Energy cost of weight training exercise

James F. Hickson, Ph.D., R.D.
Program in Nutrition
University of Texas

Michael J. Buono, Ph.D.
Department of Physical Education
San Diego State University

Jack H. Wilmore, Ph.D.
Department of Physical Education
University of Arizona

Stefan H. Constable, Ph.D.
School of Medicine
Washington University

Progressive resistance, weight training exercise is widely used by athletes to increase skeletal muscle size and strength (1,2). Due to the intensity of work sets, it has a high rate of energy expenditure relative to other forms of activity (3). However, the intermittent nature of work sets results in an energy expenditure per exercise session equal to that of low-intensity, steady-state exercise (3).

Investigations of energy metabolism and weight lifting activity have focused on the caloric cost of individual work sets (4), or represented the energy use of uncontrolled activity (5,6). Although Wilmore et al. (7) did report the energy cost of a complete and standardized weight lifting session, the fast-paced regimen which they used was not typical of strength building programs.

The purpose of the present study was to characterize the energy cost of a standardized weight training program designed to improve muscular strength.

Methods

Subjects

Four healthy young, adult males volunteered to serve as subjects in the project (Table 1). The men were 19–26 years old, 12–19% body fat by weight (8), and familiar with weight training exercise techniques.

Exercise program

The weight training program designed for use in the present study was a general body routine (2). It included exercise movements for working the skeletal muscles of the legs, chest, shoulders, arms, and back. The program was divided into two parts, A and B, to be completed on alternate days in order that body parts exercised on one day would be rested on the next day. This type of alternating, or split, routine is commonly used by athletes in advanced stages of training (2). However, our subjects performed both parts A and B of the program with a 24–48 hour rest period in between exercise sessions.

Part A of the exercise program worked the chest, shoulders, and arms with five movements including: 1) bench press; 2) shoulder shrugs; 3) overhead press; 4) arm biceps curls; and 5) triceps pushdown. Part B included five movements for the back and legs including: 1) leg extensions; 2) lat pulldowns; 3) seated rowing; 4) knee extensions; and 5) leg biceps curls. The exercise movements have been described by Parker and Marsh (2). As the sixth exercise movement, both program parts included an abdominal exercise ( crunchy ) which involved flexion of the abdominal muscles without concurrent flexion of the hip flexors (9).

Exercises for each part were performed in the order given above with the abdominal exercise as the last movement. Universal Gymnasium Machines (Universal Division, Walter Kidde and Company, Inc., Cedar Rapids, Iowa) were selected for use instead of free weights in order to reduce intersubject variability in the execution of the exercise movements.

The exercise movements of each program part were performed in timed, six-minute cycles in order to further standardize activity among subjects. An exercise cycle consisted of three, 30-second work sets separated by 1-minute rest periods and followed by a 2.5-minute final rest period. The 30-second interval was chosen because very brief, intense work is associated with the development of muscular strength (1,10). In addition the work set length was sufficient time to perform the optimum number of 6–9 repetitions of each exercise movement (11,12). Three work sets per movement was a second condition for the optimal development of strength (11). A single exercise movement was performed during any given cycle. Since there were six movements per part of the regimen, each exercise session lasted for a total time of 36 minutes.

Weight loads for exercise movements were determined according to subjects’ individual strength capabilities at 75–80% of the maximal load which could be lifted for a given movement (11–13). This resulted in the assignment of weight loads which each man could handle for 6–9 repetitions during a work set (11). Initial weight loads for the several movements often had to be reduced for subsequent sets in order for subjects to perform a minimum of six repetitions (11).

Energy measurements

Values for the energy cost of exercise were based on measurements of subjects’ oxygen consumption during performance (i.e., respiration calorimetry). Expired air samples for analysis were collected by connecting subjects to a flexible hose from a Beckman Metabolic Measurement Cart (MMC). The MMC is a computerized, portable metabolic analysis system; the procedure has been detailed and validated by Wilmore and his colleagues (14). Oxygen consumption was continuously assessed in 2-minute intervals during the 14–20-minute pre-exercise rest period, the 36-minute exercise period, and the 14-minute post-exercise recovery period. Energy measurements were not taken during subjects’ 5-minute, pre-exercise warm-up periods.

Subjects’ oxygen uptakes were greater than 25% above resting values at the end of recovery measurements. Therefore, subsequent values to within 5% of the resting level were extrapolated from the first 14 minutes’ data. This was done by subtracting the mean value of oxygen consumption during the pre-exercise rest from each of the seven post-exercise recovery data points. The resultant numbers were transformed into their natural logs.
and linear regression analysis was performed on these logs versus the respective, cumulative time of measurement (2.4-6 minutes, etc.) by using a computerized procedure (15). The natural logs for extrapolated values were obtained by putting time values of 16 and higher into the linear regression equation until the resulting "y" value became negative in sign. These natural logs were then converted to volume of oxygen consumed by putting the numbers into the equation $y = e^x$ at the "x" position.

Respiratory exchange ratio (RER) values could not be used for calculation of percent fuel contribution by carbohydrate and fat due to subject hyperventilation (16). In addition, the RER is most precise for persons engaged in steady-state exercise rather than intermittent activity such as weight lifting. Therefore, a value of 5.00 kcals/liter oxygen consumed was taken as the conversion factor to calculate subjects' energy uses. According to Lusk (17), the value allows for a contribution to energy production of 90% kcals from carbohydrates and 10% from fats. The factor was chosen since weight training activity stresses carbohydrate utilization (18, 19).

**Results and Discussion**

The calculated caloric expenditure data of the program parts for the four subjects are shown in Table 2. Oxygen uptake, and therefore, energy expenditure, were both significantly greater (p<0.05) during exercise than during the pre-exercise rest period. The subjects' mean resting energy expenditure was 1.8±1.2 kcals/min. During exercise, the mean gross energy expenditures were 6.7±1.4 kcals/min for part A and 8.2±1.2 kcals/min for part B (n.s.). These levels of energy use for weight lifting exercise are comparable to light endurance activity such as walking at a faster than normal or brisk pace (15).

The mean net energy expenditure for part A of the exercise program, excluding recovery, was 174 kcals/session; for part B it was 229 kcals (n.s.). These energy cost measurements can be compared to those of other investigators if their figures are adjusted to reflect a 36-minute, 18-work set exercise period. As shown in Table 3, the calculated overall average net energy expenditure across investigations is 179 kcals/36-minute session.

The higher energy expenditure for part B, relative to part A, was probably due to the use of leg muscle groups. The leg muscles are among the largest in the body, and they require proportionately more energy for activity. This same trend has been observed by McArdle and Foggia (4) in their comparison of leg exercise with two upper body exercises.

**Practical Application**

Athletes often believe that weight lifting exercise sessions expend very large amounts of energy such as that contained in a meal, perhaps 1000 kcals. The results of the present study indicate that this level of energy expenditure is unlikely even for the athlete who performs more than 18 work sets per session. For example, our subjects would have had to perform 82 work sets to expend 1000 kcals (assuming a mean expenditure of 220 kcals/session including recovery). Practically speaking, this number of sets would not be possible given the work loads used (75-80% 1-RM). In addition, the common experience of competition-level body builders, reported in the popular literature, indicates that they perform about 20-30 sets per exercise session. Therefore, athletes' association of weight lifting and high energy expenditure only partly reflects the energy demands of activity; it probably also reflects the energy requirements of building skeletal muscle tissue for size and strength gains.

**References**


(Continued, page 66)

**Investigator**

<table>
<thead>
<tr>
<th>Investigator</th>
<th>Kcals</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present study</td>
<td>174–222</td>
<td></td>
</tr>
<tr>
<td>Laritcheva et al. (6)</td>
<td>191</td>
<td></td>
</tr>
<tr>
<td>McArdle and Foggia (4)</td>
<td>93–144</td>
<td></td>
</tr>
<tr>
<td>Wilmore et al. (7)</td>
<td>206</td>
<td></td>
</tr>
</tbody>
</table>

**Mean±Standard deviation**

179±40

**Table 1: Subject descriptions.**

<table>
<thead>
<tr>
<th>Subject code</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Body fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DS</td>
<td>26</td>
<td>87.0</td>
<td>15.6</td>
</tr>
<tr>
<td>DA</td>
<td>25</td>
<td>70.8</td>
<td>15.8</td>
</tr>
<tr>
<td>TD</td>
<td>19</td>
<td>74.4</td>
<td>12.5</td>
</tr>
<tr>
<td>FG</td>
<td>21</td>
<td>97.2</td>
<td>19.2</td>
</tr>
</tbody>
</table>

*Body fat was determined anthropometrically (8).*

**Table 3: Calculated values for reported investigations of the net energy cost of weight lifting exercise for men."**

<table>
<thead>
<tr>
<th>Source</th>
<th>Part A</th>
<th>Part B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subject</td>
<td>Caloric expenditure (Kcal)</td>
<td>Gross pre-exercise/minute</td>
</tr>
<tr>
<td></td>
<td>DS</td>
<td>DA</td>
</tr>
<tr>
<td>-------</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* A value of 5.00 Kcals/liter of oxygen consumed was used to calculate caloric cost.
† Exercise period times of 34 minutes are shown for subjects TD and FG in Part A and for DS and TD in Part B.
‡ Net cost calculated by subtracting average pre-exercise resting energy expenditure from gross exercise expenditure.
§ Recovery energy cost estimated from extrapolated data.

**Table 2: Caloric cost of the strength-building exercise program."**

23

NSCA Journal October-November 1984