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Energy Cost of the ACSM Single-set Resistance Training Protocol

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ABSTRACT

The purpose of this study was (a) to assess the energy cost and intensity of a single-set resistance training (RT) protocol conducted according to the recent ACSM guidelines and (b) to compare obtained values to those recently reported as eliciting health benefits via endurance-based physical activity (PA). Twelve subjects, mean age 26.7 ± 3.8 years, performed 1 set of a 15 repetition maximum (15RM) for each of 8 RT exercises. Metabolic data were collected via a portable calorimetric system. Training intensity in metabolic equivalents (METS) was 3.9 ± 0.4 for men and 4.2 ± 0.6 for women (not significant). Total energy was 135.20 ± 16.6 kcal for men and 81.7 ± 11.1 kcal for women ($p < 0.008$). We concluded that the ACSM single-set, 8-exercise RT protocol is a feasible alternative for achieving moderate-intensity (3–6 METS) PA, but it is not sufficient to achieve a moderate amount (150–200 kcal) of PA.

Key Words: strength, kilocalorie expenditure, health, physical activity

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Introduction

The Surgeon General's report (27) and others (21, 28) have recently emphasized the health-related benefits of moderate intensities and moderate amounts of physical activity (PA). These reports have recommended that U.S. adults accumulate a minimum of 30 minutes of moderate-intensity PA on most, preferably all, days of the week. Moderate-intensity PA is classified as 3–6 metabolic equivalents (METS), and a moderate amount of PA as 150–200 kcal/day. PA in these reports was defined as ''any bodily movement produced by skeletal muscles that results in energy expenditure'' but referred almost exclusively to endurance-based activities (21, 28). It has been reported that relatively small changes in those activities that serve to increase daily PA reduce the risk of chronic disease and perhaps contribute to enhanced quality of life (21). As a consequence of these data, there has been a concerted effort in the literature to measure and document the energy cost of a wide variety of physical activities. However, although the energy cost of endurance-based/steady-state exercise has been extensively reviewed, little data is available on the energy cost of resistance training (RT). Ainsworth et al. (1, 2) have recently published exhaustive compendiums of hundreds of modes and intensities of PA. RT appears in these compendiums in the form of only 3 entries: conditioning exercise (circuit training, general [8.0 METS]); conditioning exercise (weightlifting [free weight, nautilus, or universal-type], powerlifting, or body building, vigorous effort [6.0 METS]); and conditioning exercise (weightlifting [free weight, nautilus, or universal-type], light or moderate effort, light workout, general [3.0 METS]). The comparatively small number of studies that have investigated the energy cost of RT focused predominantly on high-volume and/or high-intensity circuit training (4, 5, 8, 11, 16, 24, 29) or the energy cost of single lifts (6, 7, 13) with far less focus on 'traditional' set-based RT (12, 18, 25).

Recently the American College of Sports Medicine (ACSM; 3) has acknowledged the broader health benefits of RT and has suggested that a single-set training protocol of 8–12 repetitions (10–15 repetitions for older adults) with 8–10 exercises that focus on major muscle groups is sufficient to elicit such benefits. We have recently reported on the strength-related benefits of single-set RT (22), but the energy cost of this protocol has not been investigated.

The purpose of this study was (a) to assess the energy expenditure (EE) and intensity of a single-set RT protocol conducted according to the recent ACSM guidelines and (b) to compare obtained values to those recently reported as eliciting health benefits via endurance-based PA.

Methods

Experimental Approach to the Problem

Our study design is descriptive in nature. No control group was needed since our study purpose was to assess only the intensity and absolute energy cost of this

Table 1. Subject characteristics (mean ± *SD*).

Variable	Group	Women	Men	*p*
Number of subjects	12	6	6	
Age (y)	26.1 ± 3.8	27.0 ± 4.0	25.2 ± 3.7	*ns*
Height (cm)	169.1 ± 16.1	155.0 ± 8.92	183.3 ± 3.8	<0.001
Weight (kg)	77 ± 19.4	62.8 ± 7.6	91.2 ± 17.1	≤0.001
% Body fat*	18.7 ± 8.2	24.0 ± 3.9	12.4 ± 7.1	≤0.01
Resting metabolic rate ($ml \cdot kg^{-1} \cdot min^{-1}$)	2.9 ± 0.6	2.7 ± 0.3	3.2 ± 0.6	≤0.005

* Jackson and Pollack (15).

specific protocol. Our results will be compared only with accepted published values for moderate-intensity (3–6 METS) and moderate amounts (150–200 kcal) of PA.

Subjects

Twelve subjects (6 men and 6 women) with a mean age of 26.7 ± 3.8 years (range 21–33 years) were recruited for this study. All subjects were recreationally active and already familiar with the RT equipment, lifts, and techniques. They were healthy with no medical or orthopedic problems that could limit their performance of the required exercises. All subjects signed a comprehensive informed consent that explained the nature and purpose of the study. The study was approved by the Institutional Review Board. Subjects' characteristics appear in Table 1.

Energy Expenditure

Resting metabolic rate and exercise energy cost were measured using a CosMed K4b^2 (Rome, Italy), a state of the art portable, lightweight calorimetric measurement system that has been validated over ranges and intensities of PAs (10, 19). The unit was attached to the subject's chest via a harness. A face mask (Hans-Rudolph, Kansas City, MO) covering the mouth and nose of the subject was connected to a bidirectional digital turbine flowmeter with an opto-electrical reader and was attached to the subject by the use of a mesh hair net and Velcro straps. A disposable gel seal (Hans-Rudolph) was positioned between the inside of the face mask and the subject to ensure an airtight seal. The CosMed system was calibrated prior to each individual test according to the manufacturer's guidelines. Test data were downloaded to a Windows-based laptop computer loaded with the CosMed Version 6 computer software program. Breath-by-breath data were averaged over 30-second intervals and later transferred into Microsoft Excel for analysis. Energy cost in kilocalories of the RT program was estimated using a constant value of 5.05 $kcal \cdot L^{-1}$ of oxygen, according to the method of Wilmore (29). Exercise intensity in METS was calculated as multiples of measured resting energy expenditure.

Procedures

Testing sessions were conducted on 3 separate days at the same time of day. Each session lasted approximately 60–90 minutes.

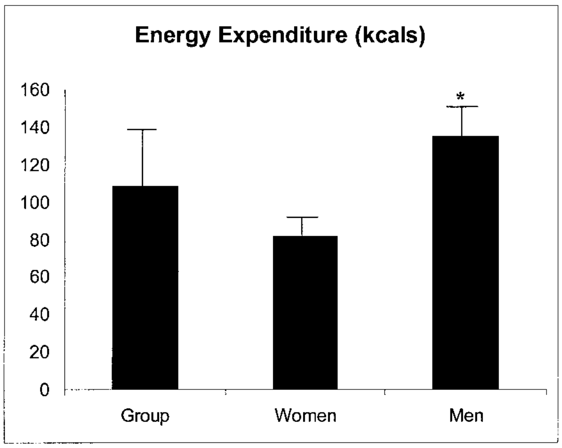
Session I: Measurement of Resting Metabolic Rate. Prior to RMR testing, subjects were required to (a) fast for 12 hours, including no caffeine or other metabolic-altering supplements and/or drugs that are not ingested regularly as part of the diet (i.e., Tylenol, Advil, diuretics, etc.); (b) engage in no PA for 24 hours prior to testing; (c) be well-hydrated; and (d) be well-rested. For the actual test session, subjects were placed in a comfortable semireclined position in a room with subdued lighting and connected to the CosMed system for a total of 40 minutes. The subjects were advised to breathe normally as in a resting state but not to fall asleep. The first 20 minutes were used for familiarization and adjustment to the environment. Resting metabolic rate (RMR) and heart rate data were collected during the second 20 minutes only. This session also served as an extensive familiarization period with the CosMed unit. Immediately following this session, participants were taken to the RT area for a familiarization session with the equipment while still wearing the CosMed unit.

Session II: Assessment of 15 Repetitions Maximum. All strength testing was conducted on Cybex (Lumex, Inc., Ronkonkoma, NY) and Hi-Tech (Hi Tec Professional Strength Systems, Paso Robles, CA) strength training machines. The ACSM recommend 8–10 exercises; however, logistical problems precluded the assessment of 10 exercises for each participant, and therefore EE was measured for 8 resistance-training exercises as follows: (a) Cybex plate-loaded leg press, (b) Cybex seated cable row, (c) Hi-Tec leg extension, (d) Cybex chest press, (e) Hi-Tec seated leg curl, (f) Cybex shoulder press, (g) Cybex bicep curls, and (h) Cybex triceps extension. Optimal positioning and range for each exercise were determined, lifting technique was clarified, and safety precautions were explained. Prior to performing the 15 repetitions maximum (15RM) test, all subjects were refamiliarized with each piece of equipment and each exercise. All subjects performed an initial warm-up set

Table 2. Volume data from resistance training (mean ± *SD*).*

	Group	Women	Men	*p*
Total kilograms lifted per session	6290 ± 2301	4249.4 ± 614.1	8330.7 ± 1131.5	<0.001
Repetitions per set	15.2 ± 0.1	15.2 ± 0.2	15.1 ± 0.2	*ns*

* Total accumulated session time = 24 minutes.



* Significantly greater than women (p < 0.05)

Figure 1. Total energy expenditure in kilocalories.

Table 3. Energy cost of resistance training session (mean ± *SD*).

	Group	Women	Men	*p*
$kcal \cdot min^{-1}$†	4.52 ± 1.3	3.41 ± 0.5	5.63 ± 0.7	<0.008**
$kcal \cdot kg^{-1} \cdot min^{-1}$	0.06 ± 0.0	0.05 ± 0.0	0.06 ± 0.0	*ns*

† 1L $O_2 \cdot min^{-1} = 5.05\ kcal^{-1} \cdot O_2 \cdot min^{-1}$; 1MET = (exercise $ml \cdot kg^{-1} \cdot min^{-1}$)/(resting $ml \cdot kg^{-1} \cdot min^{-1}$).
** *p* value adjusted for multiple comparisons.

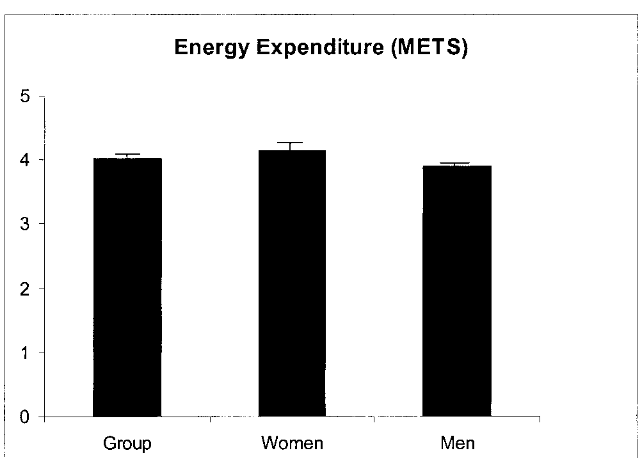


Figure 2. Total energy expenditure in METS.

of 15 repetitions at a light weight. Additional weight was then added for the second trial, and the subject performed a further set of 15 repetitions. This process continued until the 15RM was established. Subjects rested 2–5 minutes between trials. The 15RM was established in less than 3 trials for all participants.

Session III: Measurement of EE During RT. Prior to testing, subjects' were required to (a) fast for 4 hours (no caffeine or other metabolic altering supplements and/or drugs that are not ingested regularly as part of the diet; i.e., Tylenol, Advil, diuretics, etc.); (b) engage in no PA/exercise the day of testing; (c) be well-hydrated; and (d) be well-rested. Subjects were connected to the CosMed system and performed a general 5-minute warm-up on a cycle ergometer. Data collection began immediately following the warm-up. Subjects performed 1 set of 15RM of the 8 RT exercises with a 2-minute recovery interval. Cadence for all lifts was standardized with a metronome using a count of 2 seconds up and 2 seconds down. The beginning and end of each individual lift phase (1 minute) and rest period (2 minutes) was electronically 'flagged' on the CosMed. The total exercise session time was 24 minutes.

Results

All subjects completed the RT session (24 minutes), exercise set (1 minute), and recovery period (2 minutes) within the allotted time. Subjects performed each lift to failure. Average completed repetitions was 15.2 ± 0.23 for women and 15.2 ± 0.05 for men and did not differ between men and women, although men lifted a significantly higher ($p < 0.0001$) total volume of weight per session (Table 2).

During the RT session, men generated a significantly higher absolute energy cost than women for all metabolic values (Figure 1), but these differences were not apparent when expressed relative to body weight (Table 3). Intensity expressed as MET values (calculated from individual RMR data) were within the moderate range and did not differ between men and women (Figure 2).

Discussion

Although RT has become an accepted component of health-related PA/exercise (3, 14, 23), its benefits have been documented almost exclusively in physiological and functional terms such as increased strength/muscle mass, bone mineral density, and functional fitness. Recent research has demonstrated the health benefits of moderate intensity and moderate amounts of PA, but the majority of this research has been concerned with endurance-based PA (27). With the development of lightweight, wearable calorimetric systems such as the CosMed K4b², assessment of energy expenditure in more intermittent PA such as RT has become much more accessible. Our study is the first to investigate the energy cost and intensity of single-set RT as recommended by the ACSM (3).

We found that performing a single set of 8 exercises for 15RM elicited a mean intensity of 3.9 ± 0.4 METS for men and 4.2 ± 0.6 METS for women. This is within the reported range of moderate intensity (3–6 METS) for both men and women. A mean intensity of 5.6 $kcal \cdot min^{-1}$ for men was also within the reported moderate-intensity range of 5–6.6 $kcal \cdot min^{-1}$ (18, 24). However, the mean intensity for women (3.4 $kcal \cdot min^{-1}$) did not achieve this level. The absolute energy cost (volume) for our participants was 108.46 ± 30.9 kcal (135.2 ± 16.3 kcal for men and 81.7 ± 11.1 kcal for women), which is less than the 150–200 kcal suggested for eliciting health benefits with endurance type activities (21). These gender differences appear to be related to differences in strength, body weight, and body composition. Men were significantly heavier and leaner than women in our study (Table 1), lifted a greater amount of weight for the same number of repetitions (Table 2), and generated a significantly greater absolute energy cost for the RT routine (Table 3). However, when these values were expressed in relation to body weight, no differences were found in energy cost (Table 3).

The small number of published studies investigating the energy cost of RT and the wide variation in sets/circuits, repetitions, and total time do not allow for anything but the broadest comparisons with our study results. The majority of studies in the literature have focused predominantly on high-volume and/or high-intensity circuit training. Intensity levels reported in these studies range from 5.2 to 6.2 METS (5, 11, 20, 24, 29), which is higher than that found in our study secondary perhaps to the shorter recovery periods and/or multiple circuits typically used in this mode of RT. There are, however, some commonalities with our protocol. In a study of 13 college-aged men, Ballor et al. (4) performed 3 circuits of 7 exercises with a similar session time to our study (24.5 vs. 24 minutes). However, these authors reported a substantially higher average exercise intensity compared with the men in our study both in METS (6.5 vs. 3.9 METS) and in kilocalories per minute (9.75 vs. 5.8 $kcal \cdot min^{-1}$). These differences were apparent despite the men in our study being approximately 10% heavier than the Ballor et al. subjects (84.57 ± 3.76 kg vs. 91.2 ± 17.1 kg) and appear to be due to the isokinetic equipment used in the Ballor et al. (4) study. This mode of exercise has no eccentric component, necessitating a ''double positive,'' push-pull technique for completing repetitions with consequent increases in energy cost. Ballor et al. (4) suggest that the metabolic cost of hydraulic circuit exercise may be greater than that of conventional training.

In contrast to this multiple circuit approach, Hempel and Wells (11), using a study designed similarly to ours, investigated the energy cost of the Nautilus Express Circuit (NEC). The NEC utilizes a single circuit of 1 set of each of 14 exercises performed to failure (8–12RM for upper- and 8–20RM for lower-body exercise) with no recovery between exercises. Total time for the circuit was 22 minutes. In a similarly aged population to our study, the Hempel and Wells (11) NEC elicited a greater MET response compared with our subjects for both women (4.8 vs. 4.2) and men (6.0 vs. 3.9), although both of the Hempel and Wells (11) values are still within the accepted MET range for moderate PA (3–6 METS). As with the Ballor et al. (4) study, differences in EE between the Hempel and Wells (11) study and our study appear to be secondary to the greater number of exercises and a greater intensity, predominantly as a result of the lack of a recovery period between exercises. In common with Hempel and Wells (11), however, we found significant differences between men and women for absolute energy costs, but no differences when energy costs were expressed per kilogram of body weight (Table 3).

Few studies have investigated the energy cost of 'traditional' RT in nonathletic populations. Energy costs between 6.1 and 9.1 $kcal \cdot min^{-1}$ have been reported for elite Olympic weightlifters (17, 25, 26), but these have generally been highly intense, multiple-set protocols conducted, with few exceptions (26), over training sessions of 1.5–4 hours. In a nonelite population, Hickson (12) reported the energy cost of a 3 set × 10 exercise RT protocol using, in parallel with our study, a 30-second work session per set, but at an intensity of 6–9RM with a 1-minute rest between sets. Participants performed a split routine of 5 upper- and 5 lower-body exercises on separate days. Total time for each session was 36 minutes. Although the total absolute energy expenditure for the Hickson (12) study cannot be viably compared with our results because of the wide disparity in sets, repetitions, and total exercise time, mean intensities were similar to our findings both for METS (4.1 vs. 3.9, calculated from the Hickson [12] study data) and kilocalories per minute (5.5 vs. 5.6). McArdle and Foglia (18) have also reported similar intensity levels to our study utilizing a 4-exercise RT protocol performed for 8RM per exercise.

The energy cost of RT, and in particular noncircuit training-based RT, has been little investigated. In this group of college aged men and women, our single-set, 8-exercise protocol conducted according to the recent ACSM guidelines appears to meet the MET threshold of moderate intensity, but not the 'volume-based' range of 150–200 kcal reported as eliciting health benefits for endurance-type activities. In our study the intensity of RT briefly approached maximal levels for all participants, but as has been reported by others in multiple-set and/or circuit RT studies, the intermittent nature of this mode of PA resulted in mean levels of intensity that are similar to that of moderate-intensity, aerobic/endurance-based activities.

We conclude that the ACSM single-set 8-exercise RT protocol is a feasible alternative for performing moderate-intensity PA. However, additional sets, repetitions, and/or exercises appear to be necessary to achieve the minimum absolute volume of 150 kcal reported as eliciting health benefits with endurance-type physical activities. Future studies should be conducted in different populations in order to address the extent to which health benefits may accrue for RT secondary to kilocalorie expenditure in the same way as has been extensively reported for endurance-based activities.

Practical Applications

The most significant finding of this study is that our single-set RT protocol was performed within the accepted moderate intensity range of 3–6 METS. This is a highly relevant finding since moderate-intensity PA has been extensively recommended for eliciting health benefits (21, 27). As confirmation of this, a series of studies were recently funded by the International Life Sciences Institute Research Foundation (2) whose goal was to measure a range of low- to moderate-level PAs in both laboratory and field settings. Although this is powerful testimony to the importance placed on measurement and quantification of PA in its broadest sense, not one of these studies addressed RT.

From a practical perspective, our study results indicate that single-set RT may be used as a viable component of a health-related PA program as recommended by the Surgeon General's report (27). Men in our study approached (~135 kcal), but did not attain, an energy cost of 150 kcal with our 8-exercise protocol, and therefore, speculatively, would need to perform an additional 1 or perhaps 2 RT exercises utilizing larger muscle groups (e.g., a pull-down) to reach this designated health-related level. Women in our study accrued approximately 82 kcal during their 8-exercise protocol, and therefore would need to perform close to 2 sets (~164 kcal) of this same routine to attain the lower end of the 150–200 kcal range. However, if the health benefits of RT energy expenditure can be accrued in the same way as has been suggested for endurance-based PA (21), these sets could be completed on 2 separate occasions during the same day. In addition, there is mounting evidence that the health benefits of PA are linked principally to the total amount of PA performed (volume). This evidence suggests that the volume (i.e., EE in kcal) is more important than the mode, intensity, or duration of an activity bout (21) for eliciting health benefits. As an example, women in our study could perform the single-set 8-exercise routine plus approximately 15 minutes of brisk walking in order to accumulate approximately 150 kcal. Further, quantification of exercise intensity by METS has been reported as providing an important prescription reference point for researchers, clinicians, and practitioners, where more traditional methods of prescribing safe and appropriate intensities (e.g., heart rate, $\%\dot{V}O_{2R}$) are either difficult or inappropriate (2). This would be important, for example, in cardiac rehabilitation where RT has become accepted as a viable complement to usual care. In these situations activities of daily living and/or return to work activities and/or post–early-phase rehabilitation exercises are increasingly being prescribed as appropriate according to their published MET levels. This topic was the subject of a major symposium at a recent ACSM national conference (9), and its importance has also been stressed by other authorities (1, 2). Finally, knowledge of the energy cost of RT may also be of interest to those who exercise at least partly for weight control (7, 25, 29). Our study, therefore, has uniquely contributed valuable health-related data for a widely practiced and increasingly high profile mode of PA, which, paradoxically, has yet to receive adequate attention in the scientific literature from an EE perspective.

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