. The Strength Decrement Index (SDI) is calculated by the formula given below.

$$SDI = \frac{Si - Sf}{Si} \times 100$$

Si = initial strength, taken before exercise.

Sf = final strength, taken after exercise.

SDI = Strength Decrement Index.

## Strength Testing

### Selection of the Strength Testing Equipment

Hunsicker and Donnelly[2] gave an historical picture of the

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[1]H. Harrison Clarke, "Strength Decrement of the Elbow Flexor Muscles Following Exhaustive Exercise," Archives of Physical Medicine and Rehabilitation, September, 1954, p. 560.

[2]Paul A. Hunsicker, Richard J. Donnelly, "Instruments to Measure Strength," Research Quarterly, December, 1955, pp. 408-419.

development of various instruments used to measure human strength during the past two hundred and fifty years and the principles of operation upon which their designs were based. The dynamometer, especially the spring steel type, has been the principal instrument utilized for strength testing. The spring steel, mercurial, and pneumatic dynamometers together with the cable tensiometer were designed to measure a single maximum effort. The ergograph and the electrical strain gauge dynamometers were developed with the idea of securing a series of muscular efforts or for making a total record of the force from the initial movement through the drop-off.

Clarke[1] made a comparison of instruments for recording muscle strength. The four instruments he compared were the cable-tensiometer, the Wakim-Porter strain gauge, the spring scale, and the Newman myometer. The evaluation of the instruments' objectivity was based upon the correlation between the results obtained by different testers. Reliability of each instrument was determined by the amount of correlation between the results recorded by the instrument on repetitions of the same tests.

The results of the study showed that the precision of the cable-tensiometer was consistently higher than it was for the other instruments. The objectivity coefficients for the tests obtained with the tensiometer varied between .90 and .95. The Wakim-Porter strain gauge had satisfactory objectivity coefficients and was generally

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[1]H. Harrison Clarke, "Comparison of Instruments for Recording Muscle Strength," Research Quarterly, December, 1954, pp. 398-411.

superior to the cable-tensiometer in the amount of strength recorded, but the results were inconsistent.

The spring scale was significantly inferior to both the cable-tensiometer and the Wakim-Porter strain gauge in the amount of strength recorded.

The Newman myometer was limited to strength efforts not exceeding sixty pounds and resulted in extremely low objectivity coefficients.

Since the cable-tensiometer had been shown to be the most suitable instrument for strength testing, it was selected for this study. Clarke's[1] methods of testing the strength of the selected muscle groups were followed.

## Equipment Used for Cable-Tension Strength Testing

Clarke[2] prescribed the following testing equipment to be used in conjunction with the cable-tensiometer.

The Testing Table. The testing table was seventy-eight inches long. A slit twenty inches long and seven inches wide was cut lengthwise in the center of the table top, ten inches from one end.

Hooks. Open eyed hooks were screwed into the table at designated places for the attachment of the pulling assemblies. These

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[1]H. Harrison Clarke and David H. Clarke, Developmental and Adapted Physical Education (Englewood Cliffs, N. J. : Prentice Hall, Inc., 1963), pp. 79-96.

[2]H. Harrison Clarke, Cable-Tension Strength Tests (Springfield: Stuart E. Murphy, 1953), pp. 2-6.

hooks were strong enough to withstand the tension applied by all of the subjects.

Pulling Assemblies. The pulling devices included a strap, a cable, and a linked chain. The regulation strap was two inches wide but varied in length according to the muscle group being tested. The trunk strap consisted of two pieces of belting; five inches by thirty inches and two inches by thirty inches. A three-thirty-second inch, flexible cable was attached to a small linked chain. Chains of different lengths were needed for testing each of the muscle groups.

Goniometer. This instrument consists of a one hundred and eighty degree protractor made of plexiglass with two eighteen inch arms. One of these arms is stationary and extends along the zero line while the other is movable permitting rotation to the proper angle.[1] This instrument was used for measuring the correct angles needed in the knee flexion and knee extension strength tests.

## Description of the Strength Tests

The methods used to find the strength decrement of the seven muscle groups were those described by Clarke.[2] For a description of the exact testing procedures refer to Appendix A.

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[1]H. Harrison Clarke, "Objective Strength Tests of Affected Muscle Groups Involved in Orthopedic Disabilities," Research Quarterly, May, 1948, p. 125.

[2]H. Harrison Clarke and David H. Clarke, op. cit., pp. 79-96.

### Training of Tester

The tester was carefully trained in cable-tensiometer testing methods before the data was collected. The procedure included: (a) the tester testing and retesting a group of selected subjects using only the seven specific muscle groups until a high consistency of testing was reached; and (b) the tester testing and retesting the muscle groups in samples of ten subjects until they reached objectivity coefficients approaching .86 to .98. These objectivity coefficients are within the limits described by Clarke.[1]

## SELECTION OF MUSCLE GROUPS TESTED

Muscle groups were selected for testing after examining Clarke's study on strength decrements from carrying Army packs. Several characteristics were representative of the muscle groups he had selected for that study.

> The muscle groups tested were those considered to be:
> (a) under direct stress in supporting the packs,
> (b) involved in stabilizing the rest of the body in relation to the pack,
> (c) primarily activated in marching, and
> (d) affected by interference with circulation caused by pressure from the pack straps.[2]

Of the eleven groups he selected on the basis of this criteria, only eight groups yielded statistically significant decrements during the

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[1]H. Harrison Clarke, "Strength Decrements from Carrying Various Army Packs on Military Marches," Research Quarterly, 26:257, October, 1955.

[2]H. Harrison Clarke, "Objective Strength Tests of Affected Muscle Groups Involved in Orthopedic Disabilities," Research Quarterly, May, 1948, pp. 255-256.

marches. These were the shoulder elevators, the trunk flexors, the trunk extensors, the hip flexors, the hip extensors, the knee flexors, the knee extensors, and the ankle plantar flexors. In this study, the ankle plantar flexors could not be measured because the tensiometer was not adequate to measure the tension applied by the subjects.

The seven muscle groups were tested on the right side of the subject's body. Martin confirmed that for children there is very little strength difference between the right and left sides of the body, and the percentage differences between the two sides are neither great enough nor constant enough to invalidate the assumption that both sides of the body are equally strong.[1] Kellogg[2] found the same to be true for adults.

## Description of the Treadmill

The treadmill was made of aluminum. It weighed one thousand pounds, and its dimensions were 48" wide, 108" long, and 28" high. The tread was made of Good-Year Wedge Grip rubber. The walking surface was eight feet long and three feet wide. The belt revolved on two $8\frac{1}{2}$" end rollers with forty-two 1.9 inch bed rollers between them.

A 220 volt electrical system drove a two horse motor at speeds which could be varied from one and one-half to ten miles per hour.

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[1]E. G. Martin, "Muscular Strength and Muscular Symmetry in Human Beings," The American Journal of Physiology, May, 1918, p. 70.

[2]Ibid., pp. 69-70.

The grade was set by using a mechanical chain driven crank located at one end. Any grade up to fifty-one percent could be set by reading the grade indicator mounted on one side.

## Selection of Speed Grade

Erickson[1] found that subjects attained maximum net efficiency while walking on a motor driven treadmill at three or three and one-half miles per hour, varying according to the individual. Because of these findings a walking speed of three miles per hour was selected.

Pilot tests were run to determine appropriate treadmill grades. The ten percent grade seemed close to maximum for the subjects at the speed and for the time it was desired to have them walk. At a grade greater than ten percent some subjects would not have finished the test.

## Description of the Pack

The pack-board used in this study was the standard pack used by the United States Forest Service. It consisted of a plywood frame and a canvas covering. The contents of this pack included: one sleeping bag, two cans of fruit juice, one shovel, four cans of soup, four accessory packs, one can of tuna, two boxes of raisins, one axe, one tarp, twelve cans of mixed fruit, one flashlight, one first-aid kit, four flashlight batteries, one file, and one canteen, weighing the total of sixty-two pounds.

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[1]Lester Erickson, "The Energy Cost of Horizontal and Grade Walking on the Motor Driven Treadmill," American Journal of Physiology, January, 1946, p. 395.

## Selection of the Subjects

Data was collected on ten volunteer non-disabled male students who were enrolled in non-professional physical education classes at Montana State University. The ten subjects were between eighteen and twenty years of age; seventy to seventy-four inches in height and weighed between one hundred and fifty-five to two hundred and forty pounds.

## Daily Testing Procedures

Three subjects were tested every afternoon at a specified time covering a period of three weeks.

Prior to each experimental period the following precautions were taken to be sure all equipment was functioning properly.

1. The speed of the treadmill was checked.
2. The angle of the treadmill was set. Angles varied from day to day and from subject to subject.
3. The back-pack was re-weighed and checked for structural deficiencies.
4. The condition of all testing apparatus was checked; tensiometer, chains, hooks, straps, goniometer.
5. Individual recording sheets were made ready. These were determined in advance because the testing sequence of each subject was based on a Latin-square distribution.

On the designated day and time, the subject came to the laboratory where he received his pre-test. Each subject was given a one minute time allotment to ready himself for the experimental walk. He

would mount the treadmill, walk thirty minutes at three miles per hour at a specified grade. At the end of the thirty minute walk, the subject would dismount the treadmill. He was then given one minute to ready himself for the post-test.

Both the pre-test and the post-test took between three and five minutes to administer. In each test the subjects were given one attempt to reach their maximum strength in all seven muscle groups. Each subject applied force gradually until maximum power was reached.

In order to reduce the actual testing time and to make the testing process as efficient as possible, the seven muscle groups were tested in this order; knee extensor, knee flexor, hip flexor, hip extensor, trunk extensor, trunk flexor, and shoulder flexor.

The ten subjects wore the same apparel which included gym trunks, gym shoes, and sweat shirt. With this type of clothing the tester was better able to place the strap in its correct position. Gym shoes aided in traction and were convenient for testing purposes.

In the study on strength decrement from marching with Army packs, Clarke[1] found a conditioning effect set in as the subjects made repeated experimental marches. This effect was negated in this study by assigning the subjects to experimental trials according to a Latin-square distribution.

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[1]H. Harrison Clarke, "Strength Decrement from Carrying Various Army Packs on Military Marches," Research Quarterly, 26:259, October, 1955.

| Subjects | First Day | Second Day | Third Day |
|---|---|---|---|
| M. A. | A | B | C |
| J. D. | B | C | A |
| B. L. | C | A | B |
| F. J. | A | B | C |
| M. K. | B | C | A |
| M. W. R. | C | A | B |
| M. A. R. | A | B | C |
| V. R. | B | C | A |
| R. S. | C | A | B |
| G. T. | A | B | C |

Figure 1. Latin-square distribution showing the sequence of experimental tests for each subject. Condition A is level grade, condition B is 5% grade, and condition C is 10% grade.

## Method of Analysis of Data

The raw data was placed on individual data sheets and the strength, strength decrement, and Strength Decrement Index computed. This data was later transferred to cumulative data sheets for ease in making the final analysis of results.

## Steps in Statistical Procedures

1. The statistical significance of the strength decrement for each muscle group at each grade was calculated using the Wilcoxon T-Test.
2. The Friedman Two-Way Analysis of Variance Test was then used to determine whether significance existed between grades.
3. If there were significant differences between grades, the Wilcoxon T-Test was used again to find the points of significance.
4. The Strength Decrement Index was computed for each individual. The Friedman Test was then used to find if there were significant differences for the sum of Strength Decrement Index for all muscle groups while walking on the level and walking at each grade.

# CHAPTER III

# ANALYSIS OF DATA

## Introduction

The statistical tests described in Chapter II were used to analyze the data. First, the strength differences between the pre-test and the post-test were tested to determine whether or not they were statistically significant. Next, it was determined whether strength decrement differences between level walking and grade walking were significant, and if they were, where the points of significance were to be found. Lastly, the differences between Strength Decrement Index while walking on the level and walking at each grade were analyzed.

## Results of Strength Decrement

Table I shows the range, median, and mean values of strength decrement for each muscle group resulting during all experimental conditions. The strength decrement for each subject, at each condition from which this table is summarized, is found in Table V of Appendix B. There was no decrement shown in four instances. In one subject, there was a six pount increment for shoulder flexion. Depite this increment, a decrement which was shown to be significant at the .005 level of confidence was found for the group as a whole.

Clarke[1] in a study of strength decrement during marching while wearing different types of footwear, found a characteristic and significant increment in the ankle dorsi flexors. No overall increment of this type was found in the data presented here. This lone incident was apparently within the normal variability of the test.

The Wilcoxon T-Test was used to determine the significance of the difference between pre-test and post-test strength. A one-tailed test was used since the expected effect was a decrease in strength. All decrements were found to be significant at the .005 level of confidence. These findings support those of Clarke[2] in his study of pack-carrying. His study showed that after nine different marches the shoulder elevators, the trunk flexors, the trunk extensors, the hip flexors, the hip extensors, the knee flexors, the knee extensors, and the ankle plantar flexors all had statistically significant strength decrement at one time or another.

In Winbigler's[3] study of strength decrement during sub-maximal

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[1]H. Harrison Clarke, "Strength Decrements from Wearing Various Army Boots and Shoes on Military Marches," Research Quarterly, 26: 266-276, October, 1955.

[2]H. Harrison Clarke, "Strength Decrements from Carrying Various Army Packs on Military Marches," Research Quarterly, 26:258-259, October, 1955.

[3]Thomas Duane Winbigler, "Strength Decrement Effects on the Muscles of the Trunk and Lower Extremities from Sub-Maximal Treadmill Running," (microcarded Masters thesis, University of Oregon, Eugene, 1950), p. 30.

TABLE I

STRENGTH DECREMENT VALUES UNDER
ALL EXPERIMENTAL CONDITIONS

| Muscle Group | Condition | Range | Median | Mean |
|---|---|---|---|---|
| Knee Extensors | A | 0.0 - 56.7 | 13.35 | 16.3 |
| | B | 11.6 - 63.3 | 26.60 | 30.3 |
| | C | 15.0 - 40.0 | 26.70 | 26.0 |
| Knee Flexors | A | 10.0 - 40.0 | 16.60 | 18.7 |
| | B | 6.7 - 36.7 | 20.00 | 19.3 |
| | C | 10.0 - 36.7 | 18.35 | 21.0 |
| Hip Flexors | A | 3.3 - 43.3 | 13.23 | 18.3 |
| | B | 5.0 - 43.3 | 13.23 | 19.7 |
| | C | 10.0 - 53.4 | 15.00 | 22.7 |
| Hip Extensors | A | 3.4 - 46.6 | 14.15 | 19.2 |
| | B | 6.7 - 33.3 | 16.65 | 17.0 |
| | C | 6.6 - 26.7 | 19.95 | 17.7 |
| Trunk Extensors | A | 6.7 - 43.4 | 20.50 | 21.0 |
| | B | 0.0 - 46.7 | 15.00 | 21.5 |
| | C | 13.3 - 50.0 | 19.25 | 23.7 |
| Trunk Flexors | A | 6.6 - 50.0 | 16.70 | 20.0 |
| | B | 6.7 - 40.0 | 25.05 | 25.2 |
| | C | 13.3 - 40.0 | 23.30 | 24.7 |
| Shoulder Flexors | A | 0.0 - 30.0 | 10.00 | 12.0 |
| | B | -6.7 - 30.0 | 15.00 | 15.0 |
| | C | 13.3 - 26.7 | 18.40 | 18.9 |

In this figure Condition A = level grade; Condition B = 5% grade; Condition C = 10% grade.

treadmill running, only the hip outward rotators and the trunk flexors showed a strength decrement statistically significant beyond the .01 level of confidence. The hip outward rotators were not tested in the present study, but the findings for the trunk flexors agree with those of Winbigler.

## Strength Decrements at Different Grades

Since the strength decrements of the seven muscle groups were statistically significant at all grade levels, the Friedman Two-Way Analysis of Variance Test $\chi_r^2$ was then used to determine whether or not there were significant differences between the strength decrements when the subjects walked at the different grade levels.

The $\chi_r^2$ values are given in Table II. The .05 level of confidence was selected as the point for rejection of the Null Hypothesis.

The knee extensors and the shoulder flexors were the only muscle groups that showed statistical significance. Although, there was a statistically significant decrement in every muscle group at every level, the differences between the decrements at every level were significant in only two instances. Apparently increasing the grade level did not generally cause a corresponding increase in strength decrement with possibly the exception of the knee extensors and the shoulder flexors.

TABLE II

SIGNIFICANCE OF THE DIFFERENCE
BETWEEN STRENGTH DECREMENTS
AT ALL GRADE LEVELS

| Muscle Groups | |
|---|---|
| Knee Extensors | 8.75* |
| Knee Flexors | .95 |
| Hip Flexors | 4.20 |
| Hip Extensors | .05 |
| Trunk Extensors | 1.40 |
| Trunk Flexors | 2.40 |
| Shoulder Flexors | 8.15* |

*These values were statistically significant beyond the .02 level.

Both muscle groups showed a significant difference in strength decrement at or above the .02 level of confidence between level walking and each grade but not between the grades themselves.

The findings in Table III suggest that the increase in strength decrement seems to come more from the transition from level walking to grade walking than from grade to grade. Again, no corresponding increase in strength decrement was shown with an increase in grade.

TABLE III

WILCOXON T-TEST VALUES BETWEEN
DECREMENTS AT EACH GRADE LEVEL

| Muscle Groups | Condition $A^1$-B | Condition A - $C^3$ | Condition $B^2$ - C |
|---|---|---|---|
| Knee Extensors | 1.00** | 8.00* | 19.5 |
| Shoulder Flexors | 8.00* | 4.00*** | 10.5 |

*This figure represents significance at the .05 level of confidence.
**This figure represents significance at the .01 level of confidence.
***This figure represents significance at the .02 level of confidence.
$A^1$ = level walking
$B^2$ = 5% grade
$C^3$ = 10% grade

TABLE IV

TOTAL STRENGTH DECREMENT INDEX

| Subjects | Cond.[1] | K.E.[2] | K.F.[3] | H.F.[4] | H.E.[5] | T.E.[6] | T.F.[7] | S.F.[8] | Total S.D.I.[9] |
|---|---|---|---|---|---|---|---|---|---|
| | A | 4.76 | 23.5 | 12.7 | 7.7 | 20.5 | 22.7 | 7.5 | 99.36 |
| M.A. | B | 9.40 | 17.3 | 11.8 | 3.5 | 4.4 | 17.9 | 11.1 | 75.40 |
| | C | 12.90 | 1.2 | 16.7 | 7.1 | 1.3 | 12.7 | 8.8 | 60.70 |
| | A | 1.40 | 8.3 | 1.8 | 16.0 | 20.1 | 16.3 | 4.1 | 68.00 |
| J.D. | B | 9.10 | 17.1 | 4.1 | 14.2 | 26.9 | 21.7 | 11.8 | 104.70 |
| | C | 14.10 | 26.2 | 5.3 | 12.0 | 22.8 | 20.9 | 9.3 | 110.60 |
| | A | 8.10 | 14.2 | 15.1 | 18.9 | 20.7 | 2.7 | 7.3 | 87.00 |
| B.L. | B | 16.50 | 4.1 | 3.9 | 8.0 | 2.1 | 13.9 | 8.8 | 57.30 |
| | C | 8.10 | 8.3 | 7.6 | 10.4 | 8.3 | 15.4 | 7.1 | 65.20 |
| | A | 17.70 | 19.0 | 15.2 | 3.9 | 15.2 | 23.1 | 10.6 | 104.70 |
| F.J. | B | 28.30 | 1.9 | 18.7 | 4.7 | 28.2 | 6.5 | 12.7 | 101.00 |
| | C | 13.90 | 16.7 | 6.9 | 4.1 | 10.2 | 8.1 | 13.8 | 73.70 |
| | A | 13.40 | 10.0 | 3.3 | 3.4 | 16.6 | 13.4 | 6.7 | 39.30 |
| M.K. | B | 4.00 | 14.0 | 4.1 | 13.8 | 4.4 | 14.7 | 8.3 | 63.30 |
| | C | 12.80 | 21.0 | 6.0 | 10.0 | 26.2 | 27.2 | 9.0 | 112.20 |
| | A | 5.10 | 13.9 | 3.5 | 3.7 | 7.2 | 8.8 | 3.7 | 45.90 |
| M.W.R. | B | 7.20 | 15.6 | 2.5 | 7.3 | 6.8 | 11.2 | 4.0 | 54.60 |
| | C | 6.20 | 5.3 | 5.8 | 12.5 | 14.4 | 17.1 | 9.3 | 70.60 |
| | A | 4.40 | 14.6 | 3.7 | 22.8 | 15.2 | 8.3 | 4.8 | 73.80 |
| M.A.R. | B | 7.30 | 14.6 | 5.8 | 10.5 | 26.2 | 16.7 | 4.5 | 85.60 |
| | C | 5.50 | 7.0 | 6.0 | 4.9 | 34.9 | 8.4 | 9.0 | 75.70 |
| | A | 0.00 | 11.1 | 12.5 | 10.0 | 12.0 | 12.7 | 5.9 | 64.20 |
| V.R. | B | 12.00 | 31.5 | 19.3 | 19.0 | 31.8 | 5.9 | 8.3 | 127.80 |
| | C | 8.20 | 25.7 | 20.0 | 12.4 | 8.9 | 14.2 | 8.5 | 97.90 |
| | A | 6.70 | 11.3 | 8.2 | 9.1 | 6.0 | 10.5 | 0.0 | 51.80 |
| R.S. | B | 14.00 | 4.1 | 9.4 | 8.9 | 0.0 | 19.0 | 3.5 | 58.90 |
| | C | 7.50 | 16.3 | 18.9 | 14.3 | 8.1 | 11.7 | 9.5 | 86.30 |
| | A | 2.90 | 11.3 | 4.2 | 5.7 | 6.0 | 3.4 | 14.3 | 47.80 |
| G.T. | B | 7.40 | 8.9 | 19.4 | 8.4 | 20.9 | 13.4 | 5.0 | 83.40 |
| | C | 9.10 | 12.5 | 8.8 | 7.1 | 9.6 | 7.2 | 10.9 | 65.20 |

1. - conditions
2. - knee extensors
3. - knee flexors
4. - hip flexors
5. - hip extensors
6. - trunk extensors
7. - trunk flexors
8. - shoulder flexors
9. - Strength Decrement Index

### Strength Decrement Index Differences

It may be recalled that S. D. I. is the proportion of pre-exercise strength lost after physical exertion. Consequently, decrements are equated for all muscle groups and can be added together to get an indication of the total effect on all muscle groups tested. These values were computed and added as shown in Table IV. The differences between the three conditions of grade were tested for statistical significance with the Friedman Two-Way Analysis of Variance Test. The $\chi_r^2$ was 2.4. A value of 5.99 had to be reached to be statistically significant at the .05 level of confidence. Since the difference was not statistically significant, it may be concluded that there was no difference in the over-all effect in these muscle groups tested at these grades.

## DISCUSSION OF RESULTS

There was a statistically significant strength decrement shown for back-packing at all three grades. In five out of the seven muscle groups, there was no significant difference between the decrements at each grade level. The knee extensors and shoulder flexors showed significant differences between back-packing on the level and back-packing up a five percent grade, and between the level and the ten percent grade but did not show a significant difference between the five percent grade and the ten percent grade. It would seem that the variable of grade does not have any effect on the strength decrement of the other five muscle groups at grades utilized in this study.

The knee extensors and shoulder flexors showed a statistically significant increase in strength decrement at the five percent and the

ten percent grades in comparison to the level grade. However, there was still no indication that the magnitude of the grade had a direct effect upon this decrement since there was no statistically significant difference between the five percent and the ten percent grades.

While walking on the treadmill at the five percent and the ten percent grades, the subjects had to lean further forward to maintain balance. In this position, they were not as free to move their arms as they were while walking at the level grade. It is possible that this change in the mechanics of walking when going from the level to a grade could be the cause of the recorded results. However, the exact explanation for these changes is outside the scope of this study.

A second subjective observation should be noted. At the five percent and the ten percent grades, subjects apparently were subjected to a greater stress as evidenced by outward signs of labored breathing and excessive sweating. However, this subjective observation was not supported by the objective results of the strength test. Possibly this test measures some factor which is relatively independent of the observed body adjustments.

# CHAPTER IV

## SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

### SUMMARY

Ten male students selected from physical education classes at Montana State University served as subjects for this study.

Muscle groups which had been shown by Clarke[1] to yield strength decrements during back-packing on military marches were tested. These muscle groups were: the shoulder elevators, the trunk flexors, the trunk extensors, the hip flexors, the hip extensors, the knee flexors, the knee extensors, and the ankle plantar flexors. In this study, the ankle plantar flexors could not be measured because the tensiometer was not adequate to measure the tension applied by the subjects.

Subjects walked thirty minutes at the rate of three miles per hour. Strength of the muscle groups before the march and after the march was measured with a cable-tensiometer. Variations in treadmill slopes were level, five percent, and ten percent grade. Results were analyzed with the Wilcoxon T-Test and the Friedman Two-Way Analysis of Variance Test.

First, the strength losses of each muscle group were tested to

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[1]H. Harrison Clarke, "Strength Decrements from Carrying Various Army Packs on Military Marches," Research Quarterly, 26:257, October, 1955.

determine whether or not they were statistically significant. Next, it was determined whether strength decrement differences between level walking and grade walking were significant and, if they were, where the points of significance were to be found. Lastly, it was determined whether or not there were significant differences for Strength Decrement Index for all muscle groups at level walking and walking at each grade.

The seven muscle groups showed strength decrement under the three conditions in all but four instances. One subject had a six pound increment for the shoulder flexors. Despite this individual's increment, a decrement which was shown to be statistically significant at the .005 level of confidence was found for the group as a whole.

Since the strength decrements of the seven muscle groups were statistically significant at all grade levels, the Friedman Two-Way Analysis of Variance Test $\chi_r^2$ was then used to determine whether or not there were significant differences between the strength decrements when the subjects walked at the different grade levels. The knee extensors and the shoulder flexors were the only muscle groups that showed statistical significance beyond the .05 level of confidence. Both muscle groups showed a significant difference in strength decrement at or above the .02 level of confidence between level walking and each grade but not between the grades themselves.

Through the use of the Strength Decrement Index, all muscle group decrements were added together to get an indication of the total effect on all of the muscle groups that had been tested. The

difference between the three conditions of grade were tested for statistical significance with the Friedman Two-Way Analysis of Variance Test. Since the difference was not statistically significant, there was no difference in the over-all effect of these muscle groups at the grades tested.

## CONCLUSIONS

The following conclusions are made within the limitations of this study.

1. There were statistically significant strength decrements in all muscle groups.
2. There was no apparent relationship between the grade and the strength decrement.
3. The increase in the decrement of the shoulder flexors and the knee extensors is apparently related to the transition from level walking to grade walking and is not related to the size of the grade.

## RECOMMENDATIONS

In view of the findings of this study and the problems encountered during its completion, it would be profitable to pursue further research. The relationship between muscle decrement and cardio-vascular respiratory adjustments should be studied. Research should be completed on the mechanics of walking on the treadmill at different grade levels. Also, strength decrement should be examined under a variety of variables such as distance, pack-weight, speed, and inclinations of the treadmill.

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## APPENDIX A

## TESTING METHODS

Knee Extension. The subject sat at the end of the testing table in a backward leaning position, with his legs hanging freely over the end of the table. The subject's arms were extended to the rear, grasping the sides of the table, with his thigh adducted at the hip joint to one hundred and eighty degrees.

The strap was placed around the leg midway between the knee and ankle joint. The knee was extended until an angle of one hundred and fifteen degrees was measured, then the chain was attached to a hook located on a piece of vertical frame attached to the under part of the table.

The assistant tester placed his right arm on the subject's shoulder and left arm around the subject's waist keeping the subject from leaning backward or lifting his buttocks off the table. The tester attached the tensiometer to the cable and told the subject when to begin. The subject would straighten out his leg, applying as much force as possible without lifting his buttocks off the table or flexing his arms.[1]

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[1]H. Harrison Clarke and David H. Clarke, Developmental and Adapted Physical Education (Englewood Cliffs, N. J. : Prentice Hall, Inc., 1963), pp. 92-94.

Knee Flexion. The subject was placed in a prone position, with his head resting on his folded arms. A folded towel was used to give the knee protection when the test was administered.

The strap was placed around the leg midway between the knee and the ankle joint. The chain was attached to a hook below the lower end of the table using the link that held the subject's knee to one hundred and sixty-five degrees.

The assistant tester lay across the subject's back to keep the subject's spine from extending. When performing the test, the subject applied as much pressure as possible without lifting his stomach off the table.[1]

Hip Flexion. The subject was placed in a supine position with his right thigh placed over the slit in the table, fully extended and adducted to a full one hundred and eighty degrees. The subject's left leg was flexed with his foot resting on the table; arms folded across his chest.

The strap was placed around the lower third of the right thigh between the knee and hip joint. The pulling assembly was placed through the slit in the table top and attached to a hook on the base of the table.

The assistant tester placed his hands on the subject's shoulders applying pressure to prevent them from lifting off the table. The subject lifted his entire leg off the table by lifting

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[1]H. Harrison Clarke and David H. Clarke, Developmental and Adapted Physical Education (Englewood Cliffs, N. J. : Prentice Hall, Inc., 1963), pp. 92-94.

from the hip. He could not gain extra force by pressing his right heel against the table top.[1]

Hip Extension. The subject was placed in a prone position with his right thigh over the slit in the table top. The right hip was adducted and extended to a full one hundred and eighty degrees. His arms were extended backward along the sides of his body.

The strap was placed around the lower third of the thigh between the hip and the knee joints. The pulling assembly was attached to a hook beneath the subject through the slit in the table.

The assistant tester lay across the subject's lower back; hanging on to the opposite side of the table, thus preventing the subject's pelvis from raising when he lifted his right leg.[2]

Trunk Extension. The subject was placed in a prone position with both hips extended and adducted to a full one hundred and eighty degrees. The subject's knees were fully extended with his arms behind back.

The strap was placed around the subject's chest close under the arm pits. The pulling assembly was placed through the slit in the table top and attached to the hook beneath.

The assistant tester lay across the subject's thighs holding on to the opposite side of the table; thus, preventing the hips from

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[1]H. Harrison Clarke and David H. Clarke, Developmental and Adapted Physical Education (Englewood Cliffs, N. J. : Prentice Hall, Inc., 1963), pp. 89-91.

[2]Ibid., pp. 88-90.

lifting when he exerted force.[1]

Trunk Flexion. The subject was placed in a supine position with both hips extended and adducted to a full one hundred and eighty degrees. The subject's knees were fully extended with his arms folded on chest.

The strap was placed around the chest, close under the arm pits. The pulling assembly was placed through the slit in the table top and attached to the hook beneath.

The assistant tester lay across the subject's thighs holding on to the opposite side of the table; thus, preventing the hips from lifting when he exerted force.[2]

Shoulder Flexion. The subject was placed in a supine position with both hips and knees flexed. The subject's feet were resting on the table with his free hand resting on chest. His right arm was held close to his side, right shoulder was flexed to ninety degrees and his right elbow was flexed ninety degrees.

The strap was placed around the subject's humerus midway between the shoulder and elbow joint. The pulling assembly was attached to the hook on a crosspiece beneath the subject's arm.

The assistant tester placed his right hand on the subject's right shoulder and his left arm across the subject's pelvis to prevent them from elevating when force was exerted.[3]

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[1]H. Harrison Clarke and David H. Clarke, Developmental and Adapted Physical Education (Englewood Cliffs, N. J. : Prentice Hall, Inc., 1963), pp. 88-90.

[2]Ibid.

[3]Ibid., pp. 84-86.

APPENDIX B

TABLE V - TEST RESULTS

| Subject | Condition | Muscle Group | Pre-Test | Post-Test | Strength Decrement |
|---|---|---|---|---|---|
| | A 0% | | 315 | 300 | 15.00 |
| M. A. | B 5% | Knee Extensors | 320 | 290 | 30.00 |
| | C 10% | | 310 | 270 | 40.00 |
| | A 0% | | 170 | 130 | 40.00 |
| M. A. | B 5% | Knee Flexors | 173.3 | 143.3 | 30.00 |
| | C 10% | | 166.6 | 146.6 | 20.00 |
| | A 0% | | 315 | 275 | 40.00 |
| M. A. | B 5% | Hip Flexors | 325.0 | 286.6 | 38.40 |
| | C 10% | | 320.0 | 266.6 | 53.40 |
| | A 0% | | 195.0 | 180.0 | 15.00 |
| M. A. | B 5% | Hip Extensors | 190.0 | 183.3 | 6.70 |
| | C 10% | | 190.0 | 176.6 | 13.40 |
| | A 0% | | 146.6 | 116.6 | 30.00 |
| M. A. | B 5% | Trunk Extensors | 153.3 | 146.6 | 6.70 |
| | C 10% | | 156.6 | 136.6 | 20.00 |
| | A 0% | | 220.0 | 170.0 | 50.00 |
| M. A. | B 5% | Trunk Flexors | 223.3 | 183.3 | 40.00 |
| | C 10% | | 210.0 | 183.3 | 26.60 |
| | A 0% | | 266.6 | 246.6 | 20.00 |
| M. A. | B 5% | Shoulder Flexors | 270.0 | 240.0 | 30.00 |
| | C 10% | | 263.3 | 240.0 | 23.30 |
| | A 0% | | 243.30 | 240.00 | 3.30 |
| J. D. | B 5% | Knee Extensors | 220.00 | 200.00 | 20.00 |
| | C 10% | | 260.00 | 223.30 | 36.10 |
| | A 0% | | 159.90 | 146.60 | 13.30 |
| J. D. | B 5% | Knee Flexors | 116.60 | 96.60 | 20.00 |
| | C 10% | | 140.00 | 103.30 | 36.70 |
| | A 0% | | 190.00 | 186.60 | 3.40 |
| J. D. | B 5% | Hip Flexors | 163.30 | 156.60 | 6.70 |
| | C 10% | | 186.60 | 176.60 | 10.00 |
| | A 0% | | 190.00 | 159.90 | 30.10 |
| J. D. | B 5% | Hip Extensors | 140.00 | 120.00 | 20.00 |
| | C 10% | | 166.60 | 146.60 | 20.00 |
| | A 0% | | 100.00 | 79.90 | 20.10 |
| J. D. | B 5% | Trunk Extensors | 86.60 | 63.30 | 23.30 |
| | C 10% | | 116.60 | 90.00 | 26.60 |
| | A 0% | | 143.30 | 120.00 | 23.30 |
| J. D. | B 5% | Trunk Flexors | 153.30 | 120.00 | 33.30 |
| | C 10% | | 143.30 | 113.30 | 30.00 |
| | A 0% | | 163.30 | 170.00 | *6.70 |
| J. D. | B 5% | Shoulder Flexors | 170.00 | 159.90 | 20.10 |
| | C 10% | | 143.30 | 130.00 | 13.30 |

*This figure represents the only increase in strength.

TABLE V (continued)

| Subject | Condition | Muscle Group | Pre-Test | Post-Test | Strength Decrement |
|---|---|---|---|---|---|
| | A 0% | | 246.60 | 226.60 | 20.00 |
| B. L. | B 5% | Knee Extensors | 243.30 | 203.30 | 40.00 |
| | C 10% | | 246.60 | 226.60 | 20.00 |
| | A 0% | | 116.60 | 100.00 | 16.60 |
| B. L. | B 5% | Knee Flexors | 163.30 | 156.60 | 6.70 |
| | C 10% | | 120.00 | 110.00 | 10.00 |
| | A 0% | | 286.60 | 243.30 | 43.30 |
| B. L. | B 5% | Hip Flexors | 253.30 | 243.30 | 10.00 |
| | C 10% | | 263.30 | 243.30 | 20.00 |
| | A 0% | | 246.60 | 200.00 | 46.60 |
| B. L. | B 5% | Hip Extensors | 210.00 | 193.30 | 16.70 |
| | C 10% | | 223.30 | 200.00 | 23.30 |
| | A 0% | | 210.00 | 166.60 | 43.40 |
| B. L. | B 5% | Trunk Extensors | 235.00 | 230.00 | 5.00 |
| | C 10% | | 223.30 | 205.00 | 18.50 |
| | A 0% | | 246.60 | 240.00 | 6.60 |
| B. L. | B 5% | Trunk Flexors | 263.30 | 226.60 | 36.70 |
| | C 10% | | 260.00 | 220.00 | 40.00 |
| | A 0% | | 183.30 | 170.00 | 13.30 |
| B. L. | B 5% | Shoulder Flexors | 190.00 | 173.30 | 16.70 |
| | C 10% | | 190.00 | 176.60 | 13.40 |
| | A 0% | | 320.00 | 263.30 | 56.70 |
| F. J. | B 5% | Knee Extensors | 223.30 | 160.00 | 63.30 |
| | C 10% | | 226.60 | 195.00 | 31.60 |
| | A 0% | | 140.00 | 113.30 | 26.70 |
| F. J. | B 5% | Knee Flexors | 106.60 | 86.60 | 20.00 |
| | C 10% | | 100.00 | 83.30 | 16.70 |
| | A 0% | | 220.00 | 186.60 | 33.40 |
| F. J. | B 5% | Hip Flexors | 190.00 | 173.30 | 16.70 |
| | C 10% | | 193.30 | 180.00 | 13.30 |
| | A 0% | | 173.30 | 166.60 | 6.70 |
| F. J. | B 5% | Hip Extensors | 143.30 | 136.60 | 6.70 |
| | C 10% | | 159.90 | 153.30 | 6.60 |
| | A 0% | | 153.30 | 130.00 | 23.30 |
| F. J. | B 5% | Trunk Extensors | 130.00 | 93.30 | 36.70 |
| | C 10% | | 163.30 | 146.60 | 16.70 |
| | A 0% | | 130.00 | 100.00 | 30.00 |
| F. J. | B 5% | Trunk Flexors | 153.30 | 143.30 | 10.00 |
| | C 10% | | 163.30 | 150.00 | 13.30 |
| | A 0% | | 156.60 | 140.00 | 16.60 |
| F. J. | B 5% | Shoulder Flexors | 156.60 | 136.60 | 20.00 |
| | C 10% | | 193.30 | 166.60 | 26.70 |

TABLE V (continued)

| Subject | Condition | Muscle Group | Pre-Test | Post-Test | Strength Decrement |
|---|---|---|---|---|---|
| | A 0% | | 280.00 | 266.60 | 13.40 |
| W. K. | B 5% | Knee Extensors | 286.60 | 275.00 | 11.60 |
| | C 10% | | 286.60 | 250.00 | 36.60 |
| | A 0% | | 173.30 | 163.30 | 10.00 |
| W. K. | B 5% | Knee Flexors | 166.60 | 143.30 | 23.30 |
| | C 10% | | 166.60 | 130.00 | 36.60 |
| | A 0% | | 163.30 | 160.00 | 33.30 |
| W. K. | B 5% | Hip Flexors | 163.30 | 156.60 | 6.70 |
| | C 10% | | 166.60 | 156.60 | 10.00 |
| | A 0% | | 160.00 | 156.60 | 3.40 |
| W. K. | B 5% | Hip Extensors | 170.00 | 146.60 | 23.40 |
| | C 10% | | 200.00 | 180.00 | 20.00 |
| | A 0% | | 136.60 | 120.00 | 16.60 |
| W. K. | B 5% | Trunk Extensors | 153.30 | 146.60 | 6.70 |
| | C 10% | | 140.00 | 103.30 | 36.70 |
| | A 0% | | 150.00 | 136.60 | 13.40 |
| W. K. | B 5% | Trunk Flexors | 146.60 | 125.00 | 21.60 |
| | C 10% | | 146.60 | 106.60 | 40.00 |
| | A 0% | | 190.00 | 183.30 | 6.70 |
| W. K. | B 5% | Shoulder Flexors | 200.00 | 183.30 | 16.70 |
| | C 10% | | 205.00 | 186.60 | 18.40 |
| | A 0% | | 263.30 | 250.00 | 13.30 |
| M. W. R. | B 5% | Knee Extensors | 280.00 | 259.90 | 20.10 |
| | C 10% | | 266.60 | 250.00 | 16.60 |
| | A 0% | | 120.00 | 103.30 | 16.70 |
| M. W. R. | B 5% | Knee Flexors | 106.60 | 90.00 | 16.60 |
| | C 10% | | 190.00 | 180.00 | 10.00 |
| | A 0% | | 186.60 | 180.00 | 6.60 |
| M. W. R. | B 5% | Hip Flexors | 200.00 | 195.00 | 5.00 |
| | C 10% | | 173.30 | 163.30 | 10.00 |
| | A 0% | | 183.30 | 176.60 | 6.70 |
| M. W. R. | B 5% | Hip Extensors | 183.30 | 170.00 | 13.30 |
| | C 10% | | 186.60 | 163.30 | 23.30 |
| | A 0% | | 93.30 | 86.60 | 6.70 |
| M. W. R. | B 5% | Trunk Extensors | 96.60 | 90.00 | 6.60 |
| | C 10% | | 93.30 | 79.90 | 13.40 |
| | A 0% | | 113.30 | 103.30 | 10.00 |
| M. W. R. | B 5% | Trunk Flexors | 120.00 | 106.60 | 13.40 |
| | C 10% | | 116.60 | 96.60 | 20.00 |
| | A 0% | | 183.30 | 176.60 | 6.70 |
| M. W. R. | B 5% | Shoulder Flexors | 166.60 | 159.90 | 6.70 |
| | C 10% | | 180.00 | 163.30 | 16.70 |

TABLE V (continued)

| Subject | Condition | Muscle Group | Pre-Test | Post-Test | Strength Decrement |
|---|---|---|---|---|---|
| | A 0% | | 266.60 | 255.00 | 11.60 |
| M. A. R. | B 5% | Knee Extensors | 275.00 | 255.00 | 20.00 |
| | C 10% | | 275.00 | 260.00 | 15.00 |
| | A 0% | | 136.60 | 116.60 | 20.00 |
| M. A. R. | B 5% | Knee Flexors | 136.60 | 116.60 | 20.00 |
| | C 10% | | 143.30 | 133.30 | 10.00 |
| | A 0% | | 180.00 | 173.30 | 6.70 |
| M. A. R. | B 5% | Hip Flexors | 173.30 | 163.30 | 10.00 |
| | C 10% | | 166.60 | 156.60 | 10.00 |
| | A 0% | | 190.00 | 146.60 | 43.40 |
| M. A. R. | B 5% | Hip Extensors | 190.00 | 170.00 | 20.00 |
| | C 10% | | 205.00 | 195.00 | 10.00 |
| | A 0% | | 153.30 | 130.00 | 23.30 |
| M. A. R. | B 5% | Trunk Extensors | 140.00 | 103.30 | 36.70 |
| | C 10% | | 143.30 | 93.30 | 50.00 |
| | A 0% | | 159.90 | 146.60 | 13.30 |
| M. A. R. | B 5% | Trunk Flexors | 140.00 | 116.60 | 23.40 |
| | C 10% | | 160.00 | 146.60 | 13.40 |
| | A 0% | | 210.00 | 200.00 | 10.00 |
| M. A. R. | B 5% | Shoulder Flexors | 220.00 | 210.00 | 10.00 |
| | C 10% | | 205.00 | 186.60 | 18.40 |
| | A 0% | | 240.00 | 240.00 | 0.00 |
| V. R. | B 5% | Knee Extensors | 260.00 | 230.00 | 30.00 |
| | C 10% | | 243.30 | 223.30 | 20.00 |
| | A 0% | | 90.00 | 80.00 | 10.00 |
| V. R. | B 5% | Knee Flexors | 116.60 | 79.90 | 36.70 |
| | C 10% | | 116.60 | 86.60 | 30.00 |
| | A 0% | | 133.30 | 116.60 | 16.70 |
| V. R. | B 5% | Hip Flexors | 190.00 | 153.30 | 36.70 |
| | C 10% | | 183.30 | 146.60 | 36.70 |
| | A 0% | | 133.30 | 120.00 | 13.30 |
| V. R. | B 5% | Hip Extensors | 176.60 | 143.30 | 33.30 |
| | C 10% | | 159.90 | 140.00 | 19.90 |
| | A 0% | | 166.60 | 146.60 | 20.00 |
| V. R. | B 5% | Trunk Extensors | 146.60 | 100.00 | 46.60 |
| | C 10% | | 150.00 | 136.60 | 13.40 |
| | A 0% | | 183.30 | 160.00 | 23.30 |
| V. R. | B 5% | Trunk Flexors | 113.30 | 106.60 | 6.70 |
| | C 10% | | 116.60 | 100.00 | 16.60 |
| | A 0% | | 170.00 | 160.00 | 10.00 |
| V. R. | B 5% | Shoulder Flexors | 159.90 | 146.60 | 13.30 |
| | C 10% | | 156.60 | 143.30 | 13.30 |

TABLE V (continued)

| Subject | Condition | Muscle Group | Pre-Test | Post-Test | Strength Decrement |
|---|---|---|---|---|---|
| | A 0% | | 300.00 | 280.00 | 20.00 |
| R. S. | B 5% | Knee Extensors | 320.00 | 275.00 | 45.00 |
| | C 10% | | 310.00 | 286.60 | 23.40 |
| | A 0% | | 146.60 | 130.00 | 16.60 |
| R. S. | B 5% | Knee Flexors | 163.30 | 156.60 | 6.70 |
| | C 10% | | 143.30 | 120.00 | 23.30 |
| | A 0% | | 243.30 | 223.30 | 20.00 |
| R. S. | B 5% | Hip Flexors | 250.00 | 226.60 | 23.40 |
| | C 10% | | 246.60 | 200.00 | 46.60 |
| | A 0% | | 183.30 | 166.60 | 16.70 |
| R. S. | B 5% | Hip Extensors | 186.60 | 170.00 | 16.60 |
| | C 10% | | 186.60 | 159.90 | 26.70 |
| | A 0% | | 166.60 | 156.60 | 10.00 |
| R. S. | B 5% | Trunk Extensors | 163.30 | 163.30 | 00.00 |
| | C 10% | | 163.30 | 150.00 | 13.30 |
| | A 0% | | 190.00 | 170.00 | 20.00 |
| R. S. | B 5% | Trunk Flexors | 210.00 | 170.00 | 40.00 |
| | C 10% | | 226.60 | 200.00 | 26.60 |
| | A 0% | | 205.00 | 205.00 | 00.00 |
| R. S. | B 5% | Shoulder Flexors | 190.00 | 183.30 | 6.70 |
| | C 10% | | 210.00 | 190.00 | 20.00 |
| | A 0% | | 340.00 | 330.00 | 10.00 |
| G. T. | B 5% | Knee Extensors | 313.30 | 290.00 | 23.30 |
| | C 10% | | 330.00 | 300.00 | 30.00 |
| | A 0% | | 146.60 | 130.00 | 16.60 |
| G. T. | B 5% | Knee Flexors | 150.00 | 136.60 | 13.40 |
| | C 10% | | 133.30 | 116.60 | 16.70 |
| | A 0% | | 240.00 | 230.00 | 10.00 |
| G. T. | B 5% | Hip Flexors | 223.30 | 180.00 | 43.30 |
| | C 10% | | 190.00 | 173.30 | 16.70 |
| | A 0% | | 176.60 | 166.60 | 10.00 |
| G. T. | B 5% | Hip Extensors | 160.00 | 146.60 | 13.40 |
| | C 10% | | 186.60 | 173.30 | 13.30 |
| | A 0% | | 280.00 | 263.30 | 16.70 |
| G. T. | B 5% | Trunk Extensors | 223.30 | 176.60 | 46.70 |
| | C 10% | | 295.00 | 266.60 | 28.40 |
| | A 0% | | 293.30 | 283.30 | 10.00 |
| G. T. | B 5% | Trunk Flexors | 200.00 | 173.30 | 26.70 |
| | C 10% | | 280.00 | 260.00 | 20.00 |
| | A 0% | | 210.00 | 180.00 | 30.00 |
| G. T. | B 5% | Shoulder Flexors | 200.00 | 190.00 | 10.00 |
| | C 10% | | 230.00 | 205.00 | 25.00 |

## APPENDIX C

## SAMPLE OF SUBJECT'S RECORD CARD

Subject:_____ Date:_____ Tester:_____

Tensiometer:_____ Condition:_____

Age:_____ Weight:_____ Height:_____

| Muscle Group | Pre-Test | Post-Test | Pre-Test Lbs. | Post-Test Lbs. | S.D.* | S.D.I.** |
|---|---|---|---|---|---|---|
| Knee Extensors | | | | | | |
| Knee Flexors | | | | | | |
| Hip Flexors | | | | | | |
| Hip Extensors | | | | | | |
| Trunk Extensors | | | | | | |
| Trunk Flexors | | | | | | |
| Shoulder Flexors | | | | | | |

* - Strength Decrement
** - Strength Decrement Index