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Energy Cost of Single-Set Resistance Training in Older Adults

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Abstract. Phillips, W.T., and J.R. Ziuraitis. Energy cost of single-set resistance training in older adults. *J. Strength Cond. Res. 18(3):606–609. 2004.*—The purpose of this study was (a) to assess the intensity and energy cost of a single-set resistance training (RT) protocol as recommended by the recent American College of Sports Medicine (ACSM) guidelines for older adults and (b) to compare obtained values to those recently reported as eliciting health benefits via endurance-based physical activity (PA). Five males and 5 females (73.1 ± 5.5 years) performed 1 set of 15 repetitions of 8 RT exercises while connected to a portable metabolic unit (CosMed K4b^2). The RT intensity (metabolic equivalents [METs]) was 3.3 ± 0.7 (males) and 3.0 ± 0.6 (females). Energy cost (kcal) was 84.2 ± 14.6 (males) and 69.7 ± 17.4 (females). We conclude that a single-set 8-exercise RT protocol may be a feasible alternative for achieving moderate intensity (3–6 METs) for older adults but that additional sets and/or repetitions appear to be necessary to accumulate moderate amounts (150–200 kcal) of PA.

Key Words. strength, aging, physical activity, energy expenditure

Introduction

The Surgeon General's Report (23) and others (5, 24) have recently stressed the importance of regular daily physical activity (PA) at "moderate" levels as a means to elicit health benefits in predominantly sedentary populations. Two forms of "moderate" physical activity have been reported by these bodies: a "moderate amount" of PA—equivalent to expending approximately 150–200 kcal in excess of normal daily energy expenditure, and "moderate intensity" PA—equivalent to 3–6 metabolic equivalents (METs). These relatively small changes in regular activities of daily living (ADL) have been reported as having a range of physical and psychological health benefits (17) for the majority of adults. For older adults such increases in PA have been reported as helping to slow, reverse, or improve a number of health conditions commonly associated with aging, including quality of life, functional ability, self-efficacy, mental cognition, and body composition (5). Physical activity in these reports was defined as "any bodily movement produced by skeletal muscles that results in energy expenditure." However, the research to date, though extensive, has been limited almost exclusively to endurance-based PA (17). Despite its well-documented impact on aspects of health and physical function, particularly in older adults (5, 13, 18, 19), little data are available on the energy cost of resistance training (RT). In 2 exhaustive "compendium" reviews Ainsworth et al. (2, 3) published the energy cost of hundreds of modes and intensities of physical activities. However, only 3 entries appear for the energy cost of RT (conditioning exercise—circuit training, general (8.0 METs); conditioning exercise—weightlifting (free weight, Nautilus, or Universal type), power lifting or bodybuilding, 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). In the scientific literature generally, only a comparatively small number of studies have investigated the energy cost of RT, and with 1 exception, (8), all have been conducted exclusively in younger adults (6, 7, 11, 12, 15, 20, 22, 25).

Recently the American College of Sports Medicine (ACSM, 1998) has acknowledged the broader health benefits of RT for older adults and has suggested that a single-set training protocol of 10–15 reps with 8–10 exercises that focus on major muscle groups is sufficient to elicit such benefits. We have recently reported the average MET value and caloric cost of such an approach in college-age students (20), but the energy cost of this protocol in older adults has not been investigated.

The purpose of this study is (a) to assess the intensity in METs, (b) to assess the energy cost in kilocalories of a single-set RT protocol conducted according to the recent ACSM guidelines for older adults, and (c) 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 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 physical activity, which have been consistently reported as eliciting health benefits in the U.S. population.

Subjects

Ten older adults (5 male, 5 female, mean age 73.1 ± 5.5) who had a minimum of 3 months of prior familiarization with RT techniques were used in this investigation. One subject had a physical limitation (fused cervical vertebrae) that did not allow him to perform the supine chest press exercise. All other subjects had no orthopedic problems that limited their performance on the exercises. All subjects signed an informed consent form that explained the nature and purpose of this study, and the protocol was approved by the institutional review board. Subjects' characteristics appear in Table 1.

Energy Cost Measures

The subjects' resting metabolic rate (RMR) and exercise energy cost were measured using a state-of-the-art, portable, lightweight, indirect calorimetry system (CosMed K4b^2,

TABLE 1. Participant characteristics (mean ± *SD*).*

	Group (n = 10)	Males (n = 5)	Females (n = 5)
Age (y)	73.1 ± 5.5	72.4 ± 4.9	73.8 ± 6.4
Weight (kg)	79.0 ± 12.4	87.5 ± 7.8	70.6 ± 10.4
Height (cm)	166.8 ± 12.8	175.9 ± 10.67	157.7 ± 6.8
BMI ($kg \cdot m^{-2}$)	28.3 ± 2.9	28.4 ± 2.6	28.3 ± 3.4
RHR ($b \cdot min^{-1}$)	60 ± 9.0	58 ± 10.0	62 ± 8.0
RMR ($ml \cdot kg^{-1} \cdot min^{-1}$)	2.6 ± 0.6	2.38 ± 0.3	2.87 ± 0.8

* *SD* = standard deviation; BMI = body mass index; RHR = resting heart rate; RMR = resting metabolic rate.

TABLE 2. Volume for resistance training session (mean ± *SD*).*

	Group (n = 10)	Males (n = 5)	Females (n = 5)
Total lifted per session	5,028.7 ± 1023.5	5,752.4 ± 502.8	4,304.9 ± 1867.9
Repetitions per set	15.4 ± 0.8	15.3 ± 0.2	15.5 ± 0.2

* *SD* = standard deviation.

Rome, Italy) that has been validated over different intensities and types of physical activities (10, 16). A harness was used to attach the system onto the participant's chest. A face mask (Hans-Rudolph, Kansas City, MO) that covered the mouth and nose of the participant was attached to a bidirectional digital turbine flowmeter and fastened to the participant by the use of a mesh hairnet and Velcro straps. To guarantee an airtight seal, a disposable gel seal (Hans-Rudolph) was positioned between the inside of the face mask and the participant. The CosMed K4b^2 system was calibrated prior to each individual test according to the manufacturer's guidelines. Breath-by-breath O_2 and CO_2 gas exchange were measured and stored within the portable unit's computer system. On completion of each test, the stored data were downloaded onto a Windows-based laptop computer into the CosMed K4b^2 Version 6 computer software program. The data were then averaged over 30-second intervals and transferred into a Microsoft Excel program for further analysis. The energy cost (kcal) of the exercise program was estimated using a constant value of 5.05 $kcal \cdot L^{-1}$ of oxygen (25). Resting and exercise energy expenditure (kcal) were then converted into MET values. In our laboratory we have found the CosMed K4b^2 to be highly reliable on repeated measures taken several days (r = 0.94, with no significant differences between trials).

Procedures

Testing sessions, lasting approximately 60–90 minutes, were performed at the same time on 3 separate days. Procedures for all 3 sessions have been previously described (20) and will be briefly summarized here.

Session I—Resting Metabolic Rate. This session served as an extensive familiarization period with the portable metabolic unit. Prior to the session, subjects were required to (a) fast for 12 hours, (b) engage in no physical activity for 24 hours prior to the testing, (c) be well hydrated, and (d) be well rested. Subjects were placed in a comfortable semireclined position and connected to the portable metabolic system for a total of 30 minutes. Subjects were advised to limit all movement, not speak unless absolutely necessary, and breathe normally as in a resting state but not to fall asleep. The first 15 minutes served as an adjustment and familiarization period for the subjects. Data collection (RMR and heart rate) occurred during the second 15 minutes.

Session II—Measurement of 15 Repetition Maximum. Eight RT exercises were performed on a Universal Gladiator module (Universal Conditioning Equipment, Cedar Rapids, IA) as follows:

1. Leg press, 2. chest press, 3. leg extension, 4. seated row, 5. calf raises, 6. shoulder press, 7. bicep curls, 8. tricep extension.

All testing and RT protocols were conducted in accordance with the guidelines set by the ACSM and the National Strength and Conditioning Association. Correct positioning and range of motion (right angle at elbow and knee) for each exercise were determined and safety precautions explained. Each participant performed a warm-up set of 15 repetitions at a light weight. At the tester's discretion, additional weight was added, and the participant performed another set of 15 repetitions. This process continued until a weight was achieved that allowed the participant to maximally complete 15 repetitions. Subjects rested 2–5 minutes between trials. The 15 repetition maximum (15RM) value was elicited in less than 3 trials.

Session III—Energy Cost of RT Protocol. Under the same testing conditions as RMR measurement, subjects were connected to the CosMed K4b^2 unit and performed a general 5-minute warm-up on a cycle ergometer. Immediately following the warm-up, data collection began. Subjects performed 1 set of 15 repetitions of the 8 RT exercises at their predetermined 15RM intensity with a 2-minute rest interval between sets. Repetition rate was standardized with a metronome, using a count of 2 up and 2 down. Each individual lift phase (1 minute) and rest period (2 minute) was electronically "flagged" on the CosMed K4b^2 unit. Total exercise session time was 24 minutes.

RESULTS

All RT sessions were completed within the allotted 24 minutes with the exception of 1 male participant who was unable to perform the supine chest press exercise because of a physical limitation. This lift was accordingly omitted from his testing session. Total completed session time and corresponding metabolic values for this individual were thus expressed and analyzed over a 21-minute time period. Average completed repetitions to failure/volitional fatigue ranged from 13 to 17 (Table 2). One female participant used dumbbells for the shoulder press and bicep curl exercises because of her inability to lift the minimal set weight on the Universal module.

Males, in comparison to females, generated a greater absolute amount of energy cost during the RT session. These differences were not apparent when adjusted for body weight (Table 3). Both males and females were within the moderate intensity range of 3–6 METs (Table 3).

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

	Group (n = 10)	Males (n = 5)	Females (n = 5)
kcal·min^{-1}†	3.2 ± 0.8	3.5 ± 0.6	2.9 ± 0.7
kcal·kg^{-1}·min^{-1}	0.04 ± 0.01	0.04 ± 0.01	0.05 ± 0.01
Total kcal	76.7 ± 19.8	84.2 ± 14.6	69.7 ± 17.4
Total kcal·kg^{-1}	1.0 ± 0.2	1.1 ± 0.1	0.8 ± 0.1
METS‡	3.1 ± 0.6	3.3 ± 0.7	30 ± 0.6

* *SD* = standard deviation.
† 1 L O_2·min^{-1} = 5.05 kcal O_2·min^{-1}.
‡ MET = (exercise ml O_2 kg^{-1} min^{-1})/resting ml O_2·kg^{-1}·min^{-1}).

DISCUSSION

In recent years, RT has become an accepted component of health-related physical activity/exercise for older adults. However, as with younger populations, such benefits have been documented almost exclusively in physiological and functional terms, such as increased strength/muscle mass, bone mineral density, and functional fitness (5, 13, 19). Recent research has demonstrated the health benefits of moderate intensity and moderate amounts of physical activity for both younger and older populations, but the majority of this research has been concerned with endurance-based physical activity (17, 23). The development of lightweight "wearable" calorimetric systems, such as the CosMed K4b^2, has made the assessment of energy expenditure in more intermittent physical activity, such as RT, much more accessible. Our study is the first to utilize this state-of-the-art equipment to investigate the intensity and energy cost of single-set RT for older adults as recommended by the ACSM (5).

In this group of older adults, we found that performing 1 set of 8 RT exercises for 15 repetitions to failure and/or volitional fatigue elicited a mean intensity of 3.3 ± 0.7 METs for males and 3.0 ± 0.6 METs for females, that is, within the moderate intensity range of 3–6 METs. Total absolute energy cost for both groups (84.2 ± 14.6 kcal for males, 69.7 ± 17.4 kcal for females) achieved only ~46–56% of the 150 kcal recommended value for health-related moderate amounts of physical activity.

We found only 1 other study that reported the energy expenditure of RT in older adults. DeGroot et al. (8) compared the energy cost of 4 different intensity and rest period combinations of a 6-exercise multiple-circuit training program with 9 male cardiac patients 54–75 years old. Subjects completed 3 sets of 30-second work intervals at either 40 or 60% of 1RM with rest times of either 30 seconds or 60 seconds. Total time was 18 minutes for the 30-second/30-second combinations and 27 minutes for the 30-second/60-second combinations. Direct comparisons are difficult because of major differences in population, protocol, and specific RT lifts. However, the gross energy cost for the longer, 27-minute circuit-training session ranged from 69 to 94 kcal per session, compared to 84.2 ± 14.6 in our study. METs ranged from 2–2.5 in the multiple circuit session, compared to 3.3 for men in our study. Our single-set, 24-minute protocol therefore accumulated only 10 kcal less than a longer, 27-minute, low-intensity 3-set protocol. This perhaps is to be expected in a rehabilitation population, typically much frailer and less confident than the independent, community living group of older adults in our study sample. We have, however, previously reported (20) similar intensities for multiple-set training programs compared to our single-set protocols even in younger, healthy adults (11, 15). Such results may indicate the utility of working at shorter and higher levels of intensity if kilocaloric expenditure is 1 goal of a training protocol.

We are aware of no other studies reporting the energy expenditure of any form of RT in older adults; however, we recently investigated the energy expenditure of an identical single-set RT protocol in college-age adults (20). We reported MET intensity levels to be 3.9 ± 0.4 for males and 4.2 ± 0.6 for females, higher than that of the older adults in our current study (3.3 ± 0.7 for males and 3.0 ± 0.6 for females) Total energy cost was 135.2 ± 16.6 kcal for younger males and 81.7 ± 11.1 kcal for younger females, in contrast to our current study values of 84.2 ± 14.6 kcal for older males and 69.7 ± 17.4 kcal for older females. Intensity in kcal·min^{-1} was also greater for younger subjects (5.6 ± 0.7 in males and 3.4 ± 0.5 in females) versus older subjects (3.5 ± 0.6 kcal·min^{-1} for males and 2.9 ± 0.7 kcal·min^{-1} for females).

Although these studies utilized identical protocols, direct comparisons remain difficult because of differences in equipment usage (Cybex vs. Universal) and specific RT exercises utilized. Lower metabolic values found with older adults versus younger adults in these studies may also be secondary to variations in body weight, lower RMR, and lower total amounts of weight lifted per session. Body weight was greater in older versus younger females (70.6 ± 10.4 kg vs. 62.8 ± 7.6 kg) but less in older versus younger males (91.2 ± 17.1 kg vs. 87.5 ± 7.8 kg). Differences were also reported in RMR, which would contribute to differences in calculated MET values for these 2 studies. In addition to these physiological differences, we have also previously reported (20) a reluctance in some older adults to exert a truly maximal effort during RT testing because of factors perhaps associated with fear of injury, expectation, and so on. Such a phenomenon is not unknown anecdotally in the literature (9) and has also been reported by other authors (14). Although we observed no overt signs of such an attitude in our subjects, it is not unreasonable to assume that this too may well have impacted the 15RM assessment and thus reduced the MET intensity levels for these subjects. We are currently conducting a comparative study using an identical protocol with older and younger adults to further elucidate the reasons for any such differences.

In this group of older men and women, our single-set, 8-exercise protocol conducted according to the recent ACSM guidelines appears to achieve the MET threshold of "moderate intensity" for both men and women. However, as with our previous research in younger populations, a single set of this type of RT is not sufficient to achieve the "volume-based" range of 150–200 kcal reported as eliciting health benefits for endurance-type activities. Differences between our current and previous studies may be due to differences in equipment, physiological characteristics ,and perhaps age-related motivational issues.

We conclude that the ACSM single-set 8-exercise RT protocol is a feasible alternative for performing moderate-intensity PA in male and female older adults. 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.

PRACTICAL APPLICATIONS

A number of valuable practical applications arise out of our findings, the most significant of which is that, in this older adult population, our single-set RT achieved a "moderate intensity" of 3–6 METs. This is a highly relevant finding since moderate-intensity physical activity has been extensively recommended for eliciting health benefits (17, 23), and little attention has been paid to RT as a potential mode of physical activity in this respect. As an example of this, a series of studies was recently funded by the International Life Sciences Institute Research Foundation (1997–98) (3). The goal of these studies was to measure a range of low- to moderate-level physical activities in both laboratory and field settings; however, not 1 of these studies addressed RT.

Our study results provide, for the first time, quantifiable evidence to indicate that single-set RT may be used with older adults as a viable mode of accumulating health-related physical activity as recommended by the Surgeon General's Report (23). Following our 8-exercise protocol, men accrued just over half (84.21 $\pm$ 14.58 kcal) and women just under half (69.74 $\pm$ 17.40 kcal) of the absolute number of kilocalories needed to attain an energy expenditure of 150 kcal. Speculatively, therefore, both groups would need to perform 2 sets of these exercises to reach this designated health-related range. However, if the health benefits of RT energy expenditure can be accrued in the same way as has been suggested for endurance-based physical activity (17), either these sets could be completed consecutively, on 2 separate occasions during the same day, or a single set could be combined with another activity to achieve similar health benefits. As an example of the latter situation, women in our study could perform the single-set 8-exercise routine, plus approximately 15 minutes of brisk walking, and would thus accumulate approximately 150 kcal. These results also align with the recommendations of a recent "blueprint" for increasing PA in older adults (21) that highlights the importance of strength exercise in this population.

Further, quantification of exercise intensity by METs has been reported as providing an important prescription guideline 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 (3). This would be important, for example, in cardiac rehabilitation where many of patients are older adults and where RT has become accepted as a viable complement to "usual care" (4). In these situations, activities of daily living and/or return-to-work activities, often in combination with post- to early phase rehabilitation exercises, are increasingly being prescribed according to their published MET level. This topic was the subject of a major symposium at a recent ACSM national conference (1), and its importance has also been stressed by other authorities (2, 3).

Finally, knowledge of the energy cost of RT may also be of interest to those, of any age, who exercise at least partly for weight control (7, 22, 25).

Our study therefore has contributed valuable functional and health-related data for a mode of exercise that is rapidly assuming greater importance in older adult populations but that paradoxically has yet to receive adequate attention in the scientific literature from an energy expenditure perspective.

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