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Research article

AEROBIC ENERGY EXPENDITURE DURING RECREATIONAL WEIGHT TRAINING IN FEMALES AND MALES

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ABSTRACT

The influence of gender on aerobic energy expenditure (EE) during weight training has not been systematically researched. We determined the absolute and relative EE during the performance of two weight training programs of different intensities, durations and total work in males and females. Eight male and seven female recreational weight trainers (20-29 y) completed two randomly ordered weight training sessions involving 2 sets of 8 standard upper and lower body lifts at a set cadence separated by 45 seconds rest between sets and lifts (48 hrs apart). Heavy (H) at 100% 8 Repetition Maximum (8RM), 8 reps, ~19 min duration and light (L) at 85% 8RM, 15 reps, ~23 min duration. VO_2 was determined continuously throughout the training sessions. Lean body mass (LBM) was estimated from skin fold measures and body weight. Energy expenditure was estimated from breath-by-breath metabolic measurements using portable metabolic assessment equipment (Cosmed $K4b^2$). Absolute EE (total kJ) and rate of energy expenditure per minute (kJ per min) were not significantly different between H and L intensities and male and female subjects. The rate of EE averaged between approximately 10-12 kJ per min. However, relative EE (J per kg LBM per min per unit work) were significantly higher ($p < 0.02$) for females compared to males in both H: (26.46±8.06 females vs 14.36±3.02 males) and L: (19.91±4.28 females vs. 9.83±3.28 males), intensities. It was concluded that females rely on a greater relative aerobic EE than males when performing recreational type weight lifting programs.

KEY WORDS: Weight training, gender, aerobic energy expenditure

INTRODUCTION

Relatively few studies have documented aerobic energy expenditure during weight training exercise (i.e. Hickson et al., 1984; Ballor et al., 1989; Kuehl et al., 1990; Phillips and Ziuraitis, 2003). The applicability of these studies to recreational weight training for fitness and health as recommended by the American College of Sports Medicine (American College of Sports Medicine, 1998; 2002) is limited in that some of these studies used forms of circuit training, a limited number of exercises or subjects or did not reproduce realistic or recreational type weight training programs. In addition, since energy expenditure in previous weight training studies was typically estimated via use of metabolic carts (i.e. Hickson et al., 1984), the mobility of the subjects was often limited and consequently the weight lifting measurements may not have reflected the actual mobility in a weight room and variety of lifts performed in typical weight training sessions.

The advent of portable metabolic analysis systems (i.e. Cosmed $K4b^2$) has made the estimation of energy expenditure during realistic weight training sessions more feasible. Interestingly, recent studies have also reported a greater relative reliance on aerobic energy sources in women compared to men during resistance type exercises (Kent-Braun et al., 2002; Mattei et al., 1999). This suggests that gender differences in relative aerobic energy expenditure while weight training, may exist. The influence of gender on aerobic energy expenditure during weight training has not been systematically quantified in previous studies, with some studies (i.e. Hickson et al., 1984), Scala et al. (1987) only reporting data on larger elite male lifters. This study sought to quantify the aerobic energy expenditure during typical recreational weight training exercises (designed primarily for enhancement of fitness and health) of different intensities (American College of Sports Medicine, 1998; 2002) in both females and males using portable metabolic analysis equipment.

METHODS

Fifteen subjects (8 male, 7 female) aged 20-29 y completed the study. All subjects signed an informed consent to participate in the study. The study had been approved by the Wilfrid Laurier University Human Ethics Board in accordance with the Tri-Council (of Canada) policy statement on ethical conduct for research involving humans. All subjects had between 3-5 months experience in recreational weight training prior to their involvement in the study and were physically active, but not competitively athletic.

Lean body mass (in kg) of all subjects was estimated from sum of 4 skin-fold measures as described by Durnin and Wormsely (1974) with estimated fat mass subtracted from body weight.

Maximum oxygen consumption (VO_2 max) was determined using the Cosmed portable $K4b^2$ metabolic system (Cosmed Corporation, Rome, Italy, 2000). Subjects completed a 5 min walking warm up followed by a graded treadmill test with the subjects running at a self-selected speed and the elevation of the treadmill increasing 2% every two minutes until volitional fatigue (McConnell, 1998). VO_2 max was determined as a plateau in oxygen consumption between two increasing workloads accompanied by a respiratory exchange ratio (RER) greater than 1.15 and heart rate within 10 $b \cdot min^{-1}$ of age predicted maximum.

In order to mimic "typical" weight training practice of recreational exercisers as recommended by American College of Sports Medicine Guidelines (1998; 2002), weight lifting exercises were performed using APEX or Universal weight lifting machines as well as free weights and a combination of upper and lower body limb lifts. The primary use of machines is typical of recreational weight lifters, although some free weights are also often employed (Fleck and Kraemer, 1997). Eight repetition maximum (8RM) for each lift/ machine was determined for each subject. The following lifts were used: 1) seated leg press (APEX), 2) incline pectoral chest press (APEX), 3) seated hamstring curl (APEX), 4) seated pull-down (latissimus) (APEX), 5) standing triceps push-downs (Universal), 6) seated quadriceps leg extensions (APEX), 7) standing biceps curl (dumbbells), 8) seated shoulder (deltoid) press (APEX).

Subsequently, subjects performed two weight-training workouts in random order, of different intensities using the above lifts in the order listed. The workouts were performed 48 hours apart and at the same time of day. In the heavy resistance workout (H), subjects performed 2 sets of 8 repetitions of each lift at a resistance equal to 100% of their pre-determined 8RM. During the light workout (L) subjects performed 2 sets of 15 repetitions of each lift at a resistance equal to 85% or their pre-determined 8RM. Participants sat quietly for 5 minutes before the beginning of each workout. In order to standardize rest and work rates, each exercise was performed at a cadence of 60 $b \cdot min^{-1}$ with each movement (lift/contraction or lower/ relaxation) corresponding to one beat. Subjects rested for 45 seconds between each set and between each lift station (machine). This resulted in a work to rest ratio of approximately 1:2 for the 100% 8RM workout and approximately 1:1.5 for the 80% 8RM workout. This is similar to the work to rest ratios used in previous studies (i.e. Hickson et al., 1984). The intensity of the lifts, the lifting tempo, the rest duration between sets and the range and type of lifts used was typical of weight training programs recommended for healthy adults performing weight training primarily for health and fitness benefits (American College of Sports Medicine, 1998; 2002). Breath by breath metabolic measurements were recorded throughout the weight lifting exercises using the Cosmed $K4b^2$ portable metabolic system. Recording began with the first lift and continued throughout the lifts and 45 second recovery sessions, and ending with the last lift.

Aerobic energy expenditure during weight lifting exercises was estimated from expired gases using the formula; 3.781 x VO_2 + 1.237 x VCO_2 x 4.2 = kilojoules (kJ), as calculated by the Cosmed metabolic system and based on the recommendations of Elia and Livesey (1992). This is similar to previous studies, which often used expired VO_2 and assumed an energy equivalent of approximately 21 kJ per litre of O_2 consumed (reported as Kcal) (i.e. Scala et al., 1987; Keuhl et al., 1990; Hickson et al., 1984).

Total work performed in the lifts for each subject was expressed as Work Units (U) and was calculated as (number of repetitions x number of sets x weight lifted in kg =U).

Peak VO_2 for each lifting exercise was determined for each subject from the recorded metabolic data in the 100% 8RM workout and converted to peak VO_2 as a percentage of VO_2 max. The mean of the peak VO_2 data was calculated for each gender.

One way analysis of variance (ANOVA) was used to compare groups (male-100% 8RM, male-85% 8RM, female 100% 8RM, female 85% 8RM). A factoral multivariate ANOVA was used to determine whether systematic differences existed between genders relative to LBM and relative amount work performed during the lifting exercises.

RESULTS

Height, weight, age and percent body fat data for the subjects are listed in Table 1. Males had significantly ($p < 0.01$) higher lean body mass (LBM) than females 66.7 ±6.8 kg vs 46.5±4.1 kg. Males also had significantly ($p < 0.05$) higher VO_2 max than females; 59.6±10.3 ml· kg^{-1}· min^{-1} vs 52.2±3.9 ml· kg^{-1}· min^{-1}. The VO_2 max values for both males and females would suggest that the subjects were fit and healthy but not elite athletes (Powers and Howley, 2001).

Table 1. Physical characteristics of subjects. Data are mean (SD).

	Males (n = 8)	**Females (n = 7)**
Age (y)	22.1 (2.9)	20.7 (1.0)
Height (cm)	176.7 (6.1)	166.7 (4.9)*
Weight (kg)	76.0 (8.8)	64.2 (7.5)*
Body fat (%)	12.0 (2.5)	26.1 (3.6)*

* females different from males ($p < 0.05$)

The rate of aerobic energy expenditure (EE) in kJ per minute for the high (100% 8RM) and low (85% 8RM) intensity workloads are depicted in Figure 1 (0∀SD)(values in Kcal; male 100% 8RM 2.7±0.8, male 85% 8RM 2.8±1.5, female 100% 8RM 2.3±0.8, female 85% 8RM 2.5±0.7). Although male values tended to be higher than female, there were no significant differences ($p > 0.05$) in the rate of absolute aerobic EE between genders or between intensities. The total energy expended for each workload in kJ is depicted in Figure 2 (values in Kcal; male 100% 8RM 50.8±15.3, male 85% 8RM 58.5±31.3, female 100% 8RM 42.2±15.0, female 85% 8RM 58.1±17.0). Although the 100% 8RM lifting intensity resulted in greater work performed per lift, the 85% 8RM lifting intensity was accompanied by a greater number of contractions per set, thereby approximately evening out the difference owing primarily to the greater amount of work performed and the consequently longer exercise times in the latter. These results indicate an average exercise intensity of approximately 2-3 METS throughout the approximately 19-23 minutes of weight training sessions.

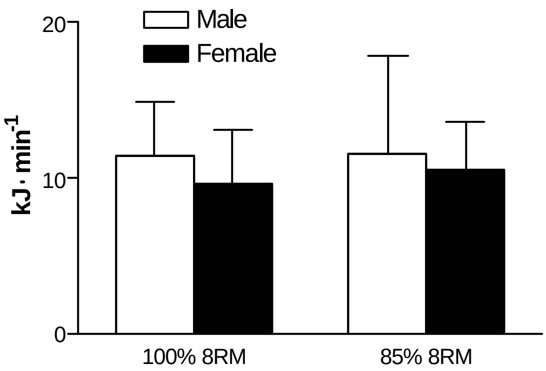

Figure 1. The rate of aerobic energy expenditure (kJoules per min) for males and females when completing weight lifting workouts (100% 8RM, 2 sets of 8 reps, total work time of approximately 19 min or 85% 8RM, 2 sets of 8 reps, total work time of approximately 23 min). There were no significant differences ($p > 0.05$) between genders or workloads in the absolute rate of aerobic energy expenditure.

The relative aerobic EE in Joules (J) per minute per kg LBM per Unit work are depicted in Figure 3 (values in cal· kg LBM^{-1}· min^{-1}· U^{-1} work; male 100% 8RM 3.4±0.7, male 85% 8RM 2.3±0.8, female 100% 8RM 6.3±1.9, female 85% 8RM 4.7±1.0). Females had significantly greater aerobic EE relative to size and work performed ($p < 0.02$) than males at both the 100% and 85% lifting intensities. A factoral multivariate ANOVA of gender and intensity revealed no significant difference in absolute or relative EE for the groups (male-100% 8RM, male-85% 8RM, female 100% 8RM, female 85% 8RM) This would suggest that there was no systematic difference between genders in the amount of work done during weight training relative to lean body mass.

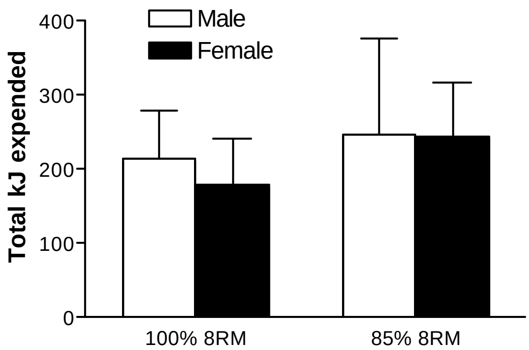

Figure 2. The total aerobic energy expended for males and females when completing workouts using 100% and 85% 8RM resistances (see Fig 1 for workload details). There were no significant differences ($p > 0.05$) between genders or workloads.

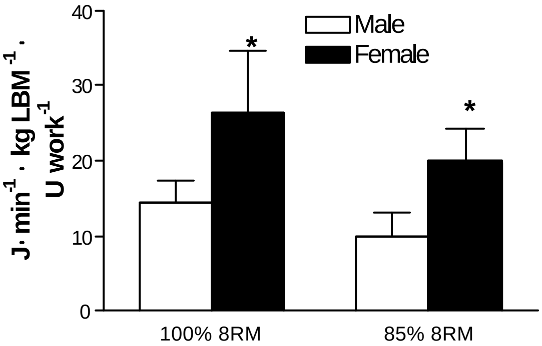

Figure 3. The relative aerobic energy expenditure (in Joules per minute per kg lean body mass per unit work). Females expended significantly more ($p < 0.02$) aerobic energy at both 100% and 85% 8RM resistances relative to body weight and total work performed (see Fig 1 for workload details).

The average peak VO_2 as a percentage of VO_2 max, for each lifting exercise in the100% 8RM workload were 44.9±3.2% for males and 57.6±6.1% for females. Females had significantly higher average peak VO_2 as a percentage of VO_2 max during the during each weight lifting exercise compared to males ($p < 0.05$).

DISCUSSION

The primary finding of this study is that females exhibited a significantly greater rate of aerobic EE relative to lean body mass and volume of work performed during weight lifting exercises than males. This difference was present in both the 85% and 100% 8RM lifting intensities. This finding is supported by the average peak VO_2 data which also demonstrates that females had relatively higher oxygen consumption during the weight lifting exercises (as a percentage of their VO_2 max) than males. Several previous studies using resistance exercises have reported separate aerobic energy expenditure data from males and females (i.e. Ballor et al., 1989; Keul et al., 1990; Phillips and Ziuraitis, 2003). These studies have not noted a gender difference in aerobic energy expenditure during weight training when expressing energy expenditure in absolute units (i.e. Kcal per minute). Such gender differences were not evident in our study as well, when aerobic energy expenditures for males and females were expressed as kJs per minute. However, this is the first study to compare genders during weight training by expressing aerobic energy expenditure in relative terms (i.e. joules per kg body weight per unit work). When body size differences and total work performed are accounted for in this study, a gender difference emerged.

The reasons for the higher aerobic energy expenditure during weight lifting relative to body size and work performed in females compared to males cannot be determined from this study. However, previous studies have noted that females rely significantly more on aerobic metabolism and expend relatively more aerobic energy than males when performing muscle contractions at intensities greater than 50% maximum voluntary contraction (MVC) (Kent-Braun et al., 2002). Kent-Braun et al. (2002) have suggested that this may at least in part be due to relatively higher muscle aerobic enzyme activities and relatively lower muscle glycolytic enzyme activities that may exist in females relative to males (Kent-Braun et al., 2002). In addition, males tend to have a relatively greater reliance on glucose as a fuel source, thereby supporting a greater potential for anaerobic activity at heavier workloads than females (Tarnopolsky et al., 1990). Hence, as previously reported (Kent-Braun et al., 2002), it is possible that females may rely relatively more on aerobic energy expenditure (and consequently less on anaerobic energy) and males may rely relatively more on anaerobic energy expenditure (and consequently less on aerobic energy) during weight training when total work and lean body mass are controlled for. Since there were no systematic differences in male and female subjects in overall aerobic fitness and weight training experience, it seems unlikely that these aerobic energy expenditure differences could be accounted for by any differences in fitness or experience between genders.

Alternatively, Mattei et al (1999) have suggested that untrained females may have a relatively higher energy cost in performing intense muscular contraction than males that is unrelated to muscle aerobic or anaerobic metabolism differences between genders. They suggest that this may be due to reduced metabolic efficiencies in ATP utilization during muscular contractions in untrained females relative to males (Mattei et al., 1999). In this case both aerobic and anaerobic energy expenditure during weight training would have been higher in females than in males when expressed relative to LBM and volume of work performed. However, since we were only able to measure aerobic energy expenditure, only this would have been evident.

These possibilities need to be followed up with further research, to discern the mechanisms involved in the relatively greater aerobic energy expenditure relative to LBM and volume of work performed by females during weight training exercises. The anaerobic contribution to weight lifting performance could not be directly measured in this study. Nevertheless, aerobic metabolism during post-exercise recovery, can at least in part be utilized for anaerobic recovery i.e. creatine phosphate resynthesis (Gaesser and Brooks, 1984). Hence, the contribution of the measured oxygen consumption during the 45 seconds recovery periods between sets and lift stations (as included in the overall aerobic energy expenditure calculations) could at least partially account for the anaerobic metabolism incurred during the weight lifting exercises.

The other finding of this study was that aerobic energy expenditure during weight training averaged between approximately 10-12 kJ per min or only approximately 2-3 METS in both genders at both 85% and 100% 8RM intensities. This is significantly less than previously reported in some studies, which noted approximately the equivalent of 28-39 kJ per minute of aerobic energy expenditure during weight training exercises (originally reported as Kcal) (Hickson et al., 1984; Scala et al., 1987; Ballor et al., 1989). Some of these differences could be due to the more aerobic circuit training nature of previously reported weight training programs (i.e. Ballor et al., 1989), the use of elite male (i.e. Scala et al., 1987) rather than recreational weight lifters or with the use of only large male subjects (Hickson et al., 1984). The aerobic energy expenditures reported in the present study are similar to those recently reported by Phillips and Ziuraitis (2003) (reported as METS-metabolic equivalents) who also used recreational lifters of both genders performing weight training according to similar American College of Sports Medicine Guidelines as employed in the present study. Hence the average aerobic energy expenditure rates of 10-12 kJ per minute reported in this study are likely realistic estimates for recreational weight lifters performing moderate intensity weight training with approximately1:2 work to rest ratios.

CONCLUSION

In conclusion, this study demonstrated that females have significantly higher aerobic energy expenditure than males during weight lifting exercises when expressed relative to lean body mass and volume of work performed. Total energy expenditures for standard weight training program as performed by recreational lifters typically expends aerobic energy at the rate of only 10-12 kJ per minute or the equivalent of approximately 2-3 METS over the course of the weight training sessions.

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