1970

Energy Expenditure of Different Exercises Performed With Uniform Resistance.

Ronnie G. Barra

Louisiana State University and Agricultural & Mechanical College

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PERFORMED WITH UNIFORM RESISTANCE

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Education in The Department of Health, Physical and Recreation Education

by
Ronnie G. Barra
B.S., Lamar State College of Technology, 1962
M.A., Stephen F. Austin State College, 1964
May, 1970
DEDICATION

The author would like to dedicate this manuscript to the late Mrs. Essie Lou Ardoin and to Mrs. W. A. Mayo.
ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to Dr. Francis A. Drury for his patience and guidance in directing this study.

Gratitude is also expressed to the subjects who volunteered to participate in this study.
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ABSTRACT

The purpose of this investigation was to study the energy expenditure involved in the execution of the curl, military press, and shrug exercises using seventy-five pounds of static resistance. A secondary purpose was to determine the relationship of body weight to the energy expended in the performance of each of the three specified exercises.

Thirty male college subjects were used in this study. The subjects were graduate and undergraduate students enrolled at Stephen F. Austin State University, Nacogdoches, Texas.

The energy cost of performing the curl, military press, and shrug exercises utilizing seventy-five pounds of static resistance was assessed. Energy expenditure was defined as the net oxygen consumed in liters during the five minutes immediately following each exercise. Oxygen consumption values were determined by the open circuit indirect method. Each exercise was for a period of ten seconds.

Analysis of variance was used in treating the data to determine if differences existed in the amount of energy expended among the three exercises. The Newman-Keuls method
was then used for locating and testing the mean differences for significance.

To further analyze the data, coefficients of correlation were employed to study the relationship between the energy expended for each of the three static exercises and body weight.

The following findings were obtained in this study:

1. Holding a resistance of seventy-five pounds in the curl position produced a greater energy expenditure than either the military press or the shrug positions. The differences were significant at the .01 level of confidence.

2. The military press position resulted in a greater energy expenditure than the shrug position. The difference was significant at the .01 level of confidence.

3. There was a significant positive correlation between body weight and energy expended for the military press position. The correlation was significant at the .05 level of confidence.

4. There was no significant correlation between body weight and energy expenditure for either the curl or shrug positions.
Based upon the findings of this study, the following conclusions were drawn:

1. When the amount of static resistance remains uniform, the energy required to perform a task will differ in relation to the position of the exercise.

2. The degree of conscious effort experienced by an individual performing at various exercise positions may be an indicator of the amount of energy needed to perform the exercise.

3. Body weight shows an inconsistent relationship to the amount of energy that is required to perform a static exercise.
CHAPTER I

INTRODUCTION

Interest has been displayed in the amount of energy needed to perform a specific task. This area of study has been investigated by many professional groups including medical personnel, coaches, physical educators, and space scientists. Researchers often utilize known energy requirements, among other variables, in the predicting of task efficiency.

Because energy requirements are considered an important variable in human performance, it would appear that research should examine both dynamic and static types of exercise.

Dynamic energy expenditure has received more attention than has static energy requirements. The recent emphasis given to isometric contraction indicates a need for information concerning energy expenditure requirements for static exercise.

The study of isometric exercise has been primarily restricted to the gaining and/or maintenance of strength, the effect on circulatory functions, and program effects on selected motor performance variables. Information concerning static energy expenditure is somewhat limited, however.
Several contemporary investigators have made statements concerning isometric energy expenditure. Clarke reporting in 1960, Pogue in 1964, Bartels et al., in 1968, and McArdle and Foglia in 1969, all indicated a need for further investigation into the area of energy expenditure as it relates to isometric exercise. Shvartz, writing in 1966, agreed with Bartels et al., that more investigation regarding isometric exercise was needed in relation to man's


6 Bartels, et al., loc. cit.
activity during space flight. In addition, Berry\textsuperscript{7} stated that one priority concerning man's capability for extended space travel was the investigation of energy expenditure during measured workloads.

The present study concerned itself with further investigating the area of static energy expenditure. Previous investigators appeared to be primarily concerned with energy cost data resulting from varying the quantity of the isometric resistance. Unlike previously reviewed investigations, this study focused upon energy measurements that were derived from three exercise positions, when each of the exercises were performed utilizing uniform resistance. Thus, the position of the exercise was the primary concern of this study.

The exercises used in this investigation were selected because of the varying degree of effort that was required to perform each exercise. It was felt by the author, as a result of interview and observation, that the curl was more difficult to perform than the military press and shoulder shrug. Also, that the military press was greater in difficulty than the shoulder shrug. Because of the varying degree of effort that is required of the body to

\textsuperscript{7}Charles A. Berry, "Status Report on Space Medicine in United States," \textit{Aerospace Medicine}, XXXX (July, 1969), 767.
perform at various exercise positions, there exists a possibility that the amount of effort may be related to the oxygen consumed in performing the exercise. Accordingly, it would appear that when assessing oxygen requirements the position of the exercise, as well as the quantity of the resistance, may need to be given consideration.

I. STATEMENT OF THE PROBLEM

Does the changing of static exercise position affect energy expenditure when each of the exercises is performed utilizing equal resistance? What is the relationship of body weight to energy expended in the performance of static exercises while utilizing equal resistance?

II. PURPOSE OF THE STUDY

The purpose of this investigation was to study the energy expenditure involved in the execution of the shoulder shrug, curl, and military press using seventy-five pounds of static resistance. A secondary purpose was to determine the relationship of body weight to the energy expended in the performance of each of the three specified exercises.
III. DELIMITATIONS OF THE STUDY

The subjects used in this study were graduate and undergraduate students enrolled in the first summer session 1969 at Stephen F. Austin State University, Nacogdoches, Texas. The participants were volunteers obtained from physical education activity classes.

1. Selection of subjects was limited to thirty male students.
2. The study was limited to three static exercises.
3. One specified resistance was used.
4. Assessment of energy requirements for each of the three exercises was through the use of the indirect method of measuring oxygen consumption.

IV. LIMITATIONS OF THE STUDY

1. Rigid control could not be maintained over temperature, humidity, and barometric pressure.
2. No special diet was prescribed.
3. Subjects were requested to minimize movements during the entire testing session. However, no rigid control could be maintained.
4. Although attempts were made to familiarize subjects with equipment and procedures, complete removal of inhibitions was impossible.
V. DEFINITION OF TERMS

Static Resistance. In this study, static resistance was defined as the ability to sustain seventy-five pounds for a period of ten seconds.

Energy Expenditure. In this study, energy expenditure was defined as the amount of heat produced in the consumption of 1 liter of oxygen. 8

Background Count. In this study, the background count was expressed as oxygen consumed during five minutes of respiration in the standing position prior to exercise.

Postexercise Count. For this study, the postexercise count was expressed as oxygen consumed during five minutes of respiration in the standing position following exercise.

\[ V_1 \text{ (liters)} \]. For this study, this symbol represented the volume of gas expired during the background count.

\[ V_2 \text{ (liters)} \]. For this study, this symbol represented the volume of gas expired during the postexercise count.

\( V \) (liters). In this study, this symbol represented the corrected oxygen value for the background count.

\( V \) (liters). For this study, this symbol represented the corrected oxygen value for the postexercise count.

\( V \) (net cost/liters). This symbol represented the corrected oxygen value for the postexercise count minus the corrected oxygen value for the background count. The oxygen value resulting from this procedure was considered to be the energy cost for the exercise.

\( \text{STPD} \). This was the symbol used to express a volume of gas at standard conditions for temperature, barometric pressure, and humidity.\(^9\)

\( \text{True } O_2 \). This was the symbol used to express the percentage of oxygen removed from a volume of inspired air.\(^10\)

**Indirect Method.** This study utilized the open circuit indirect method of assessing oxygen consumption. The open circuit approach required inspiration of room air and expiration into a Douglas bag with the content analyzed.

\(^9\text{Ibid.}, \text{p. 434.}\)

\(^10\text{Ibid.}, \text{p. 6.}\)
for volume, oxygen, and carbon dioxide concentration. The indirect method is based on the following:

Because all of the body's metabolic processes utilize oxygen and produce carbon dioxide, (either during activity or immediately after), the energy output is directly related to the quantity of these respiratory gases.11

**Effort.** In this study, effort was defined as the degree of conscious difficulty experienced in the performance of a static exercise.

CHAPTER II

REVIEW OF THE LITERATURE

The review of literature for this study was limited to static exercise and its relationship to energy expenditure.

The author was in agreement with Clarke\(^1\) that little textbook coverage has been given the area of static energy expenditure. It should be further noted generally, that the literature regarding static exercise was limited in reporting energy cost data. Isometric investigators, Hettinger and Muller\(^2\) stated that: "Static exercise affords rapid muscle training with very little use of time and energy." This statement has implications for the area under investigation.

The relationship of body weight and energy expenditure while performing static exercises was given little consideration in the studies reviewed. Considering the apparent relationship of body weight to the energy cost


of dynamic exercise as reported by Brown, Henry, Johnson, and Morehouse and Miller, it appeared that a comparable relationship involving body weight and the energy cost of static exercise should be investigated.

The studies reviewed were classified into the following categories: (1) studies involving energy expenditure resulting from varying static work loads, and (2) general studies concerning static energy expenditure.

Energy requirements taken from selected studies reviewed are presented in Appendix B, page 51. This information was presented in order that the reader may review some of the energy expenditures that have resulted from research with static exercise.

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3 Ibid., p. 99.
I. STUDIES INVOLVING ENERGY EXPENDITURE RESULTING FROM VARYING STATIC WORK LOADS

Clarke studied the metabolic cost of static exercise in relation to work load and found a somewhat linear relationship between the amount of isometric work done and net oxygen requirement. The exercise for this study involved the subject holding weights of twenty, thirty-five, and fifty pounds in a standing position for a period of five minutes with each weight. The mean net O₂ requirement nearly doubled as the weight was changed from twenty to fifty pounds.

Bartels et al., reported the effects of a ten second submaximal isometric exercise upon net oxygen cost. This isometric exercise involved much of the large musculature. The findings showed a wide variability in net oxygen cost among subjects, and also considerable variability in the case of each subject from one trial to another.

Each subject exercised in a semi-reclining, fixed

---

7 Clarke, op. cit., pp. 3-6.
position against a spring dynamometer. A bout consisted of sixty per cent of the previously determined maximum effort.

Bartel's study confirmed the work of Clarke in finding a relationship between work done and net oxygen cost, \( r = 0.853 \). Bartel's investigation dealt with the research contained in a study by Martin.

Sharkey, using an ergometer, measured the oxygen cost of static leg exercises. The exercises were performed in a semi-reclining position against resistances of 80, 120, or 160 pounds per leg, with each lasting for a period of thirty seconds. The resistance loads represented approximately ten to forty per cent of the subject's maximal strength.

It was indicated that an apparent positive straight line relationship existed between oxygen consumed and resistance load. The author summarized by saying that some

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9 Clarke, op. cit., p. 6.


studies support a linear or proportional relationship of work load to oxygen consumption in static effort, while others present a disproportional or curvilinear relationship.

Royce, using the strong muscles of the lower extremities, studied the oxygen consumed while statically exercising against resistances of 70, 100, 130, and 160 pounds. The subject performed in a supine position on a movable platform with the knee set at an approximate 115 degree angle. It was concluded that a linear relationship existed between oxygen intake and the magnitude of isometric load.

Cathcart et al., in an investigation in 1922, studied the effects upon energy metabolism while maintaining isometric work loads in two lying and two sitting positions. The types of static efforts investigated were: (1) continuous, (2) intermittent, and (3) gradually increased. They concluded that light isometric work loads


did not cause a reduction of oxygen intake during an effort and there was no marked increase in oxygen intake following an effort.

As reported by Cathcart et al., an investigation by Chauvean and Tissot (1896-7) indicated that when a static load is constant, the energy metabolism is practically proportional to the degree of shortening of the contracting muscle; i.e. to the degree of flexion of the arm. It was also concluded that when the load varies, and the degree of flexion held constant, the energy metabolism is proportional to the load supported. Johansson (1901) later agreed that the carbon dioxide output was proportional to the load. Koraen (1902) also varied the angle of contraction of the arms and found that the carbon dioxide output increased with the shortening of the muscle.

Bornstein and Poker (1903) disagreed somewhat with the findings of some of the previously mentioned authors when they found that, metabolism during the static effort did not increase proportionally with the adding of resistance nor with the length of the effort, but rather it increased more rapidly.

Ibid., pp. 161-162.
II. GENERAL STUDIES CONCERNING STATIC ENERGY EXPENDITURE

McArdle and Foglia investigated the energy required to isometrically perform the two-arm curl, two-arm press, bench press and squat. The performer exercised against a bar that was placed in a position half-way through the range of motion of a corresponding weight-lifting exercise. Each exercise was for six seconds at maximum exertion. Their findings indicated that the two-arm curl and squat were significantly larger in energy cost than either the bench press or the two-arm press. No differences existed between the bench press and the two-arm press, nor the two-arm curl and squat.

Waite investigated the metabolic cost of a semi-isometric endurance exercise. The oxygen consumption rates of fit and unfit women who had been working at a rate of 225 foot pounds of work per minute were compared. The

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quadriceps muscle was isolated for study and the exercise was considered to be submaximal. The exercise was performed in a reclining position and consisted of lifting a five pound (pulley attached) weight nine inches off the floor. Each subject exercised for a total of sixteen minutes at a rate of sixty repetitions per minute.

The results indicated that: (1) the fit group demonstrated greater physical efficiency than the unfit group, and (2) extremely high and low scores on selected physical fitness tests may be an indicator of physical efficiency.

The isometric energy cost for exercising the right elbow flexor muscle was measured by Pogue.\(^\text{17}\) The exercise was performed from a supine position. Three maximum contractions of six seconds duration each, with a one-second pause between each contraction, constituted a bout. It was concluded that the eighteen second bout of exercise was equal in energy cost to a man carrying a load of eighty kilograms at a speed of 3.1 to 3.5 kilometers per hour.

Stephens studied the energy cost of sustaining a ten pound weight for a one minute period. The exercise was performed from a sitting position with the weight strapped to the ankle of the extended leg. It was concluded that the exercise produced no significant increase in energy requirements in relation to base conditions.

Hansen and Maggio added a bout of isometric contraction to a twenty-five minute period of dynamic exercise. The exercise consisted of riding a bicycle ergometer at 300 kilopound-meters per minute, with the isometric phase introduced at the end of ten minutes of riding for a period of 1.5 minutes. The static phase was induced by having the subject hold in either hand two kilograms of weight. The results showed a total oxygen consumption increase due to the adding of the isometric phase. The introduction of the static phase was for the purpose of studying the effect it had on heart rate in relation to oxygen consumption during a dynamic activity.

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III. SUMMARY OF THE LITERATURE

The literature in the area of static energy expenditure was very limited. In summarizing the available literature reviewed, there seem to be indications that:

1. When the nature of an exercise remains constant, there exists a positive linear relationship between isometric load and energy expenditure. However, some authors report a disproportional or curvilinear trend.

2. When an isometric load is held at different angles, the energy cost increases with the shortening of the muscle.

3. In general, most investigations have employed absolute measures of isometric resistance as opposed to relative measures such as maximum and percentage of maximum.
CHAPTER III

PROCEDURES FOR THE STUDY

The assessment of energy requirements for specified static exercises and the relationship of body weight to each exercise was the focus of this study.

Static exercises selected for investigation were the shoulder shrug, curl, and military press. Each participant was tested at the three exercise positions with seventy-five pounds utilized as the resistance for each exercise. Measurement of the energy expended was by the indirect method. Oxygen utilization values were computed in liters per ten second contractions.

I. SUBJECTS

Thirty male college subjects were used in this study. The subjects were volunteers from graduate and undergraduate classes enrolled in the first summer session 1969 at Stephen F. Austin State University, Nacogdoches, Texas. Four subjects that were tested in a pilot study in May, 1969 were included as part of the total testing group.

The subjects ranged in age from seventeen to twenty-seven years and varied in weight from 143 to 228½ pounds.
II. ORIENTATION

All subjects involved in the study were given an orientation program which was designed to familiarize them with the purpose of the study, the equipment that was to be used, and the testing procedures.

The subjects were instructed to refrain from eating two hours prior to the testing session. In addition they were requested to limit their physical activities to classroom requirements. Those who were participating in physical activity classes were excused from participation on the day of testing.

Prior to the administration of the tests, the investigator again explained testing procedures and answered any questions that were asked by the subject.

III. TEST ADMINISTRATORS

Test administrators working in this study were the writer and two other male physical educators. One of the two was a staff member and the other a senior physical education major employed as a research laboratory assistant.

All of the testers had previous experience in working with equipment used in the study. However, an orientation program was conducted to familiarize each
testor with the procedures that were to be used for each of the specified testing positions. The orientation program was composed of three sessions.

The writer was present during all testing periods for any consultation needed by assistants regarding the testing program.

IV. TESTING EQUIPMENT

The following equipment was used in conducting the study:

**Mercury Barometer.** A Model P-411 Mercury Barometer, manufactured by Warren E. Collins, Inc., was used to observe barometric pressure and provide data applicable to STPD corrections of collected gases.

**Douglas Gas Bags.** Two Douglas gas bags were used; one with a capacity of sixty liters and the other one hundred liters. The Douglas bags were manufactured by Warren E. Collins, Inc., and were numbered P-341-60 and P-341-100 respectively. These bags were used for the collection of expired air.

**Rubber Mouthpiece.** A number P-357 moulded contour mouthpiece, manufactured by Warren E. Collins, Inc., was used. This piece of equipment was attached to a modified Douglas valve and facilitated the control of inspiring and expiring of air.
**Modified Douglas Valve.** A Model P-311 Douglas valve, made by Warren E. Collins, Inc., was utilized to direct expired air toward the Douglas bag.

**Stopcock - Three Way Tap Valve.** This valve, Model P-321 manufactured by Warren E. Collins, Inc., was the final regulator with regard to the entrance of the expired gases into the Douglas bag.

**Oxygen Analyzer.** A Model 777 Oxygen Analyzer, manufactured by Beckman Instruments, Inc., was used for assessing the percentage of oxygen in the expired air.

**Carbon Dioxide Analyzer.** For this study, a Model 2050 Electronic Carbon Dioxide Analyzer was used. This piece of equipment was manufactured by Harvard Apparatus Company, Inc., and was used to assess the percentage of carbon dioxide in the expired air.

**Gas Meter.** A Warren E. Collins, Inc., Model P-350, gas meter was used to measure the total volume of expired air and gas temperature.

**Noseclip.** A rubber noseclip, Model P-358, manufactured by Warren E. Collins, Inc., was used for closing off the nostrils in order that the expired air be directed only to the Douglas bag.
Scales. A Health-O-Meter adjustable platform scale, Model 400 CEK, manufactured by Continental Scale Corporation, was used for determining the subject's body weight.

Stopwatches. Two stopwatches were used: one was a German-made Junghams and the other, a Swiss-made Chesterfield Antimagnetic. They were used for timing the exercises and rest periods, and for timing the background and postexercise counts.

Barbell and Weights. Seventy-five pounds of weight provided the necessary resistance. The weight consisted of standard plastic coated plates which were equally distributed at either end of an aluminum bar.

The following equipment is shown in Figure 1, page 25: Barbell and Weights, Carbon Dioxide Analyzer, Mercury Barometer, Oxygen Analyzer and Gas Meter.

V. TESTING PROCEDURE

Order of Testing. The orders of testing positions were determined by the process of randomization. The first order established was: (1) Press, (2) Curl, and (3) the Shrug. This order was then rotated to give the three sequences shown on page 24.
<table>
<thead>
<tr>
<th>1</th>
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<th>3</th>
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</thead>
<tbody>
<tr>
<td>Press</td>
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<tr>
<td>Curl</td>
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<td>Press</td>
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<tr>
<td>Shrug</td>
<td>Press</td>
<td>Curl</td>
</tr>
</tbody>
</table>

The three sequences were assigned to the first three subjects and this order was followed for each succeeding groups of three subjects.

**Weight Measurement.** The subject was weighed on the day of testing.

**Dress.** Participants wore gym shorts, shirt and tennis shoes.

**Calibration.** Using the air calibration method, the gas analysis equipment was calibrated prior to the analysis of the content for each Douglas bag. This method assumes that the per cent concentration of oxygen and carbon dioxide in room air is 20.9 and zero per cent respectively.

The range switch of the oxygen analyzer was set at zero, with the meter needle also adjusted to zero by the zero control. The range switch was then set to the 0-25 per cent position and, with the sensor exposed to room air, the meter needle was adjusted to read 20.9 per cent oxygen by using the calibrate control switch.

The range switch of the carbon dioxide analyzer was set at the 0 to 7.5 per cent position. With the
Figure 1. Equipment used in determining energy expenditure. (A - weight, B - carbon dioxide analyzer, C - mercury barometer, D - oxygen analyzer, E - gas meter)
analyzer monitoring room air, the meter needle was adjusted to zero using the bridge balance control.

**Curl.** The subject assumed a position in which the forearms were parallel to the floor and the elbows approximately three inches apart. The back was in a slight arch and the legs were kept straight. The feet were positioned in a vertical line with the shoulders. The Curl position is shown in Figure 2, page 27.

**Military Press.** The subject assumed a position in which the weight could be held at eyebrow level with the hands gripping the bar at shoulder width. The forearms were held in a vertical position in relation to the floor. The back was slightly arched and the legs were kept straight. The feet were placed in a vertical line with the shoulders. The Military Press position is shown in Figure 3, page 28.

**Shoulder Shrug.** The subject assumed a position in which the arms were fully extended downward in a vertical line to the floor. Using an overhand grip, the hands were placed on the exercise bar to coincide with the width of the shoulders; the feet were also placed at shoulder width. The back was slightly arched and the legs kept straight. The Shoulder Shrug position is shown in Figure 4, page 29.
Figure 2. Procedure and position of subject for the curl exercise.
Figure 3. Procedure and position of subject for the military press exercise.
Figure 4. Procedure and position of subject for the shoulder shrug exercise.
**General Assessment Procedure.** The subject rested in a reclining position for a period of fifteen minutes. During this period, personal data were recorded. In addition, barometric pressure and room temperature were recorded.

Following the fifteen minute rest period, the subject stood for two minutes. The noseclip was then positioned and the mouthpiece inserted. Five minutes of quiet respiration followed, with the expired air collected in a sixty liter Douglas bag. The subject was then requested to assume the proper exercise position.

The weight was placed in the subject's grip by two of the testers and breathing ceased. The tester instructed the subject to hold the contraction against the resistance for ten seconds. At the end of the exercise the weight was removed and breathing resumed. The postexercise expired air was collected in a one hundred liter Douglas bag for a period of five minutes. Upon completion of the five minute postexercise expiration period, the subject returned to the reclining position for a ten minute rest period.

During the ten minute rest period, the content of the Douglas bags was analyzed for per cent oxygen and
carbon dioxide. The volume and gas temperature for each bag were also assessed.

The percentage of oxygen was assessed by placing the sensor of the oxygen analyzer into the Douglas bag. The oxygen concentration reading was recorded on the subject's personal data sheet. The bag was then attached to the carbon dioxide analyzer, where the percentage of carbon dioxide concentration was registered and recorded on the data sheet. Following the carbon dioxide reading, the Douglas bag was attached to the gas meter and the content was forced through the meter by manually squeezing the bag until it was emptied. The volume of gas in liters was recorded along with the temperature of the gas.

The above procedure was repeated until the subject had been tested in all exercise positions. The subject was then weighed. All testing was conducted on the same day.

To determine the ten second energy expenditure for each of the exercises, the following procedure was utilized:

1. The volumes of expired air for the background and postexercise period were adjusted to standard conditions using the formulas:

\[
\text{Adjusted Volume Background Count } (V_{1}) = \text{Volume Gas}_{1} \times \text{STPD}_{1}, \text{ and}
\]
Adjusted Volume Postexercise Count \( (V_2) \) =

\[ V_{gas_2} \times STPD_{2}, \]

where \( STPD_1 \) and \( STPD_2 \) were obtained by inserting the respective gas temperatures and barometric pressures into the STPD nomogram (See Appendix D) reported by Consolazio et al.  

2. The volumes of oxygen consumed during the background and postexercise period were calculated using the formulas:

\[
VO_{2_1} \text{ (liters)} = \frac{V_1 \times True \, O_2_1}{100}, \text{ and}\]

\[
VO_{2_2} \text{ (liters)} = \frac{V_2 \times True \, O_2_2}{100},
\]

where \( True \, O_2 \) was obtained by inserting the respective oxygen and carbon dioxide percentages into the True \( O_2 \) nomogram (See Appendix E) reported by Consolazio et al.  

3. The net oxygen cost for each exercise was determined using the formula:

\[
VO_2 \text{ (liters)} = VO_{2_2} - VO_{2_1}
\]

---


VI. STATISTICAL ANALYSIS

Analysis of variance for correlated groups\(^3\) was used to test for significant differences among the exercises. The Newman-Keul\(^4\) test was utilized to locate the existing differences.

The following correlations were computed:
1. Body weight with energy cost for the curl.
2. Body weight with energy cost for the press.
3. Body weight with energy cost for the shrug.

---


Analysis of variance was utilized to test for significant differences among energy expenditures for the three exercises. The single group method by Garrett\textsuperscript{1} was used for the analysis of variance. Further analysis of the differences was made through the use of the Newman-Keuls\textsuperscript{2} method for testing differences among means. This method permitted all possible comparisons among means, while holding a constant level of confidence.

Coefficients of correlation were calculated to determine the relationship between body weight and energy expenditure for each of the three exercises. The calculation of the coefficients of correlation was by the method described by Garrett.\textsuperscript{3}


\textsuperscript{3}Garrett, \textit{op. cit.}, pp. 139-141.
I. ANALYSIS OF ENERGY EXPENDITURE DIFFERENCES FOR THE CURL, SHRUG, AND MILITARY PRESS

The means and standard deviations for the energy expended at the exercise positions are presented in the following table.

TABLE I

SUMMARY OF MEAN ENERGY EXPENDED IN THE PERFORMANCE OF THE CURL, MILITARY PRESS, AND SHRUG EXERCISES UTILIZING SEVENTY-FIVE POUNDS OF STATIC RESISTANCE

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Number</th>
<th>Mean (liters of oxygen)</th>
<th>Standard Deviation</th>
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<td>Curl</td>
<td>30</td>
<td>.489</td>
<td>.175</td>
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<td>Military Press</td>
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<td>Shrug</td>
<td>30</td>
<td>.099</td>
<td>.152</td>
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</table>

As shown in the above table, variations in the amount of mean energy required to perform the specified exercises were observed. In testing these observed differences for significance, the analysis of variance showed an F ratio of 56.226, which was significant among trials, at the .01 level of confidence. The results of this analysis are shown in Table II, page 36.
TABLE II
ANALYSIS OF VARIANCE OF ENERGY EXPENDED IN THE PERFORMANCE OF THE CURL, MILITARY PRESS AND SHRUG EXERCISES UTILIZING SEVENTY-FIVE POUNDS OF STATIC RESISTANCE

<table>
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<tr>
<th>Source of Variance</th>
<th>Sums of Squares</th>
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<th>Mean Squares</th>
<th>&quot;F&quot; Ratio</th>
<th>P</th>
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<td>Among Trials</td>
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<td>Total</td>
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</table>

F needed at the .05 level of confidence = 3.15; F needed at the .01 level of confidence, = 4.98.

The results found in Table II indicated that significant differences existed in mean energy expenditure between two or more of the exercise positions. To locate the existing differences, the Newman-Keuls Test was utilized. See Table III, page 37.
TABLE III
COMPARISONS AMONG THE MEAN ENERGY EXPENDITURES FOR THE CURL, MILITARY PRESS, AND SHRUG EXERCISES UTILIZING SEVENTY-FIVE POUNDS OF STATIC RESISTANCE

<table>
<thead>
<tr>
<th>Comparison</th>
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<th>Mean Differences (liters of oxygen)</th>
<th>&quot;Q&quot;</th>
<th>Significance</th>
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<tr>
<td>Curl vs Press</td>
<td>2.60</td>
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<td>Curl vs Shrug</td>
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<td>Press vs Shrug</td>
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</table>

Q needed at the .05 level of confidence with 2 and 60 df 2.83; at the .01 level of confidence, 3.76.
Q needed at the .05 level of confidence with 3 and 60 df 3.40; at the .01 level of confidence, 4.28.

The results observed in the above table indicated that the curl required a significantly greater energy expenditure than either the military press or the shrug. In addition, the military press was found to require significantly more energy to perform than the shrug. The differences among the exercise positions were all significant at the .01 level of confidence.
In summary, analysis of variance indicated that significant differences existed among the exercise positions. Further analysis of the differences among exercise positions indicated that the curl exercise produced a significantly greater expenditure than either the press or the shrug, and that the military press produced a significantly greater expenditure than did the shrug.

II. ANALYSIS OF THE RELATIONSHIP OF BODY WEIGHT TO THE ENERGY EXPENDED FOR THE THREE STATIC EXERCISES

The relationship of body weight to the amount of energy required to perform the designated exercises is presented in the following table.

**TABLE IV**

RELATIONSHIP OF BODY WEIGHT TO ENERGY EXPENDED IN THE PERFORMANCE OF THE CURL, MILITARY PRESS, AND SHRUG UTILIZING SEVENTY-FIVE POUNDS OF STATIC RESISTANCE

<table>
<thead>
<tr>
<th>Variables</th>
<th>Number</th>
<th>Coefficient of Correlation</th>
<th>P</th>
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<tr>
<td>Body weight and curl</td>
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<td>Body weight and military press</td>
<td>30</td>
<td>.368*</td>
<td>.05</td>
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<tr>
<td>Body weight and shrug</td>
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<td>N.S.</td>
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</table>

df = 28  \( r \) at .05 = .361  \( r \) at .01 = .463
As shown in Table IV, page 38, the relationship between body weight and the curl and shrug was non-significant. The relationship of body weight to the military press was significant at the .05 level of confidence.

In summary, the coefficients of correlation indicated that a significant relationship existed between body weight and the military press. This indicated that as body weight increased, the amount of energy expenditure also increased.

Non-significant relationships existed between body weight and the curl and shrug exercises. The non-significant relationships indicated that body weight was not significantly related to the amount of energy expended while performing either the curl or shrug exercise.
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

I. SUMMARY

The purpose of this investigation was to study the energy expenditure involved in the execution of the curl, military press, and shrug exercises using seventy-five pounds of static resistance. A secondary purpose was to determine the relationship of body weight to the energy expended in the performance of each of the three specified exercises.

Thirty male graduate and undergraduate students attending Stephen F. Austin State University, Nacogdoches, Texas, participated in this study. Testing was during the academic school year 1968-69. The subjects ranged in age from seventeen to twenty-seven years and varied in weight from 143 to 228.5 pounds.

The energy cost of performing the curl, military press, and shrug exercises utilizing seventy-five pounds of static resistance was assessed. Energy expenditure was defined as the net oxygen consumed in liters during the five minutes immediately following each exercise. Oxygen consumption values were determined by the open circuit
indirect method. Each exercise was for a period of ten seconds.

Analysis of variance was used in treating the data to determine if differences existed in the amount of energy expended among the three exercises. The Newman-Keuls method was then used for locating and testing the mean differences for significance.

To further analyze the data, coefficients of correlation were employed to study the relationship between the energy expended for each of the three static exercises and body weight.

II. FINDINGS

The following findings were obtained in this study:

1. Holding a resistance of seventy-five pounds in the curl position produced a greater energy expenditure than either the military press or the shrug positions. The differences were significant at the .01 level of confidence.

2. The military press position resulted in a greater energy expenditure than the shrug position. The difference was significant at the .01 level of confidence.
3. There was a significant positive correlation between body weight and energy expended for the military press position. The correlation was significant at the .05 level of confidence.

4. There was no significant correlation between body weight and energy expenditure for either the curl or shrug positions.

It was felt by the author, as a result of interview and observation, that different exercise positions require varying degrees of effort to perform a task. The findings pertaining to the oxygen consumed in performing the various exercises seemed to warrant the general conclusion that the degree of effort perceived by the performer is directly related to the amount of energy cost as determined by oxygen consumption.

The present study failed to show a consistent relationship between body weight and static resistance. This finding was in contrast to the generally accepted positive relationship between body weight and dynamic exercise. A possible explanation for the inconsistency between body weight and the three static exercises might be found by considering the position of the exercises. Since the military press was the only exercise significantly
related to body weight, it might be assumed that the larger individual had more mass in the arms and shoulders than the smaller individual. Consequently, the former was required to support more weight during the performance than the latter, which resulted in a greater energy expenditure for the heavier person. Evidently, the mass of the individual did not affect the energy expended for the curl and shrug exercises.

III. CONCLUSIONS

Based upon the findings of this study, the following conclusions were drawn:

1. When the amount of static resistance remains uniform, the energy required to perform a task will differ in relation to the position of the exercise.

2. The degree of effort experienced by an individual performing at various exercise positions may be an indicator of the amount of energy needed to perform the exercise.

3. Body weight shows an inconsistent relationship to the amount of energy that is required to perform a static exercise.
IV. RECOMMENDATIONS

The following areas are in need of further investigation:

1. The effects that static resistances have upon the energy expended while performing static exercises.

2. Factors that affect individual energy expenditure requirements from trial to trial in the performance of a specified static exercise.
BIBLIOGRAPHY
BIBLIOGRAPHY

A. BOOKS


B. PERIODICALS


Sharkey, Brian J. "A Physiological Comparison of Static and Phasic Exercise," The Research Quarterly, XXXVII (December, 1966), 520-531.


G. UNPUBLISHED MATERIAL


APPENDIX A

TEN SECOND ENERGY EXPENDITURE DATA FOR THE STATIC EXERCISES: CURL, MILITARY PRESS, AND SHRUG

<table>
<thead>
<tr>
<th>SUBJECTS</th>
<th>WEIGHT (Lbs.)</th>
<th>CURL</th>
<th>PRESS</th>
<th>SHRUG</th>
<th>TOTAL ENERGY</th>
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Energy expenditure given in liters of oxygen
APPENDIX A

TEN SECOND ENERGY EXPENDITURE DATA FOR THE STATIC EXERCISES: CURL, MILITARY PRESS, AND SHRUG

<table>
<thead>
<tr>
<th>SUBJECTS</th>
<th>WEIGHT (Lbs.)</th>
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TOTAL 5.361.0 14.6577 9.7055 2.9710 27.3342

Energy expenditure given in liters of oxygen
# APPENDIX B

## ENERGY EXPENDITURE VALUES FROM SELECTED REVIEW OF LITERATURE STUDIES

<table>
<thead>
<tr>
<th>AUTHOR</th>
<th>Exercise</th>
<th>Duration of Exercise</th>
<th>Resistance</th>
<th>NET ENERGY COST/LTRS.</th>
</tr>
</thead>
<tbody>
<tr>
<td>McArdle</td>
<td>Squat</td>
<td>6 - Seconds</td>
<td>Maximum</td>
<td>0.772 ± 0.137</td>
</tr>
<tr>
<td>and</td>
<td>2-Arm Curl</td>
<td>6 - Seconds</td>
<td>Maximum</td>
<td>0.545 ± 0.168</td>
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<tr>
<td></td>
<td>2-Arm Press</td>
<td>6 - Seconds</td>
<td>Maximum</td>
<td>0.517 ± 0.210</td>
</tr>
<tr>
<td></td>
<td>Bench Press</td>
<td>6 - Seconds</td>
<td>Maximum</td>
<td>0.439 ± 0.244</td>
</tr>
<tr>
<td></td>
<td>and Foglia</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bartels et al.</td>
<td>Semi-reclining 10 - Seconds Sixty % Maximum</td>
<td>0.628 ± 0.189</td>
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<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Pogue</td>
<td>Right elbow flexor muscle, from supine position</td>
<td>18 - Seconds Maximum</td>
<td>0.714 ± 0.187</td>
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<tr>
<td></td>
<td>Royce</td>
<td>Strong 5 - Minutes 160 lbs.</td>
<td>1.200</td>
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</tr>
<tr>
<td></td>
<td>and</td>
<td>muscles of 130 &quot;</td>
<td>0.891</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>lower 100 &quot;</td>
<td>0.588</td>
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<tr>
<td></td>
<td></td>
<td>extremities, 70 &quot;</td>
<td>0.313</td>
<td></td>
</tr>
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<td></td>
<td></td>
<td>supine position</td>
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<td></td>
<td>Clarke</td>
<td>Standing 5 - Minutes 50 lbs.</td>
<td>1.445 ± 0.520</td>
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<tr>
<td></td>
<td>and</td>
<td>erect, with 35 &quot;</td>
<td>1.070 ± 0.130</td>
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<td></td>
<td></td>
<td>subject holding 20 &quot;</td>
<td>0.775 ± 0.120</td>
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<td>weight against thighs</td>
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<tr>
<td></td>
<td>Sharkey</td>
<td>Leg 30 - Seconds 160 lbs.</td>
<td>3.493</td>
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<tr>
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<td>and</td>
<td>extension from 120 &quot;</td>
<td>2.468</td>
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<td></td>
<td>semi-reclining 80 &quot;</td>
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<td>position</td>
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<td>Stephens</td>
<td>Leg 1 - Minute 10 lbs.</td>
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<td>extension from sitting position</td>
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APPENDIX C
DATA SHEET

NAME _________________________
WEIGHT ____________
AGE _______________
DATE ______________
BAROMETRIC PRESSURE ____________
TEMPERATURE ______________

<table>
<thead>
<tr>
<th>Curl</th>
<th>Press</th>
<th>Shrug</th>
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<tr>
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<td>P</td>
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<tr>
<td>P</td>
<td>B</td>
<td>P</td>
</tr>
<tr>
<td>*B</td>
<td>P</td>
<td></td>
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</table>

ORDER OF TESTING
1.  
2.  
3.  

Energy Cost: _____ _____ ______

*B (background
P (postexercise)
Remarks and calculations:
APPENDIX D

NONOGRAM FOR DETERMINING STPD FACTORS
APPENDIX E

NOMOGRAM FOR CALCULATING TRUE OXYGEN
The author was born in Groves, Texas, May 10, 1937. He attended elementary and junior high school in Port Arthur, Texas, and graduated from Port Neches High School, Port Neches, Texas, in 1955.

From 1955 to 1962, the author spent his service time with the United States Marine Corps and attended Lamar State College of Technology in Beaumont, Texas, where he obtained the Bachelor of Science degree in Physical Education.

From January, 1962 to September of the same year, he worked as Associate Youth Secretary for the Beaumont, Texas Y.M.C.A. He spent the following two years as teacher-coach in the South Park School District, Beaumont, Texas, and as a graduate student at Stephen F. Austin State College, Nacogdoches, Texas.

The Master of Arts degree in Physical Education was obtained during the summer of 1964. He spent the following year in private business and in the summer of 1965 entered the doctoral program in physical education and education at Louisiana State University, Baton Rouge, Louisiana.

The Doctor of Education degree, with a major in Physical Education, was awarded in May, 1970.
The author is presently teaching at Stephen F. Austin State University, Nacogdoches, Texas, where he has been employed since September, 1966.
EXAMINATION AND THESIS REPORT

Candidate: Ronnie G. Barra

Major Field: Physical Education

Title of Thesis: Energy Expenditure of Different Exercises Performed With Uniform Resistance

Approved: 

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

May 12, 1970