5-1972

# The Energy Expenditure in Comparison of the Universal Gym and Olympic Weights

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# THE ENERGY EXPENDITURE IN COMPARISON OF THE UNIVERSAL GYM AND OLYMPIC WEIGHTS

by

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A thesis submitted in partial fulfillment of
the requirements for the degree

of

MASTER OF SCIENCE

in

Health, Physical Education, and Recreation

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Logan, Utah

1972

ACKNOWLEDGMENT

The writer would like to express his appreciation to his committee members for their guidance and time to make this study possible: Chairman, Dr. Lanny Nalder, Professor Nolan Burnett, and Dr. Edwin L. Peterson.

Appreciation is extended to those subjects who participated in the study.

To my wife for her constant encouragement, patience, and hours of effort in helping analyze the data, I am especially grateful.

Ted Albert Zimmerman

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THE ENERGY EXPENDITURE IN COMPARISON OF THE

UNIVERSAL GYM AND OLYMPIC WEIGHTS

by

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Utah State University, 1972

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The purpose of the study was to investigate whether more energy is expended on the Universal Gym or on the Olympic Weights. Ten male volunteer students between the ages of 18 and 24 in a beginning weight training class were used for subjects. The test periods included a pre-test and a post-test. The subjects performed the military press and curls on both apparatuses. The expired air was collected in a Douglas bag; then, gas samples were taken from the bag and were analyzed for oxygen and carbon dioxide percentages. The respiratory quotient was determined from the volume of expired air and $O_2$ and $CO_2$ percentages. Then, the energy expended per minute was calculated.

The results showed the mean of 7.627 cal/min for the Olympic Weights and 5.441 cal/min for Universal Gym. More energy was expended in using the Olympic Weights.

(43 pages)

# CHAPTER I

## INTRODUCTION

There are two types of weight training apparatuses, the Universal Gym and the Olympic Weights. The Universal Gym is an apparatus that has several different stations, each provides for the performance of a different exercise. The stations are all connected together with a metal frame. The Olympic Weights consist of barbells, dumbbells and individual weights. The individual weights can be put on or taken off of the barbells or dumbbells depending on how much weight a trainer wants to use in exercising.

The Universal Gym has achieved widespread use among amateur weight trainers. Professionals, however, prefer to use the Olympic Weights. The reason for this preference is due to the fact that poundage on the Olympic Weights can be increased by two and one-half pound intervals which allows them a more gradual increase. Whereas, ten pounds is the smallest poundage interval on the Universal Gym. Many athletes prefer the Universal Gym because weight changing is simply a matter of moving a pin from one poundage to another. This ease in weight changing prevents boredom and gives the trainer a good rest between sets. On the other hand, weight changing on the Olympic Weights involves carrying the weights, putting them on and taking them off. As a result of this weight changing, the athlete gets bored and this also interferes with a good rest period between sets.

Justification of the Study

Coaches and trainers believe that weight training is very helpful for their athletes. Not knowing that energy expenditure is very important in weight training, many coaches and trainers cannot decide whether to use the Universal Gym or the Olympic Weights for their training program. Unfortunately, to this date there is no documented evidence as to which of the two methods utilizes more energy.

This study could contribute to knowledge on energy expenditure in weight training. It could also help coaches to determine which method of weight training to use. For example, they would be able to determine where less energy is expended per exercise so additional exercise could be used to work the entire body in shorter time. They would also know where more energy is expended when only few exercises are desired.

> The purpose of physical training is to prepare the body for instant responses to physical demands and to strengthen it for efficient activity during a reasonable length of time. There are two types of physical training: for fitness, and for athletics![1]

Finally, it informs amateur weight trainers as to which method of weight training conserves their energy for additional exercise.

Purpose of the Study

The purpose of this study was to compare energy expenditure between the Universal Gym method of weight training and the Olympic Weights method of weight training using two standard exercises, the military press and curls.

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[1]Bob Hoffman, Weight Training for Athletes (New York: Ronald Press Company, 1961), p. 3.

## Basic Assumptions

1. It was assumed that the individuals would perform to their maximum capabilities.

2. The distance between shoulder girdle muscles and bar would be the same in both methods of weight training.

3. It was assumed that each individual would be familiar with both methods of weight training.

## Delimitation of the Study

The following two delimitations were made:

1. A beginning male weight training class at Utah State University.

2. Shoulder girdle exercises; specifically, the military press and curls.

## Limitations of the Study

The following were limitations of the study that could not be controlled:

1. Subjects diet and eating habits.
2. Control of boredom during exercising.
3. Assurance that all performers would try to do their best.
4. That the individual would be loyal to the instructions concerning the research program, stating that they did not lift any weights immediately prior to the test.
5. The subjects would not eat anything 12 hours before being tested.

Method of Procedure

Subjects were tested using both the Universal Gym and the Olympic Weights as their methods of weight training. They were tested on both exercises on each apparatus. Although poundage differed between the two exercises, the poundage was the same on the different apparatuses. The isotonic method of weight training was used to exercise the shoulder girdle and arm muscles. A Douglas bag was used for gas collection. The Douglas bag ". . . has proved very successful in practice for short period work, for it is simple to operate, readily adaptable to a great variety of conditions and has the advantage of portability."[2]

The first test given to the individual subject was the Basal Metabolism Rate pre-test. The Basal Metabolism Rate test was given with the McKesson Recording Waterless Metabolor Model No. 185. The use of this instrument involved two procedures for the metabolism test. The first procedure was measuring the rate at which oxygen was absorbed by the subject by inhaling a known oxygen constant from the apparatus. The second procedure was to compute the rate of metabolism oxidation from the quantity of oxygen used in six minutes.

This instrument was charged with metalime or soda lime granules which saturated the carbon dioxide. When the granules turned a violet color they were removed. A cylinder of oxygen was attached to the instrument from which each subject breathed. The pen was filled with ink and placed at the base line of the chart. The inhaler unit was

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[2]C. C. Douglas, "The Development of Experimental Methods for Determining the Energy Expenditure in Man," Proceedings of the Nutrition Society, XV, (1965), p. 493.

adjusted to the subjects face. The subjects were instructed not to eat anything after midnight the day before the test. The inhaler was placed on the subject, the oxygen valve was opened and the chart drive motor was started and ran for six minutes.

Calculations for determining the number of calories for the Basal Metabolism Rate test are as follows:

A. The volume of oxygen consumed per hour and the temperature of the apparatus and the barometric pressure are recorded. At the intersection of the temperature and barometric columns on Table A will be found a factor. This factor is multiplied by the volume of oxygen consumed per hour to get calories per hour.

B. The subject's height and weight on Table B and at the intersection of these two rows of figures shows the subject's surface area in square meters. Calories per hour divided by the square meters determines calories per square meter per hour.

C. Calories per square meter per hour and age of the subject are applied to Table C to find if the subject's resting rate is above or below normal.

The following preparations were made before and during the collection of air samples from the subjects. First, five syringes were sealed with an acid base and an eraser was put on the tip of each needle to keep the expired air in the syringe without contamination. All syringes were labeled for each subject. Second, a check of the face masks was made to verify that the fixtures were securely attached and that there were no leaks. Third, the Douglas bag, its

clamps and plug were taken to the room along with a metronome, which was used to maintain a regular tempo and speed of repetitions while the subjects were exercising. All the material was in the experimenting room. Fourth, the Wet Test Meter had to be balanced on the floor. The Wet Test Meter is designed to provide an accurate measurement of the total volume of gas flowing through it. The gas source is connected to the meter and the gas flows into the quadrant of the rotor. The rotor records the number of liters while turning. Fifth, one cotton ball with rubbing alcohol was used to wipe out the inside of the face mask which was then left to dry. The clock and metronome were placed on a desk so that the subjects could face them while exercising.

The subject put the mask on his face and then the mask was attached to the Douglas bag. At the same moment the subject began performing, the military press, the clock and metronome were started. Thus, the subject, metronome and clock all began simultaneously. The weight training exercises were performed with a weight that enabled the subject to exercise for 30 seconds. The weight each subject used was determined in the pre-test. As the subject lifted, he kept in time with the metronome. Each subject lifted for 30 seconds, then stopped lifting and continued to breathe for another 30 seconds. The 30 seconds of extra breathing were used so that the oxygen could be exchanged within the body. When the lifting and breathing period was over, the experimenter disconnected the Douglas bag from the face mask. A plug was put in the Douglas bag to hold in the expired air. Next the clamp was removed and some air extracted into the syringe. After placing the eraser back on the needle, the

syringe was put on ice. The clamp was replaced on the Douglas bag and the bag was connected to the Wet Test Meter. The air was forced out of the Douglas bag into the Wet Test Meter until the bag was empty. The number of liters were indicated on the Wet Test Meter in liters and milliliters. The Wet Test Meter was reset to zero. The face mask was then removed from the subject and cleaned with rubbing alcohol. The whole process was then repeated on another subject doing the same exercises.

After five subjects had been tested, all of the equipment was taken back to the lab. The next testing date, five more subjects were tested doing the same exercise on the same apparatus. Then, on the next testing date, group one was tested doing the military press again, but on the other apparatus, the Universal Gym. The poundage was the same as used on the Olympic Weights.

The curl exercise was administered in the same manner as the military press except the poundage was changed, but was the same on both apparatuses.

Once the air samples were in the lab, the five syringes were taken off the ice and set in the lab for half an hour to let the air come back to its natural temperature. When analyzing started, the experimenter began with the last air sample taken. The Fry Gas Analyzer was used to determine the oxygen and carbon dioxide content in the air samples. The analyzer is accurate to the $\pm$ 0.05 percent. The two gas sample readings obtained from doing the military press were then combined with the volume of expired air and calculated into calories in order to find out on which apparatus the most energy was expended. The same was done with the gas samples from the curls.

The following procedure was used for analyzing the air samples:

A. Preparation of the air sample

1. A 21-gauge hypodermic needle was attached to a 5.0 milliliter glass syringe with a glass tapered tip.
2. The barrel of the syringe was moistened by drawing up a small amount of 0.5 percent sulfuric acid ($H_2SO_4$) into the syringe. The excess acid was expelled. Acid was used instead of oil because it proved more satisfactory in the cool temperatures at the experiment location as the plungers slid more easily. The use of acid instead of oil is the standard technique in the Fry analysis.
3. Approximately 5.0 milliliters of gas was removed from the clamped-off rubber bladder. This sample was sufficient for the gas analysis made.
4. The needle was immediately plugged by inserting the free end into a soft rubber eraser to avoid minor errors due to diffusion of gases or accidental movement of the plunger.
5. The samples were allowed to equilibrate to room temperature and pressure before analysis at the laboratory (about 30 minutes).

B. Introduction of the gas into the Fry Gas Analyzer

1. The knob on the instrument was turned until the mercury came up to the bottom of the cup at the top of the buret.
2. A dropperful of 0.5 percent $H_2SO_4$ was placed in the cup and the acid was drawn down to the top of the bulb at the base of the buret.

3. The air from the syringe prepared above was injected into the instrument through the injection port on the bulb at the base of the buret. No gas was left trapped in the side arm.
4. Any mercury that was pushed up into the buret was allowed to fall back into the bulb.
5. The knob of the instrument was turned so that the air sample was pushed up into the buret. Any excess gas was expelled through the cup at the top of the buret so that a column of gas in the buret measured approximately 6 cm.
6. The contents of the buret were adjusted so that the excess air was removed from the buret leaving only a fluid seal on top of the gas bubble. A syringe with an 18-gauge needle was most efficient in this process.
7. The top of the gas meniscus was set at zero on the buret.
8. After allowing four minutes for the acid to drain down from the walls of the buret, the meniscus was again adjusted to zero and the lower meniscus level of the buret was read.
9. A dropperful of 0.5 N potassium hydroxide (KOH) was placed in the cup so that it was on top of the remaining acid seal.
10. The contents of the buret were drawn down to the bottom of the buret. In doing so, the walls of the buret were coated with KOH.
11. The gas bubble was then moved up and down the buret

several times so that the $CO_2$ was absorbed by the KOH.

12. After the $CO_2$ had been absorbed, the excess KOH was removed with a syringe and the upper meniscus was adjusted to zero. A new reading was then made.
13. A dropperful of $O_2$ absorber was placed in the cup and the steps were repeated. This reagent absorbs the oxygen ($O_2$) from the solution and the difference in volume is due to the removal of the oxygen from the air sample. The remaining air contains the nitrogen and other inert gases.
14. The sample and reagents were expelled and the apparatus was washed three times with 0.5 percent $H_2SO_4$ to clean the buret and acidify the apparatus for the next analysis.

C. Reagents for the Fry Gas Analyzer

1. Acid rinse - 0.5 milliliters of $H_2SO_4$ was added to 100 milliliters of distilled water and placed in a plastic bottle. A syringe was used for extraction.
2. $CO_2$ absorber - 7.0 gm of KOH was added to 250 milliliters of distilled water (0.5N). A small plastic squeeze bottle with a slip-on cover was filled from the prepared stock solution.
3. $O_2$ absorber - one gram of 2-anthroquinonesulfonic acid (sodium salt) and 10 gm sodium hydrosulfite were dissolved in 100 milliliters of 0.5 N KOH. Mix rapidly to dissolve the reagents and filter through gauze. The solution may be stored in 50 milliliter syringes or in

a volumetric flask sealed with a hypodermic stopper. The volumetric flask was used with a syringe fitted with a 26-gauge needle. All precautions must be taken to prevent the solution from being exposed to the air and taking up the $O_2$ present to become exhausted.[3]

## Calculations

To determine the energy expenditure for the military press and curls, all volumes of measured gas were converted to respiratory quotient and then calculated into the number of calories. The following form was used:

| Final Air Respiration | Initial |
|---|---|
| % $CO_2$ _____ | .03% $CO_2$ |
| % $O_2$ _____ | 20.93% $O_2$ |

Expired Air Volume = _____Liter/minute at 25°c at 640 mm Hg

_____x .77 = volume of STP

Initial Final % $CO_2$ = Liters/minute_____

STP volume _____x Initial Final % $O_2$ = Liters/minute_____

Initial Final = % $CO_2$ _____

% $O_2$ _____

Expired air volume x % $O_2$ consumed = volume of $O_2$ consumed

_______________ x ___________ = _________________

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[3]Le Grande C. Ellis, Instructions for the Operation of the Fry Gas Analyzer (Unpublished pamphlet of instruction, Utah State University, Department of Physiology, 1969), pp. 1-9.

Expired air volume x % $CO_2$ produced = volume of $CO_2$ produced

________________ x ____________ = ___________________

Respiratory Quotient = $\frac{\text{Volume } CO_2}{\text{Volume } O_2}$ __________ = __________

________cal/ml $O_2$ consumed x volume of liters/minute ______

Number of calories/minute ______

The $O_2$ and $CO_2$ percentages were samples taken from the Douglas bag and analyzed by the Fry Gas Analyzer. The test was comprised of performing the military press and the curls both on the Universal Gym and on the Olympic Weights. The results from each apparatus were compared for each exercise.

Subjects

There were ten male volunteer subjects. They ranged in age from 18 to 24 years. The details on their height, weight and age are listed in Table 1.

Table 1. Anthropometric measures of the subjects

| Subject | Age | Height, cm | Weight, kgm |
|---|---|---|---|
| 1 | 19 | 178.0 | 75.0 |
| 2 | 19 | 173.0 | 67.0 |
| 3 | 19 | 186.0 | 81.0 |
| 4 | 20 | 173.0 | 81.0 |
| 5 | 19 | 173.0 | 68.0 |
| 6 | 19 | 172.0 | 65.0 |
| 7 | 19 | 172.0 | 57.0 |
| 8 | 24 | 186.0 | 111.0 |
| 9 | 20 | 168.0 | 66.0 |
| 10 | 18 | 186.0 | 88.0 |

Height of the subjects ranged from 186.0 centimeters to 168 centimeters. The heaviest subject was 111.0 kilograms and the lightest subject was 65.0 kilograms.

Definition of Terms

The following definitions will be used throughout the paper:

1. Universal Gym: This is an apparatus that has several different stations. Each station is used to do a different exercise in weight training.

2. Olympic Weights: These are the weights used for competition lifting.

3. Military Press: An exercise in weight training in which the individual presses the weight from his shoulder to over his head.

4. Curls: An exercise in weight training in which the individual grips the bar with his palms up and his arms extended. The individual then pulls the bar to his chest, bending at the elbows.

5. Isotonic: Shortening of muscles during contractions when the load remains the same.

6. Weight training: As used in this study denotes a routine of exercises performed with barbells and the Universal Gym.

7. Mean ($\bar{X}$): The sum of all scores, divided by the total number of scores.

8. Calorie (cal): The amount of heat required at a pressure of one atmosphere to raise the temperature of one gram of water 1 c.

9. Energy: The capacity for executing work.

10. Volume of liters: The total amount of expired air utilized by the body in a given exercise period.

11. Respiratory quotients: $\frac{\%\ CO_2\ \text{produced}}{\%\ O_2\ \text{consumed}}$

12. Set: The number of repetitions in a particular exercise.

# CHAPTER II

# LITERATURE REVIEW

In weight training, both the Universal Gym and the Olympic Weights have become very important during the past five years for college and high school athletic programs. Today there is hardly a sport that does not have an off-season weight training program. Kusinitz has stated that coaches at both high school and college levels are confronted with a common problem. This problem is that they must fit practice and training for varsity sports into a limited amount of time. It is difficult for them to decide whether to spend the entire time practicing, or to spend part of the time practicing and the other part of the time in supplementary training.[4]

Successful coaches have stressed weight training as a form of supplementary training to improve the performance of their athletes. In stressing weight training, too many coaches often confuse it with weight lifting which disillusions their athletes in lifting weights.

> In weight lifting the competitior endeavors to raise a maximum weight in a single lift, whereas in weight training, the participant executes many consecutive repetitions of each exercise with a weight which has been found to be compatible with his strength and endurance.[5]

Most weight training is done to strengthen the muscles in the body. Forty-three percent of the body bulk consists of 250 million

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[4]L. Kusinitz, "Strength Training in the Varsity Athletic Program," Physical Educator, XXVI, (December, 1969), pp. 176-77.

[5]Edward Chui, "The Effects of Systematic Weight Training on Athletic Power," Research Quarterly, XXI, (October, 1950), p. 188.

muscle filaments. The body responds to the slightest disturbance in the environment while performing freely. The body is consistantly under change; consequently, it is not a permanent structure. Bones construct 18 percent of the body weight, skeletal muscles number 656 on the body. Some muscles are inefficient and cannot be strengthened for body use.[6] "On any reckoning, these differences are small and weight is the most important factor in determining individual energy expenditure."[7]

Many things effect energy expenditure; such as, age, sex, body size and structure, body position, race, culture, type of work, types of recreations, season and heat, food intake, and altitude.[8] Energy expenditure estimations are difficult, however, because errors will arise in a failure to determine length of time spent in any activity rather than the metabolic cost of that activity.[9] The apparatuses and tables used for measuring energy expenditure have changed through the years; consequently, the results vary depending upon what type of apparatus and calories tables are used for calculations. Energy expenditure has been studied to extremes in sports and in the daily life work of individuals. "There is a large variation in energy expenditure by individuals leading the same type of life."[10] Differing

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[6]Bob Hoffman, Weight Training for Athletes (New York: Ronald Press Company, 1961), pp. 3-34.

[7]R. Passmore and J. V. G. A. Durnin, "Human Energy Expenditure," Physiological Reviews, XXV, (1955), p. 826.

[8]R. Passmore and J. V. G. A. Durnin, "Human Energy Expenditure," Physiological Reviews, XXV, (1955), pp. 801-40.

[9]Ibid.

[10]Ibid., p. 828

values of energy expenditure per day are due to body weight and activities outside of working hours. Therefore, even the energy expenditure of one individual will vary from day to day and from week to week.[11]

In order that the subjects in this study perform the assigned exercises with uniformity, it was necessary to inform them on how to successfully use their energy. They were told that while performing the exercises, they must be sure to extend and flex joints, and to pause between repetitions. Homola said,

> In all exercises, the joints should be fully flexed and extended with a pause between repetitions at the starting point. It is not necessary to maintain constant tension of the muscles by keeping the joints partially flexed. In fact, by relaxing the muscles momentarily while the joints are fully extended, as in curls, the athlete can prevent muscle shortening and increase the flow of blood to reduce the oxygen debt.[12]

Since energy was an important factor in this study, it was necessary to understand a few facts about it. For example, body size was extremely important in determining energy expenditure, because an obese person will always expend more energy than the slender person. Furthermore, females consistently show more energy expenditure than males because they have a greater surface area.[13] The influence of the season and heat on energy output also causes

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[11]R. Passmore and J. V. G. A. Durnin, "Human Energy Expenditure," Physiological Reviews, XXXV, (1955), pp. 801-40.

[12]Samuel Homola, "Increase Strength Speed and Flexibility Through Weight Training," Scholastic Coach, XXXVII, (December, 1967), p. 52.

[13]Wallace P. McKee and Robert E. Bolinger, "Calorie Expenditure of Normal and Obese Subjects During Standard Work Test," Journal of Applied Physiology, XV, No. 2 (1960), pp. 197-201.

it to vary greatly.[14] "A modest but consistant increase in mean energy expenditure occurred at all levels of activity in the winter thermoneutral, summer-hot, and winter-hot experiments over the summer-thermoneutral experiments."[15]

Finally, elevation increases the basal expenditure of energy instead of increasing the energy used to perform the actual work.[16] There are three components of energy expenditure. They include energy expended while asleep in bed which is about 50 calories per day; energy expended while at work which will vary from 1.67 cal/min to 5 cal/min; and energy expended while not at work. There are two types of work. "In positive work, muscles contract concentrically (shorten); in negative work they 'contract' eccentrically (elongate)."[17] Both of these types of work are a product of force and distance. The work performed on a load involves both positive and negative work. Lifting the load involves positive work and negative work results by lowering the load.

> Unduly heavy, energy expenditure over 12.5 cal/min. Very heavy, energy expenditure over 10.0 cal/min. Heavy, energy expenditure over 7.5 cal/min. Moderate, energy expenditure over 5.0 cal/min. Light, energy expenditure over 2.5 cal/min.[18]

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[14]Armand J. Gold, Abraham Zornitzer and Shlomo Samueloff, Influence of Season and Heat on Energy Expenditure During Rest and Exercise," Journal of Applied Physiology, XXVII, No. 1 (1969), pp. 9-12.

[15]Ibid., p. 9

[16]Wallace P. McKee and Robert E. Bolinger, "Calorie Expenditure of Normal and Obese Subjects During Standard Work Test," Journal of Applied Physiology, XV, No. 2 (1960), pp. 197-200.

[17]Peter V. Karpovick, Physiology of Muscular Activity (Philadelphia and London: W. B. Saunders Company, 1969), p. 67.

[18]R. Passmore and J. V. G. A. Durnin, "Human Energy Expenditure," Physiological Reviews, XXV, (1955), p. 832.

The third component of energy expenditure was energy expended while not at work. This energy expenditure has a wide range of calories expended. "At work, during recreation and asleep, weight is the dominant factor determining individual variation in energy expenditure."[19] Factors affecting energy expenditure differ greatly depending on the activity which is involved. Following are several examples of different activities, the calories expended in performing that activity, and factors affecting energy expenditure.

Table 2. An overview of metabolic cost of sporting activities done in previous years[20]

| Activity | Body wt, kg | Cal/min | Cal/kg/ 10 min |
|---|---|---|---|
| Canoeing 2.5 mph | 68.0 | 3.00 | 0.441 |
| Canoeing 4.0 mph | 68.0 | 7.00 | 1.029 |
| Volleyball | 68.0 | 3.50 | 0.505 |
| Pitching horseshoes | 73.2 | 3.79 | 0.518 |
| Shooting pool | 59.1 | 1.77 | 0.299 |
| Playing ping pong | 73.2 | 4.90 | 0.566 |
| Playing baseball (except pitcher) | 68.1 | 4.67 | 0.686 |
| Calisthenics | 68.1 | 5.00 | 0.734 |
| Rowing for pleasure | 68.1 | 5.00 | 0.734 |
| Bicycling on level roads | 68.1 | 5.00 | 0.734 |
| Archery | 69.0 | 5.20 | 0.754 |
| Golfing | 63.0 | 5.00 | 0.794 |
| Snowshoeing 2.27 mph | | 6.19 | 0.835 |
| Bowling | 73.2 | 7.84 | 0.975 |
| Playing tennis | 70.0 | 7.10 | 1.014 |
| Playing basketball | 73.2 | 8.56 | 1.032 |

[19] R. Passmore, "Daily Energy Expenditure by Man," Proceedings of the Nutrition Society, XV, (1956), p. 88.

[20] C. F. Consolazio, R. E. Johnson, and L. Pecara, Physiological Measurements of Metabolic Functions in Man (New York: McGraw-Hill Book Company, Inc., 1963), p. 331.

Table 2. Continued

| Activity | Body wt, kg | Cal/min | Cal/kg/ 10 min |
|---|---|---|---|
| Playing football (American) | 73.2 | 10.19 | 1.178 |
| Playing football (Association) | 68.0 | 8.90 | 1.308 |
| Sled pulling (87 lb) 2.27 mph | | 9.30 | 1.242 |
| Mountain Climbing | 68.1 | 10.00 | 1.470 |
| Playing squash | 67.0 | 10.20 | 1.522 |
| Cross Country running | 65.0 | 10.60 | 1.630 |
| Running long distance | 68.1 | 15.00 | 2.203 |
| Sprinting | 68.1 | 23.30 | 3.423 |
| Running | 73.2 | 37.94 | 5.514 |
| Dancing, fox trot | 80.0 | 5.20 | 0.650 |
| Waltz | 76.0 | 5.70 | 0.750 |
| Rumba | 69.0 | 7.00 | 1.014 |
| Swimming, (pleasure) | 73.2 | 11.69 | 1.454 |
| Breast Stroke 20 yd/min | 71.0 | 5.00 | 0.704 |
| Breast Stroke 30 yd/min | 71.0 | 7.50 | 1.056 |
| Breast Stroke 40 yd/min | 71.0 | 10.00 | 1.408 |
| Back Stroke 40 yd/min | 90.0 | 11.00 | 1.222 |
| Side Stroke 40 yd/min | 90.0 | 11.00 | 1.222 |
| Crawl 45 yd/min | 90.0 | 11.50 | 1.278 |
| Crawl 55 yd/min | 90.0 | 14.00 | 1.556 |

First of all, posture, walking and running were considered. The cost of energy concerning posture, in terms of calories per minute are as follows: lying down, 1.14; sitting, 1.19; standing, 1.25.[21] Energy cost while walking depends upon speed of the individual's gait, differing occasions with the same individual and also the course of the same walk.[22] "The ground covered may also change, not only in type of

[21]Peter V. Karpovick, Physiology of Muscular Activity (Philadelphia and London: W. B. Saunders Company, 1969), pp. 45-107.

[22]R. Passmore and J. V. G. A. Durnin, "Human Energy Expenditure," Physiological Reviews, XXXV, (1955), pp. 801-40.

surface smooth or rough, but also in gradient; it may be level, uphill, or downhill all the way, but sometimes it is a mixture of all three."[23] Running expenditure depends on the degree of training, speed, distance, and efficiency of the subject. Energy expenditure of running will vary from 9 cal/min to 20 cal/min depending on speed alone.[24]

> The basal rates probably depend more on the metabolism of the internal organs than do any of the other rates, but there must be a muscular element in them, and the small increases in the expenditure per minute when people sit up and then stand up may be attributed to the small additional amounts of muscular energy needed for these tasks.[25]

Skiing and snowshoeing energy expenditure is determined by the speed and distance of the individual skiier or snowshoer. The energy cost in skiing is also affected by the type of surface. Loose snow increases energy expended, whereas, packed snow decreases the amount of energy expended. Carrying a pack while skiing and snowshoeing will also increase the amount of energy expended.[26]

Energy cost while swimming is affected by a number of factors; such as, speed, distance, stroke, skill of the individual, and

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[23] Ibid., p. 805

[24] R. Passmore and J. V. G. A. Durnin, "Human Energy Expenditure," Physiological Reviews, XXXV, (1955), pp. 801-40.

[25] J. Booyens and R. A. McCance, "Individual Variations in Expenditure of Energy," The Lancet, CCLXXII, (1957), p. 228.

[26] Peter V. Karpovick, Physiology of Muscular Activity (Philadelphia and London: W. B. Saunders Company, 1969), pp. 45-107.

condition of the individual. The order of increasing energy cost is as follows: crawl stroke (highest), back stroke, breast stroke, and side stroke.[27]

In doing calisthentics the energy cost will vary from individual to individual. The tempo and rhythm of the movement during the performance of calisthentics will effect energy expenditure. Energy cost of a handstand is 2.010 liters of oxygen per minute. The energy cost of a handstand is approximately five and one half times over that of sitting. This increase of energy is due to the weakness of the upper extremities in doing the handstand.[28]

Football is one sport where direct energy expenditure calculations are impossible. Indirect measurements, however, have found some data concerning energy expenditure in which the players consume 5600 calories a day. The players will expend 2500 calories in a practice. Energy expenditure during practice is calculated to about 13.3 cal/min for each actual football play.[29]

Most of the data collected on bicycling energy expenditure is taken from stationary bicycle ergometers. In actual bicycling, however, surface area and speed will both effect energy output. Conditioning of the individual and the legs of the individual, and size of the bicycle tire will affect it also. For example, a large bicycle tire causes about 1 cal/min more energy output than the

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[27]R. Passmore and J. V. G. A. Durnin, "Human Energy Expenditure," Physiological Reviews, XXXV, (1955), pp. 801-40.

[28]Peter V. Karpovick, Physiology of Muscular Activity (Philadelphia and London: W. B. Saunders Company, 1969), pp. 45-107.

[29]Ibid.

smaller racing bicycle tire. Most experiments on bicycling have been long range programs in which the subjects ride for hours. The average energy cost of bicycling is about 2.5 cal/min.[30]

Weight lifting energy expenditure differs according to the individuals muscular force. "The muscular force depends on body weight because body weight is forty percent muscle."[31] The type of weight lifting, isotonic or isometric, will affect energy expenditure. Isotonic weight lifting uses two times as much energy as isometric. This difference is due to the full range of motion which is used in isotonic weight lifting.[32]

Snow shoveling energy expenditure is affected by two major factors. First is the condition of the snow. Wet snow requires more energy than does dry snow. Second is the eagerness of the shoveler. The amount of each load and the height of the snow will effect energy output to some extent. The usual energy expenditure in shovelling is about 6 to 7 cal/min.[33]

Household energy expenditure is attributed to many factors; such as, size of family, size of house, amount of help received, labor saving devices and the housekeeper's attitude toward housework. The average energy expenditure in doing housework is 1600 calories per

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[30]R. Passmore and J. V. G. A. Durnin, "Human Energy Expenditure," Physiological Reviews, XXXV, (1955), pp. 801-40.

[31]Peter V. Karpovick, Physiology of Muscular Activity (Philadelphia and London: W. B. Saunders Company, 1969), p. 101.

[32]Peter V. Karpovick, Physiology of Muscular Activity (Philadelphia and London: W. B. Saunders Company, 1969), pp. 45-107.

[33]Ibid.

day. It may range, however, from 881 calories on a Sunday to 4378 calories on a wash day.[34]

Thus, it has been shown by the preceeding examples that energy expenditure varies tremendously from individual to individual, from activity to activity, within an individual and within an activity. Although the expenditure of energy does vary greatly, there are only three sources from which a person may obtain this energy.

The three sources of energy which the body provides during muscular activity are glycogen, carbohydrates and protein. Glycogen is the main source for energy, being one percent of the muscle weight. Glycogen is useful only in the presence of oxygen which transforms it into explosive energy. Burned glycogen is lactic acid. This acid is removed from the body when it is combined for a second time with oxygen in order to leave the muscles through the blood system to the liver which changes it into its original form, glycogen. Carbohydrates, like glycogen, are stored as fat in the body. Fats are used only in endurance activities and heavy prolonged weight training, because so much oxygen is required to convert fat into energy. The final source of energy, protein, is seldom used as a source of energy due to the fact that it is needed as a repair and restoration mechanism for destroyed tissue.[35] "In experiments of short duration, since the metabolism of proteins may be disregarded, the variations in respiratory quotient may be interpreted in the light of carbohydrate and fat metabolism."[36]

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[34] Ibid.

[35] Bob Hoffman, Weight Training for Athletes (New York: Ronald Press Company, 1961), pp. 3-34.

[36] Peter V. Karpovick, Physiology of Muscular Activity (Philadelphia and London: W. B. Saunders Company, 1969), p. 47.

There are two methods of measuring energy output; direct calorimetry and indirect calorimetry. The latter will be used for this study. Indirect calorimetry produces carbon dioxide from the oxygen utilized. This energy output and the respiratory gases are directly related. For this reason, one has two methods of indirect calorimetry; closed-circuit and open-circuit. "The closed-circuit method illustrated in Fig. 8-3- the subject inspires from a face mask that is connected to an oxygen chamber (which is charged from an $O_2$ cylinder)."[37] "Thus, only the $O_2$ that remains after the respiratory exchange is returned to the oxygen chamber, and the changes in the volume of the $O_2$ that remains in the chamber, are recorded from breath to breath."[38] The closed-circuit's only advantage is simplicity, because accuracy is at the $\pm$ 10 percent level of true value. Estimation of respiratory quotient $CO_2$ must be made because no value was obtained. "In the open-circuit system, the subject inspires directly from the atmospheric air and expires into a rubberized canvas bag called a 'Douglas bag!"[39]

> The Douglas bag (Douglas, 1911) is a special instance of such an 'instrument' in which all the air is collected and is available for subsequent analysis and volume measurement. It is just those qualities which make the Douglas bag an absolute method for laboratory work that militate against its employment in the field.[40]

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[37] Herbert A. de Vries, Physiology of Exercise for Physical Education and Athletics (Dubuque, Iowa: Wm. C. Brown Company Publishers, 1966), p. 36.

[38] Ibid.

[39] Ibid., p. 151.

[40] H. R. Noltie, "Modern Techniques of Measuring Energy Expenditure," Proceedings of the Nutrition Society, XV, (1956), p. 77.

Gas samples will be taken from the bag and measured by a gas meter, $CO_2$ and $O_2$ concentrations of air in the atmosphere are constant, 0.03 and 20.93 percent, respectively. There is no physiological bearing on the remaining gasses, (79.04 percent) are considered $N_2$.

# CHAPTER III

## RESULTS

In this study the total volume of expired air ranged from 36.5 to 12.0 liters/min. The largest total volume of expired air for Olympic Weights with the military press was 34.0 liters/min, the smallest was 17.0 liters/min, and the $\overline{X}$ total volume of expired was 26.5 liters/min. For the Universal Gym, with the military press, the range was from 31.0 liters/min to 17.0 liters/min, and the $\overline{X}$ was 23.9 liters/min.

The $\overline{X}$ total volume of expired air for Olympic Weights with curls was 27.7 liters/min, whereas for the Universal Gym the $\overline{X}$ total volume of expired air was 20.1 liters/min.

The $\overline{X}$ range of the total volume of expired air for Olympic Weights was 52.4 liters/min, but the $\overline{X}$ range for the Universal Gym was 44.8 liters/min.

The percentage of $O_2$ and $CO_2$ ranged from 19 percent $O_2$ and 2 percent $CO_2$ as shown in Table 3. The $\overline{X}$ percentage of $O_2$ for the Universal Gym was 33 percent. The $\overline{X}$ percentage of $CO_2$ for Olympic Weights was 6.6 percent and the $\overline{X}$ percentage of $CO_2$ for the Universal Bym was 5.6 percent.

The military press range of $O_2$ and $CO_2$ was 15 percent $O_2$ and 2.5 percent $CO_2$ as shown in Table 4. The $\overline{X}$ percentage of $O_2$ for military press was 17.42 percent and the percentage of $CO_2$ was 3.1 percent. The percentage range of $O_2$ and $CO_2$ for curls was 19 percent $O_2$ and 2 percent $CO_2$ as shown in Table 3. The total $\overline{X}$ range for

$O_2$ was 17.15 percent, whereas the total was 3.1 percent for $CO_2$.

The $\overline{X}$ percentage of $O_2$ and $CO_2$ for Olympic Weights with military press was 17.30 percent for $O_2$ and 3.3 percent for $CO_2$. The Universal Gym $O_2$ and $CO_2$ percentage for military were 17.55 percent for $O_2$ and 2.9 percent for $CO_2$.

Table 3. Number of calories, percentage of carbon dioxide and oxygen in expired air performing curls on olympic weights

| Subjects | $CO_2$ % Expired Air | $O_2$ % Expired Air | Cal/min |
|---|---|---|---|
| 1 | 2.0 | 19.0 | 2.016 |
| 2 | 4.0 | 16.0 | 3.840 |
| 3 | 3.0 | 17.0 | 3.800 |
| 4 | 3.0 | 17.0 | 5.225 |
| 5 | 4.0 | 16.0 | 5.784 |
| 6 | 5.0 | 16.0 | 4.536 |
| 7 | 3.0 | 17.0 | 3.325 |
| 8 | 3.2 | 16.0 | 4.212 |
| 9 | 3.2 | 16.0 | 4.680 |
| 10 | 3.0 | 18.0 | 3.528 |

Table 4. Number of calories, percentage of carbon dioxide and oxygen in expired air performing military press on the olympic weights

| Subjects | $CO_2$ % Expired Air | $O_2$ % Expired Air | Cal/min |
|---|---|---|---|
| 1 | 3.0 | 18.0 | 3.528 |
| 2 | 3.0 | 18.0 | 2.016 |
| 3 | 5.0 | 15.0 | 4.338 |
| 4 | 3.0 | 17.0 | 3.325 |
| 5 | 2.5 | 17.0 | 4.680 |
| 6 | 3.0 | 18.0 | 3.528 |
| 7 | 3.0 | 18.0 | 2.520 |
| 8 | 4.0 | 17.0 | 4.536 |
| 9 | 3.0 | 17.0 | 3.325 |
| 10 | 3.0 | 18.0 | 3.528 |

The largest number of calories burned by a subject was 5.784 cal/min and the smallest was 1.512 cal/min as shown in Tables 3 and 5. The number of calories ranged from 4.680 cal/min to 1.740 cal/min with the military press, and the $\overline{X}$ was 3.318 cal/min. The curl range for the number of calories was 5.784 cal/min to 1.512 cal/min and the $\overline{X}$ was 3.381 cal/min.

Table 5. Number of calories, percentage of carbon dioxide and oxygen in expired air performing the curls on the Universal Gym

| Subject | $CO_2$ % Expired Air | $O_2$ % Expired Air | Cal/min |
|---|---|---|---|
| 1 | 3.0 | 18.0 | 3.024 |
| 2 | 3.0 | 18.0 | 3.024 |
| 3 | 3.0 | 18.0 | 2.520 |
| 4 | 3.0 | 17.0 | 2.832 |
| 5 | 3.0 | 17.0 | 4.750 |
| 6 | 2.5 | 17.0 | 2.340 |
| 7 | 3.0 | 18.0 | 1.512 |
| 8 | 3.0 | 17.0 | 1.900 |
| 9 | 3.0 | 17.0 | 1.748 |
| 10 | 3.0 | 18.0 | 3.024 |

The $\overline{X}$ number of cal/min expended for the Olympic Weights was 7.627, whereas the $\overline{X}$ for the Universal Gym was 5.441 cal/min. The $\overline{X}$ number of calories for the Olympic Weights with military press was 3.532 cal/min. The Universal Gym $\overline{X}$ number of calories for military press was 3.081 cal/min as shown in Table 6.

The largest poundage used for exercising during the experiment was 90 pounds; the smallest was 40 pounds as shown in Table 7.

Table 6. Number of calories, percentage of carbon dioxide and oxygen in expired air performing military press on the Universal Gym

| Subjects | $CO_2$ % Expired Air | $O_2$ % Expired Air | Cal/min |
|---|---|---|---|
| 1 | 3.0 | 17.0 | 3.816 |
| 2 | 3.0 | 18.0 | 2.016 |
| 3 | 3.0 | 18.0 | 3.528 |
| 4 | 3.0 | 18.0 | 2.520 |
| 5 | 3.0 | 18.0 | 3.024 |
| 6 | 3.0 | 18.0 | 3.528 |
| 7 | 3.0 | 18.0 | 1.740 |
| 8 | 3.0 | 18.0 | 2.520 |
| 9 | 10.0 | 12.0 | 5.040 |
| 10 | 2.5 | 15.0 | 0.000 |

Table 7. Poundage used according to exercise and subject

| Subjects | Military Press Poundage | Curls Poundage |
|---|---|---|
| 1 | 80 | 70 |
| 2 | 50 | 60 |
| 3 | 80 | 70 |
| 4 | 90 | 70 |
| 5 | 80 | 60 |
| 6 | 50 | 50 |
| 7 | 50 | 40 |
| 8 | 60 | 60 |
| 9 | 60 | 50 |
| 10 | 50 | 50 |

Military press poundage ranged from 90 lbs. to 50 lbs. Curl poundage ranged from 70 lbs. to 40 lbs. The $\overline{X}$ weight for military press was 65 lbs. and the $\overline{X}$ weight for curls was 58 lbs.

The Basal Metabolism Rate test results of the subjects are shown on Table 8. The highest rating of the subjects was 83 percent above normal and the lowest rating was 2 percent above normal.

Table 8. Basal metabolism rating

| Subject | Cal/hr | Cal/sq meter/hr | Rating |
|---|---|---|---|
| 1 | 144.40 | 75.6 | 83% above normal |
| 2 | 101.08 | 56.0 | 37% above normal |
| 3 | 119.13 | 56.0 | 37% above normal |
| 4 | 119.13 | 61.4 | 49% above normal |
| 5 | 119.13 | 66.5 | 63% above normal |
| 6 | 119.13 | 68.0 | 66% above normal |
| 7 | 82.03 | 50.0 | 22% above normal |
| 8 | 140.79 | 61.2 | 54% above normal |
| 9 | 73.86 | 42.0 | 2% above normal |
| 10 | 129.96 | 61.0 | 49% above normal |

The calories per hour correspond to the ratings in direct proportions. Thus, the subject with the highest Basal Metabolism Rating expends the highest number of calories per hour. Accordingly, the subject with the lowest rating expends the lowest number of calories per hour.

Table 9. Table 13-2. The caloric equilvalents of oxygen and carbon dioxide for nonprotein respiratory quotients[40]

| Nonprotein respiratory quotient | Kcal/liter | |
|---|---|---|
| | Oxygen | Carbon dioxide |
| 0.70 | 4.686 | 6.694 |
| 0.72 | 4.702 | 6.531 |
| 0.74 | 4.727 | 6.388 |
| 0.76 | 4.752 | 6.253 |
| 0.76 | 4.776 | 6.123 |
| 0.80 | 4.801 | 6.001 |
| 0.82 | 4.825 | 5.884 |
| 0.84 | 4.850 | 5.774 |
| 0.86 | 4.875 | 5.669 |
| 0.88 | 4.900 | 5.568 |
| 0.90 | 4.928 | 5.471 |
| 0.92 | 4.948 | 5.378 |
| 0.94 | 4.973 | 5.290 |
| 0.96 | 4.973 | 5.205 |
| 0.98 | 5.022 | 5.124 |
| 1.00 | 5.047 | 5.047 |

The above table was used to calculate the number of calories burned by each subject on each apparatus. A nonprotein respiratory quotient between 0.70 and 0.78 indicates that more fats than carbohydrates are being burned. A quotient between 0.80 and 0.88 indicates that an equal number of carbohydrates and fats are being burned. A quotient between 0.90 and 1.00 indicates that more fats than carbohydrates are being burned.

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[40]C. F. Consolazio, R. E. Johnson, and L. Pecara, Physiological Measurements of Metabolic Functions in Man (New York: McGraw-Hill Book Company, Inc., 1963), p. 439.

# CHAPTER IV

# SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

## Summary and Conclusions

The purpose of this study was to compare energy expenditure between the Universal Gym method of weight training and the Olympic Weight method of weight training in performing the military press and curls. Before the experimenting began, each subject was given the Basal Metabolism Rate test in order to determine the subject's resting rate. There was a wide range of basal metabolism rate scores going from 83 percent above normal to 2 percent above normal.

An indirect method employing the Douglas bag was used for collection of expired air. The Douglas bag has a face mask attachment which the subjects wore while performing each exercise. This face mask did not hinder their performance. There was one, one minute test period given on four different days. The tempo of exercising was controlled by the metronome.

The subjects were male volunteers whose weights varied between 125 and 241 pounds. Also, they were all beginning weight trainers.

The Wet Test Meter was used to record the volume of expired air. Gas samples were taken at the end of each exercise and stored on ice until they could be analyzed. The samples remained on the ice for 35 to 70 minutes. The Fry Gas Analyzer was used to analyze the gas samples for $O_2$ and $CO_2$ percentages.

Table 10 shows that Subject #7 expended 1.512 cal/min which was the lowest number of cal/min expended while doing the Universal Gym

exercises. By comparison, Subjects #1 and 2 expended 2.016 cal/min for the lowest number of cal/min expended with the Olympic Weight's exercises.

Table 10. Data summary

| | | | | Olympic Weights | | Universal Gym | |
|---|---|---|---|---|---|---|---|
| Subject | Height cm | Weight kgm | Age | Military Press cal/min | Curls cal/min | Military Press cal/min | Curls cal/min |
| 1 | 178.0 | 75.0 | 19 | 3.528 | 2.016 | 3.816 | 3.024 |
| 2 | 173.0 | 67.0 | 19 | 2.016 | 3.840 | 2.016 | 3.024 |
| 3 | 186.0 | 81.0 | 19 | 4.338 | 3.800 | 3.528 | 2.520 |
| 4 | 173.0 | 81.0 | 20 | 3.325 | 5.225 | 2.520 | 2.832 |
| 5 | 173.0 | 68.0 | 19 | 4.680 | 5.784 | 3.024 | 4.750 |
| 6 | 172.0 | 65.0 | 19 | 3.528 | 4.536 | 3.528 | 2.340 |
| 7 | 172.0 | 57.0 | 19 | 2.520 | 3.325 | 1.740 | 1.512 |
| 8 | 186.0 | 111.0 | 24 | 4.536 | 4.212 | 2.520 | 1.900 |
| 9 | 168.0 | 66.0 | 20 | 3.325 | 4.680 | 5.040 | 1.748 |
| 10 | 186.0 | 88.0 | 18 | 3.528 | 3.528 | 0.000 | 3.024 |

The largest number of cal/min expended by any subject was 5.784 cal/min which was achieved on the Olympic Weights with the curls. The smallest number of cal/min expended by any subject was 1.512 cal/min which was done on the Universal Gym with the curls.

Subject #5 showed the largest average of cal/min expended for the entire study with a $\overline{X}$ of 4.560 cal/min. By comparison, Subject #7 showed the smallest average of cal/min expended for the entire study with a $\overline{X}$ of 2.274 cal/min.

In general, it can be concluded that greater energy expenditure occurred with the Olympic Weights. Following are some reasons for this difference in energy expenditure. First, the subjects had to

balance the weights themselves while exercising with the Olympic Weights. Secondly, they had to control the weight with the Olympic Weights. Finally, while exercising with the Olympic Weights, subjects had to pick the weight up from the ground before beginning the exercise.

Another study should be done comparing the strength between the Universal Gym and the Olympic Weights. To do this, one would have to consider the following factors: (1) changing the weight, (2) picking up the weight, (3) balancing the weight, and (4) controlling the weight all on the Olympic Weights.

## Recommendations

As a result of this study, recommendations for future studies are as follows:

1. Use other exercises for the same study.

2. Beginning weight trainers should consider these findings before training.

3. Coaches should study findings before setting up a program for their athletes.

4. Use a different gas analyzer.

5. Use a different method of determining energy expenditure.

6. Compare strength between Olympic Weights and Universal Gym.

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# APPENDIX

Figure 1. Performing military press on Universal Gym

Figure 2. Performing curls on Universal Gym

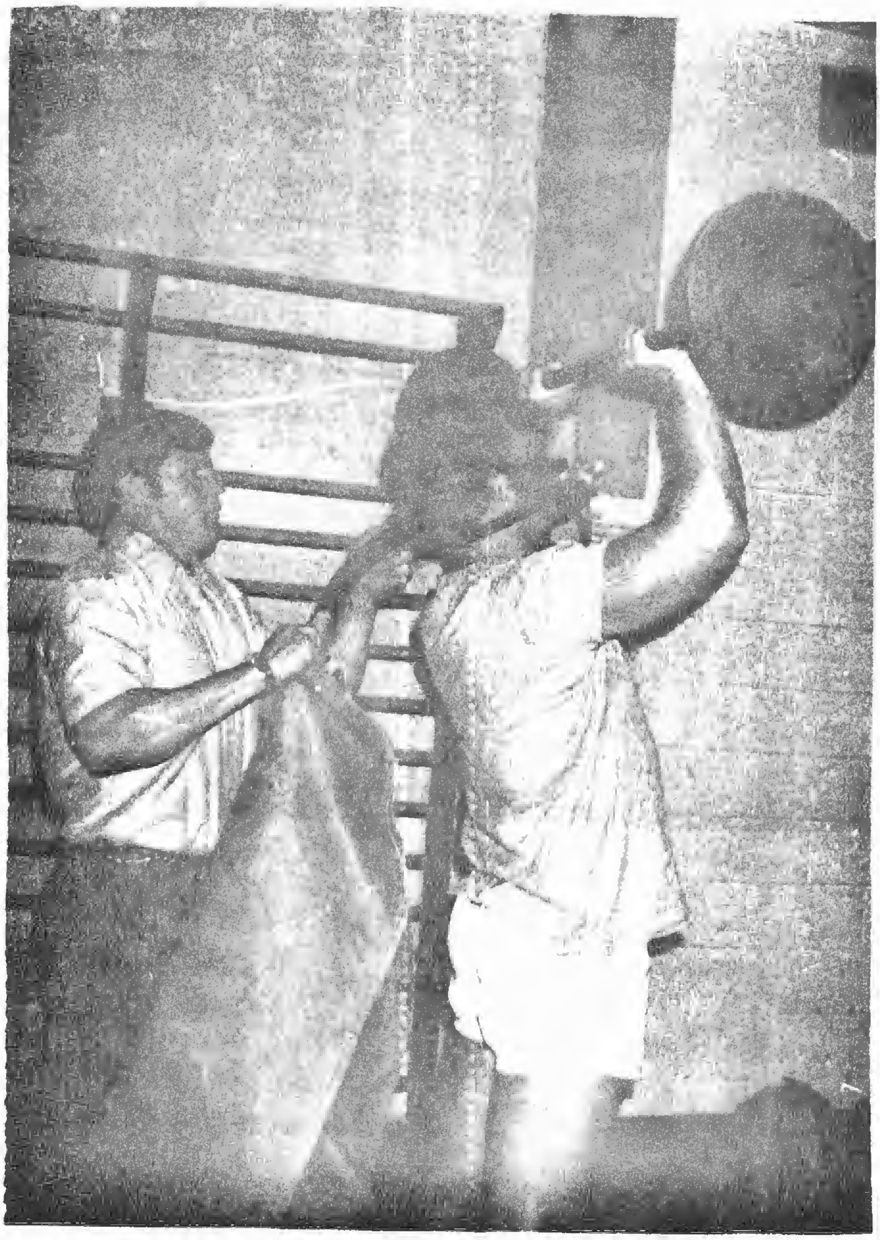

Figure 3. Performing military press on Olympic Weights

Figure 4. Performing curls on Olympic Weights

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