The Effect of Acute Resistance Training on Resting Metabolic Rate in Men

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The Effect of Acute Resistance Training on Resting Metabolic Rate in Men

by

Steven William Ball

A Thesis
Submitted to the
Faculty of the Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Science
Department of Health, Physical Education, and Recreation

Western Michigan University
Kalamazoo, MI
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I simply cannot forget to thank my father Dr. Thomas E. Ball for help with the selection of the idea and extensive input in piecing together this manuscript.

Lastly, I would like to thank my wife, Jennifer, for putting up with my early morning hours in the lab and for her patience and support while I typed away day after day.

Steven William Ball
The Effect of Acute Resistance Training on Resting Metabolic Rate in Men

Steven William Ball, M.S.
Western Michigan University, 2008

The purpose of this study was to investigate the effect of different frequencies of resistance training on an individual’s resting metabolic rate (RMR). Six healthy males between the ages of 18 and 35 participated in two separate trials. The first trial involved two full-body resistance training bouts, 48 hours apart with RMR measurements pre- and post-bout and a RMR measurement 24 hours following each. The second trial consisted of four split-body resistance training bouts on four consecutive mornings with RMR measurements pre- and post-bout each morning with a fifth morning for one final RMR measurement, 24 hours after the final bout of exercise. This was a repeated measures design and the order of conditions was randomized. Analysis of variance was used to interpret the data. It was concluded that mean RMR for each protocol was not significantly different (1.5275 ± 0.1976 kcal·min⁻¹, 1.5273 ± 0.1690 kcal·min⁻¹). A secondary finding was that respiratory exchange ratio (RER) decreased as RMR increased, showing a greater oxidation of fat post exercise, although there was not a statistically significant difference. These results led to the conclusion that RMR will be the same for two different resistance training programs as long as the work is constant between both. The practical application of these results would be that if an individual is choosing a resistance training regimen to raise RMR and lose weight, the program can be selected based on time constraints.
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INTRODUCTION

Resting metabolic rate (RMR) is the quantity of kilocalories the human body utilizes to sustain metabolic reactions and processes while at rest with very little or no movement, in a relaxed reclined or supine position, with the body being free from fever or anxiety. Any movement or perturbations (i.e. fever or anxiety) will increase metabolic rate higher than at resting levels. RMR measurements are often determined 10-12 hours after a meal to eliminate any postprandial increases in RMR from digestion (16,19). RMR accounts for the majority of an individual’s daily energy expenditure (2,3,8,16,19,22). Thus, it plays a significant role in the loss or maintenance of body weight.

The equilibrium between the amount of kilocalories taken in through the diet and the amount of kilocalories utilized via metabolic processes and physical activity is referred to as energy balance. An individual in energy balance will not gain or lose body weight. Negative energy balance is when the number of kilocalories utilized is greater than the number of kilocalories ingested. An individual in negative energy balance will lose body weight. Positive energy balance is when the number of kilocalories ingested is greater than the number of kilocalories utilized. An individual in positive energy balance will gain body weight. Dieting alone is not the best way to lose body weight because it puts the body into negative energy balance and results in lost muscle mass and a decreased RMR to compensate for the caloric deficit (4,6,10,16). Traditionally, weight loss is achieved through caloric restriction and low to moderate intensity aerobic exercise.
However, a review by Winett and Carpinelli (24) states that this method only works in reducing body fat to a certain extent; lean body mass is then lost, fewer kilocalories are needed, and RMR is significantly decreased making further weight loss or maintenance very difficult.

Resistance training has been shown to have significant health benefits including increased bone mineral density, improved musculoskeletal strength and function, maintenance of functional abilities, as well as increasing RMR (8,9,15,16,18,19,24). In a study by Melby et al. (15) RMR and excess post-exercise oxygen consumption (EPOC) were tested immediately following a bout of high-intensity resistance exercise. Metabolic rate was elevated during a 2 hour post test (EPOC or post-exercise metabolic rate) and remained elevated during a measurement taken 14 hours later (RMR). Other studies revealed that both high-intensity endurance and resistance training prevented a decline in RMR during extended negative energy balance, due to an increase in fat-free mass (3,4,16). An increase in RMR also leads to a similar increase in fat oxidation (15,19).

Researchers have hypothesized that exercise induced muscle damage causes the increased RMR. Dolezal et al. (9) investigated the change in RMR after an acute resistance bout with an eccentric overload. The eccentric overload was necessary to cause a maximum amount of muscle damage. They found that RMR was significantly elevated in trained and untrained men, and they concluded that it was due to greater muscle damage via the eccentric overload.
The question that still remains, however, is if the elevated RMR is a result of chronic exercise training (i.e. increase in fat-free mass) or simply a sum of acute bouts. Bullough et al. (5) researched discrepancies in different studies investigating effects of exercise on RMR. They had eight endurance trained athletes and eight untrained subjects participate in a study. The eight trained men were measured for RMR under four conditions; high intensity exercise (75% VO$_2$max for 90 minutes) while in energy balance, no exercise while in energy balance, high intensity exercise while in negative energy balance, and no exercise while in positive energy balance. The untrained subjects were tested for RMR under a single condition of no exercise and energy balance. The results revealed only the trained subjects, who exercised with a high intensity while in energy balance, had a significantly higher RMR, 24-48 hours post exercise, than the untrained subjects. The researchers concluded that diet needs to be constant and in balance with energy expenditure for RMR to be significantly elevated (3,4,10,11,14,19). They also suggested that trained subjects may have adapted to an elevated RMR because of their consistency of acute bouts, not necessarily as a consequence a chronic adaptation (5,15). However, this study used endurance training as the mode of exercise, rather than resistance training. Other researchers have concluded that resistance trained individuals had a significantly higher RMR, 24-48 hours post exercise, than those who were endurance trained (4,8,18,19).

Some authors report that resistance training 2-3 times per week is adequate for preserving or increasing muscular strength and size (3,4,7,8,24). However, it is unknown
if this frequency maintains an elevated RMR or if it will return to baseline before the next resistance training bout. It is currently popular among weight lifters to resistance train four or more days per week using a split-body exercise routine, meaning they will work on their upper body and lower body on alternating days. Another method used among weight lifters is to exercise different portions of the body on different days. For example, an individual will exercise their arms one day, chest and shoulders the next, back and abdominals the next, and legs on the last day, repeating the cycle after a day off. The questions that arise are: what frequency of resistance training is best for maintaining an elevated RMR with a constant weekly amount of work? And is the elevated RMR at its peak or does the next bout of exercise elevate the RMR to a greater extent than it was previously (i.e. an additive effect)?

The purpose of this study was to determine whether doing four split-body resistance training bouts over a five day period would differ from doing two full-body resistance training bouts over a similar period in maintaining an elevated RMR, and if the sum of the acute bouts are cumulative in regards to RMR or if the RMR simply remains at its previously elevated level. It was hypothesized that the four split-body resistance training bouts will keep the RMR elevated to a greater extent than the two full-body resistance training bouts. In addition, the RMR during the four split-body resistance training bouts will continue to build upon itself after each bout, every 24 hours. Therefore, the mean RMR for the week of the four bouts will exceed that for the week of only the two bouts. It is also hypothesized, that as a complement to the elevated RMR,
respiratory exchange ratio (RER) will decrease showing a higher percentage of fat oxidation.

METHODS

Approach to the Problem

RMR measurements were taken for two separate resistance training trials; the first trial included two full-body resistance training bouts (2DAY) separated by 48 hours, the second trial included four split-body resistance training bouts (4DAY), 24 hours apart. RMR was measured pre and post exercise bout and every morning of the trial. 24, 48, and 72 hour post baseline RMR measurements were taken to determine if the previous RMR had an additive affect upon the next bout of resistance training or if it simply remained at the same level. The mean RMR for the week was also calculated to determine any differences between the two trials.

Subjects

Six male resistance-trained subjects participated in this study. All were healthy, non-smokers, and free of any metabolic or cardiovascular diseases. Subjects did not take any medications, drugs, or dietary supplements other than a daily multi-vitamin and two of the subjects consumed a daily protein meal-replacement drink. Subjects were considered recreational resistance-trainers, in that they had been resistance training 2-3 times per week for the past 6 months, and were free from any athletic competitions for the past year. Subjects were instructed to maintain consistency in their diet throughout their participation in the study. Approval was obtained from the Human Subjects
Institutional Review Board and all subjects signed informed consent before participating.

Subject characteristics can be found in Table 1.

| Table 1: Subject Characteristics (Mean ± SD) (n=6) |
|-----------------|-----------------|
| Age (y)         | 22.5 ± 2.5      |
| Height (cm)     | 180.5 ± 5.6     |
| Weight (kg)     | 86.8 ± 9.8      |
| Body fat (%)    | 12.96 ± 6.90    |

Procedures

Instrumentation

A health history questionnaire established by the American Heart Association and the American College of Sports Medicine was used to determine the health status of the subjects (see Appendix A). A brief questionnaire derived from the Western Ontario and McMaster Universities Index of Osteoarthritis (WOMAC) was used to assess if subjects have had any musculoskeletal problems or injuries (see Appendix B). Lange Skinfold Calipers (Beta Technology Inc., Santa Cruz, CA) were used to calculate body composition. The Thermotron Environmental Chamber (Holland, MI) was used to control temperature and humidity during RMR measurements. RMR testing was done in a 24°C, 45% humidity environment. Resistance training bouts were performed in the Student Recreation Center weight room. The ParvoMedics Metabolic Cart (Sandy, UT) was used to obtain the RMR values via indirect calorimetry. A Polar Heart Rate Monitor
(Lake Success, NY) was used to track heart rate during the RMR testing. Dumbbells of adequate weight were used for resistance during the resistance training bouts.

**Orientation**

All subjects visited the Human Performance Research Laboratory a minimum of three days prior to data collection for an orientation visit. RMR was taken to acclimate the subject to the protocol and seven skinfold sites were measured to calculate percent body fat (Jackson/Pollock, Siri) (1). After a set of 15-20 repetitions with approximately 50-60% 1RM, the subject performed a predicted one repetition maximum test (1RM) for twelve different exercises. Subjects performed a set of each exercise to failure. Failure was defined as when another repetition could not be completed with proper technique throughout the range of motion. If failure was not reached before the 20th repetition on the first attempt, the weight was adjusted and a second attempt was made. The number of repetitions and the amount of weight lifted was then used in the following equation to find the 1RM: \[ \text{kg} / [1.00 - (\#\text{RM} \times 0.02)] \] (1).

**RMR Measurement**

RMR measurements involved the subject resting in a semi-darkened room at a reclined position (30° above the horizontal) in a dental chair in the environmental chamber with limited movement for 30 minutes. The metabolic cart mouthpiece and nose clip were then attached and the subject rested for 15 more minutes. In much of the literature on the topic of RMR, a ventilated hood or canopy was used for measurement. Although this maybe the most acceptable method of measuring RMR, a study by Segal
discovered there to be no difference in RMR between the uses of ventilated hood, face
mask, or mouthpiece (21). Due to the short duration of the RMR measurement in the
current study, the comfort, which was a significant reason for using the ventilated canopy,
was not an issue. The metabolic cart was calibrated according to the manufacturer’s
guidelines. The RMR is presented in kilocalories per minute (kcal·min⁻¹). RER was also
measured to see the change in fat oxidation post exercise.

Investigation Trials

The morning of each session subjects drove themselves to the laboratory
immediately after awakening, not having had breakfast or a shower. RMR measurements
were made pre and post exercise bout as well as 24, 48, and 72 hours following the initial
baseline measurement. The order of trials was randomized with a minimum of three days
between trials for the subject’s RMR to return to a pre-exercise level. Subjects ingested
an Ensure® shake (350 kilocalories, 57% carbohydrate, 28.2% fat, 14.8% protein)
(Abbott Laboratories, Abbott Park, IL) immediately following the pre-exercise RMR
measurement and a minimum of 15 minutes prior to the resistance training bout.
Subjects had been asked not to ingest anything besides water after 9:00 pm the night
before the session to eliminate the thermic effect of food on RMR. Subjects were asked
not to use alcohol or caffeine 24 hours prior to beginning the trial. Each subject
completed a brief questionnaire at the beginning of each session to confirm that they
followed protocol, body weight was measured prior to starting each session, and a Polar
heart rate monitor was worn during the RMR measurement. Table 2 contains a timeline
of each trial.
The resistance training exercises were paired and performed as a superset (completing one exercise and then another of a different muscle group before returning to the first exercise for a second set) for two sets of 10 repetitions at 75% of predicted 1RM. Exercise program A included: dumbbell incline press and dumbbell dead lift, lateral raises and overhead triceps extension, dumbbell pectoral flys and single-leg standing calf raises. Exercise program B included: single-arm bent over row and split squats, bent arm pullovers and standing biceps curl, upright row and lateral lunges. Exercises were performed in the order listed. No more than 45 seconds rest was allowed between each exercise and no more than three minutes rest was allowed between each superset, however, subjects were encouraged to go from one exercise to the next as quick as they could.

<table>
<thead>
<tr>
<th>Table 2: Schedule of Experimental Protocol</th>
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</thead>
<tbody>
<tr>
<td><strong>Trial 1 (2DAY)</strong></td>
</tr>
<tr>
<td>2 bouts/week</td>
</tr>
<tr>
<td><strong>Day 1</strong></td>
</tr>
<tr>
<td>0700-0745 RMR</td>
</tr>
<tr>
<td>0800-0845 Program A+B</td>
</tr>
<tr>
<td>0845-0930 PEMR</td>
</tr>
<tr>
<td><strong>Day 2</strong></td>
</tr>
<tr>
<td>0700-0745 RMR</td>
</tr>
<tr>
<td>0800-0830 Program A</td>
</tr>
<tr>
<td><strong>Day 3</strong></td>
</tr>
<tr>
<td>0700-0745 RMR</td>
</tr>
<tr>
<td>0800-0845 Program A+B</td>
</tr>
<tr>
<td>0845-0930 PEMR</td>
</tr>
<tr>
<td><strong>Day 4</strong></td>
</tr>
<tr>
<td>0700-0745 RMR</td>
</tr>
<tr>
<td>0800-0830 Program B</td>
</tr>
<tr>
<td><strong>Day 5</strong></td>
</tr>
<tr>
<td>No testing</td>
</tr>
</tbody>
</table>

| **Trial 2 (4DAY)**                       |
| 4 bouts/week                             |
| **Day 1**                                |
| 0700-0745 RMR                            |
| 0800-0830 Program A                       |
| 0830-0915 PEMR                            |
| **Day 2**                                |
| 0700-0745 RMR                            |
| 0800-0830 Program B                       |
| 0830-0915 PEMR                            |
| **Day 3**                                |
| 0700-0745 RMR                            |
| 0800-0845 Program A                       |
| 0830-0915 PEMR                            |
| **Day 4**                                |
| 0700-0745 RMR                            |
| 0800-0830 Program B                       |
| 0830-0915 PEMR                            |
| **Day 5**                                |
| 0700-0745 RMR                            |
could. Subjects were free to drink water as needed. Work was consistent between the two trials.

Statistical Analyses

SPSS Version 15.0 (Chicago, IL) was used to perform two separate, one-way repeated measures analyses of variance (ANOVA). Bonferroni’s Post Hoc Test was used to determine differences between data points for each trial. A paired samples t-test was used to determine differences between trials. Results are presented as mean ± standard deviation (SD). The alpha level was established a priori at α=0.05.

RESULTS

The RMR for the 2DAY was not significantly different for the week as a whole from the 4DAY. The mean for the 2DAY was 1.5275 ± 0.1976 kcal·min⁻¹ and the mean for the 4DAY was 1.5273 ± 0.1690 kcal·min⁻¹. The means for the two trials correlated highly, r=0.95 (p<0.05). A small effect size was observed for 2DAY (Partial Eta Squared=0.37). A moderate effect size was observed for 4DAY (Partial Eta Squared =0.40). The daily RMR is presented in Table 3. The daily RER is presented in Table 4. Immediate post-exercise metabolic rate (PEMR) and RER are presented in Table 5.
Table 3: Resting Metabolic Rate (Mean ± SD) (n=6)

<table>
<thead>
<tr>
<th></th>
<th>2DAY</th>
<th>4DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>1.4767 ± 0.2723</td>
<td>1.4833 ± 0.2445</td>
</tr>
<tr>
<td>24h post</td>
<td>1.5833 ± 0.2511</td>
<td>1.4900 ± 0.1401</td>
</tr>
<tr>
<td>48h post</td>
<td>1.4550 ± 0.1897</td>
<td>1.5667 ± 0.1592</td>
</tr>
<tr>
<td>72h post</td>
<td>1.5950 ± 0.1223</td>
<td>1.4800 ± 0.2180</td>
</tr>
<tr>
<td>96h post</td>
<td>-</td>
<td>1.6167 ± 0.1337</td>
</tr>
</tbody>
</table>

Measurements are presented in hours post baseline. Exercise bouts were completed 15 minutes after baseline and 48h post (2DAY), and 15 minutes after baseline, 24, 48, and 72h post (4DAY).

Table 4: Respiratory Exchange Ratio (Mean ± SD) (n=6)

<table>
<thead>
<tr>
<th></th>
<th>2DAY</th>
<th>4DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>0.85 ± 0.06</td>
<td>0.87 ± 0.04</td>
</tr>
<tr>
<td>24h post</td>
<td>0.82 ± 0.05</td>
<td>0.84 ± 0.03</td>
</tr>
<tr>
<td>48h post</td>
<td>0.86 ± 0.02</td>
<td>0.84 ± 0.05</td>
</tr>
<tr>
<td>72h post</td>
<td>0.84 ± 0.04</td>
<td>0.84 ± 0.02</td>
</tr>
<tr>
<td>96h post</td>
<td>-</td>
<td>0.81 ± 0.05</td>
</tr>
</tbody>
</table>

Measurements are presented in hours post baseline. Exercise bouts were completed 15 minutes after baseline and 48h post (2DAY), and 15 minutes after baseline, 24, 48, and 72h post (4DAY).
Table 5: Immediate Post-Exercise Metabolic Rate and Respiratory Exchange Ratio (Mean ± SD) (n=6)

<table>
<thead>
<tr>
<th>Exercise Bout 1</th>
<th>2DAY</th>
<th>4DAY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEMR</td>
<td>1.7634 ± 0.1792</td>
<td>1.6336 ± 0.1290</td>
</tr>
<tr>
<td>RER</td>
<td>0.68 ± 0.08</td>
<td>0.76 ± 0.07</td>
</tr>
<tr>
<td>Exercise Bout 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEMR</td>
<td>1.7397 ± 0.1452</td>
<td>1.6666 ± 0.1556</td>
</tr>
<tr>
<td>RER</td>
<td>0.74 ± 0.07</td>
<td>0.73 ± 0.05</td>
</tr>
<tr>
<td>Exercise Bout 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEMR</td>
<td>-</td>
<td>1.7081 ± 0.1860</td>
</tr>
<tr>
<td>RER</td>
<td>-</td>
<td>0.76 ± 0.05</td>
</tr>
<tr>
<td>Exercise Bout 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEMR</td>
<td>-</td>
<td>1.8334 ± 0.1300</td>
</tr>
<tr>
<td>RER</td>
<td>-</td>
<td>0.76 ± 0.06</td>
</tr>
</tbody>
</table>

PEMR: Post-Exercise Metabolic Rate (this is not a true resting measurement since it is immediately following exercise)

**DISCUSSION**

In this study we investigated the differences in RMR during two resistance training trials, a two-day full-body resistance training trial and a four-day split-body resistance training trial. The primary purpose was to determine, which frequency of resistance training would impact RMR to the greatest extent. A secondary purpose was to determine if there was an effect of subsequent resistance exercise building upon the previously elevated RMR, or if it simply remains elevated (i.e. not additive).

The methodology of this study is not representative of one particular research article; it was developed after a review of the literature. An analysis of weight loss studies determined that a sufficient volume of exercise was needed to elicit significant weight loss (13,15,16,20). Intensity of exercise is a more important factor in determining
the increase in RMR than is the duration of exercise (6,12,15). These studies showed an increasing RMR with increasing intensity of exercise, regardless of mode. Marked increases in RMR will only occur when exercise is of adequate intensity (13,15,16,20). Bryner et al. (4) used a repetition range of eight to twelve repetitions to failure. Two or three sets of 8-12 repetitions will increase or maintain muscle strength and mass (3,4,7,8,24). That is why for the current study a two set, 10 repetition exercise bout was used. 75% 1RM was used to keep the intensity consistent between all subjects. The exercise bouts were performed as a superset to accentuate intensity. Future investigators might examine the differences between traditional resistance training and superset resistance training.

Previous research has concluded that RMR will return to baseline within 72 hours post exercise (7,8,9,16,17,23,24). It was also discovered that after a high-intensity, eccentric resistance exercise bout, RMR had returned to baseline within 72 hours, however, RMR was still elevated at 48 hours post exercise (9). Therefore, to maximize metabolic efficiency, high-intensity resistance training should be done at least every 48 hours. To our knowledge there is a lack of research investigating the effect of resistance training frequency on RMR. Perhaps, resistance training every 24 hours (four or more days/week), with a similar workload, would be more beneficial for weight loss and maintenance. It was discovered in the current study that resistance training every 24 hours did not impact RMR any more than resistance training every 48 hours, when work was kept constant. If more work is done in a given day or a given week then more kilocalories will be used and RMR will most likely be higher.
It was hypothesized that doing four split-body resistance training bouts in a five day period would raise the RMR higher than doing two full-body resistance training bouts, and by resistance training every 24 hours the RMR would continue to elevate past its previously raised level. The findings of the current study did not support this hypothesis. There was not a significant difference in the weekly RMR (mean of every 24 hour RMR measurement) between the two resistance training trials. This suggests that the weekly volume of work, rather than the frequency, will determine the weekly RMR. There was, however, a slight cumulative effect shown in the 4DAY. Although it was not statistically significant, the RMR level on the final day was higher than on the previous days. This suggests that resistance training every 24 hours will consistently raise the RMR higher after every bout, although further research would have to be done and the length of training would have to be increased in order to see if that is in fact the case. Perhaps a study that lasted 6-12 weeks would give more of an indication of a possible training adaptation (i.e. increase in fat-free mass). The findings also suggest that this elevated RMR is due to a sum of acute bouts and not a chronic adaptation, because there was insufficient time for adaptations to occur. In both trials the RMR had returned to near baseline after 48 hours of no exercise. Long term research would need to be done to determine if the RMR elevation is a chronic adaptation or a sum of acute bouts.

Although there was no significance between daily RMR measurements a trend can be seen. 24 hours after the first bout of exercise the RMR increased; it returned to baseline level 48 hours post, and increased again after the second bout of exercise. This
is to be expected as RMR will increase after a bout of resistance exercise
(8,9,15,16,18,19,24). Although the increase in RMR was less pronounced during the
4DAY, it was consistent throughout the trial, due to the subsequent exercise bout being
performed 24 hours later. 24 hours after the first bout of exercise the RMR increased
very slightly, but 24 hours after the second bout of exercise, 48 hours after baseline, the
RMR reached just below the level of the 2DAY 24 hour post measurement (2DAY 24
hour post: 1.5833 ± 0.2511 kcal·min⁻¹, 4DAY 48 hour post: 1.5667 ± 0.1592 kcal·min⁻¹).
24 hours after the third bout of exercise the RMR dropped back to baseline level; perhaps
the body had grown accustomed to the short bout of exercise. However, after the fourth
and final bout, the RMR increased higher than any from the 2DAY. It is likely that the
short 24 hour rest between bouts contributed in elevating the RMR, thus making up for
the bouts of shorter duration. An inverse trend can be seen with the RER; as RMR
increases, RER decreases, showing that a greater percentage of the kilocalories utilized
were fat kilocalories. This finding supports those of previous studies that fat oxidation
increases after resistance exercise (15,19).

When reviewing the immediate post-exercise data it can be seen that the higher
workload from the 2DAY elicits a higher PEMR and lower RER, although it is not
significant. The mean PEMR for the 2DAY is 1.7516 ± 0.0167, and for the 4DAY it is
1.7104 ± 0.0875. The mean immediate post-exercise RER for the 2DAY is 0.71 ± 0.04,
and for the 4DAY it is 0.75 ± 0.01. This lower RER in the 2DAY trial shows a greater
amount of fat oxidation. However, this immediate post-exercise effect does not last for
24 hours. Therefore, more research investigating EPOC after resistance training and its
contribution to fat-loss is needed. Due to the similarity of the PEMR between trials, it is suggested that a superior fat-loss strategy would be to resistance train every 24 hours, because there will be an increased period of EPOC more often throughout the week.

In the current study the subjects’ diets were not managed or recorded. Subjects were simply told to keep their diet consistent throughout the study. Two of the subjects ingested a protein meal-replacement drink on a regular basis (one or two per day). It is feasible that the extra protein in the diet of those two subjects would increase RMR. Future studies investigating RMR should have the subjects keep a diary of their diet to be sure that it is consistent. Perhaps, a study could be completed investigating RMR with or without a protein meal-replacement drink.

The researchers of the present study believe that the information uncovered would be beneficial to the fitness professional with some complimentary findings. Conceivably, more investigation on the frequency of resistance training could be done. Testing RMR for three full-body workouts per week versus six split-body workouts would possibly raise RMR to a greater degree, thus contributing more to body weight loss. A current trend is to train one portion of the body, one day at a time; for example, an individual will do their arms one day, chest and shoulders the next, back and abdominals the next, and legs on the last day, repeating the cycle after a day off. A study examining RMR after concentric resistance training versus eccentric resistance training, or the metabolic differences of opposite muscles, would add to weight loss knowledge and possibly lead to the development of more successful fat reduction exercise programs.
PRACTICAL APPLICATIONS

The findings of this investigation suggest that RMR during a week of resistance training will be elevated to an equivalent degree whether resistance training is done every 48 hours or every 24 hours, as long as the work done for that week is constant. Fitness professionals can use this information to be more flexible with the type of workout they develop for their clients. If the goal is to lose body weight, resistance training on a consistent basis will be best for elevating RMR. The individual can choose the frequency of training that will best suite their busy schedule. However, because of the greater workload of the full-body bout it may take up to an hour to complete; the split-body workout only takes 15-20 minutes. If the individual does not have an hour to spare, but they can fit a 30 or 45 minute workout into most days throughout the week, they may be able to do more than half of the full-body workout on those days. For example, if an individual is going to resistance train the upper body the first day and lower body the next, they may be able to do more exercises on the appropriate days then they would otherwise be able to fit into a full-body workout, thus expending more kilocalories and raising the RMR to a greater extent. Although the current study did not measure PEMR for a continuous, extended period of time post exercise, the immediate post-exercise data shows that due to the greater workload of the full-body bout, PEMR and fat oxidation increased higher than after a single split-body bout. However, resistance training every 24 hours leads to more extended periods of increased metabolic rate and fat utilization.
throughout the week. Thus, suggesting that a greater amount of fat can be lost when resistance training at least half of the body every day.
REFERENCES


# APPENDIX A

AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire

## TABLE 2. AHA/ACSM Health/Fitness Facility Preparticipation Screening Questionnaire

Assess your health needs by marking all true statements.

### History

- You have had:
  - a heart attack
  - heart surgery
  - cardiac catheterization
  - coronary angioplasty (PTCA)
  - pacemaker/implantable cardiac defibrillator/rhythm disturbance
  - heart valve disease
  - heart failure
  - heart transplantation
  - congenital heart disease

If you marked any of the statements in this section, consult your healthcare provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

### Symptoms

- You experience chest discomfort with exertion.
- You experience unreasonable breathlessness.
- You experience dizziness, fainting, blackouts.
- You take heart medications.

### Cardiovascular risk factors

- You are a man older than 45 years.
- You are a woman older than 55 years or you have had a hysterectomy or you are postmenopausal.
- You smoke.
- Your blood pressure is >140/90.
- You don't know your blood pressure.
- You take blood pressure medication.
- Your blood cholesterol level is >240 mg/dl.
- You don't know your cholesterol level.
- You have a close blood relative who had a heart attack before age 55 (father or brother) or age 65 (mother or sister).
- You are diabetic or take medicine to control your blood sugar.
- You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week).
- You are >20 pounds overweight.

If you marked 2 or more of the statements in this section, consult your healthcare provider before engaging in exercise. You might benefit by using a facility with a professionally qualified exercise staff to guide your exercise program.

### Other health issues:

- You have musculoskeletal problems.
- You have concerns about the safety of exercise.
- You take prescription medication(s).
- You are pregnant.

None of the above is true. You should be able to exercise safely without consulting your healthcare provider in almost any facility that meets your exercise program needs.

AHA/ACSM indicates American Heart Association/American College of Sports Medicine.

These forms are taken from the following reference:

Gary J. Belkin, MD, Clay Bernard, Chairman, MD; David DeMott, MD; Carl Foster, PhD; Evelyn Freischtz, PhD; Neil Gordon, MD; Russell Foster, PhD; James Ripp, MD; Terry Buzza, PhD. Recommendations for Cardiovascular Screening, Staffing, and Emergency Policies at Health Fitness Facilities. Circulation. 97: 2283-2293, 1998.
APPENDIX B
Musculoskeletal/Physical Activity Questionnaire

Musculoskeletal

Asses your health needs by marking all true statements.

You have had:

___ broken bones
___ muscle strains
___ joint sprains
___ muscle, bone, tendon, or ligament surgery
___ pain or difficulty doing any physical activity
___ stiffness in any muscles or joints

Physical Activity

Check all true statements.

You have:

___ used dumbbells before
___ weight-lifted more than twice per week consistently for the past 6 months
___ participated in exercise other than weight lifting
___ weigh-lifted competitively
___ taken dietary supplements or performance-enhancing drugs, i.e. hydroxycut, steroids, creatine, etc.
___ been a bodybuilder
___ been free of organized athletic competition for the past year

Average hours exercising per week __________________________

Characteristics

DOB ________________

Sex ________________

Name __________________________

Phone Number ____________________

Email ___________________________
APPENDIX C
Daily Confirmation of Protocol Questionnaire

Check all true statements.

You have:

___ Exercised outside of the parameters of the study since it began
___ Ingested caffeine in the last 24 hours
___ Ingested alcohol in the last 24 hours
___ Had any food or beverage besides water since 9:00 pm last night
___ taken any supplements besides a daily multivitamin since the study began
APPENDIX D
Subject Characteristics Form

Name ____________________
Height ______________
Weight ______________
DOB ___________ Age _______
Signed Informed Consent? _______

IRM

Incline DB Press ___ @ ______
DB Dead Lift ___ @ ______
Triceps Extension ___ @ ______
Lateral Raises ___ @ ______
DB Flys ___ @ ______
Standing Calf ___ @ ______
Bent over row ___ @ ______
Split Squats ___ @ ______
Bent arm pullovers ___ @ ______
Biceps curl ___ @ ______
Upright row ___ @ ______
Lateral lunges ___ @ ______

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<th>Trial 3</th>
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<tr>
<td>Triceps</td>
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<td></td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
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<tr>
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<td></td>
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</tr>
<tr>
<td>Suprailiac</td>
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</tr>
<tr>
<td>Midaxillary</td>
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<td></td>
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<tr>
<td>Thigh</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SSF =

BF% =
If so, you may be qualified to participate in a research study that measures the effect weight training has on your resting metabolic rate. Subjects can earn up to $50 for participation. You must meet all of the following criteria to qualify.

- Male, 18-35 years of age.
- Has weight lifted at least twice per week for the past 6 months.
- Non smoker.
- No known cardiovascular problems.
- No known muscle, bone, or joint problems.
- Must NOT be taking any dietary supplements or performance enhancing drugs (a daily multivitamin and/or protein shake is acceptable).
- Must be willing to stop all exercise outside of the research study for the duration.
- Must be willing to donate approximately 1-2.5 hours of your time on four consecutive mornings, for two separate trials.

If you meet all the criteria and are interested in participating in the above-mentioned study, please call Steve Ball at 517-525-1608 or email at steven.w.ball@wmich.edu
APPENDIX F
HSIRB Approval Letter

Date: January 26, 2007

To: Tim Michael, Principal Investigator
Steve Ball, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number: 07-01-04

This letter will serve as confirmation that your research project entitled “The Effects of Acute Resistance Training on Resting Metabolic Rate in Men” has been approved under the expedited category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition, if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: January 26, 2008
Date: June 18, 2007

To: Tim Michael, Principal Investigator
Steve Ball, Student Investigator for thesis

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number: 07-01-04

This letter will serve as confirmation that the changes to your research project "The Effects of Acute Resistance Training on Resting Metabolic Rate in Men" requested in your memo dated June 5, 2007 and clarified in your memo dated June 13, 2007 (subjects to be paid up to $50 for participating; number of trials changed from three to two; content of trials adjusted; total length of study changed from 5 weeks to 12 days; purpose statement changed; testing changed from thermoneutral state to semi-neutral state; between trials days changed from 7 to 2; individual assessment times reduced to 1-2.5 hrs) have been approved by the Human Subjects Institutional Review Board.

The conditions and the duration of this approval are specified in the Policies of Western Michigan University.

Please note that you may only conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reappraisal if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: January 26, 2008
APPLICATION FOR CONTINUING REVIEW OR FINAL REPORT FORM

In compliance with Western Michigan University's policy that "the HSIRB's review of research will be conducted at appropriate intervals but not less than once per year," the HSIRB requests the following information:

I. PROJECT INFORMATION

PROJECT TITLE: The Effects of Acute Resistance Training on Resting Metabolic Rate in Men
HSIRB Project Number: 07-01-04

Previous level of review: ☐ Full Board Review ☒ Expedited Review ☐ Administrative (Exempt) Review
Date of Review Request: 12/07/07 Date of Last Approval: 01/26/07

II. INVESTIGATOR INFORMATION

Have all investigators completed human subjects protections training at www.citiprogram.org?
☒ Yes ☐ No (Training must be completed before protocol can be renewed)

PRINCIPAL INVESTIGATOR OR ADVISOR
Name: Timothy Michael Ph. D.
Department: HPER Mail Stop: 5426 Electronic Mail Address: tim.michael@wmich.edu

(1) CO-PRINCIPAL OR STUDENT INVESTIGATOR
Name: Steven Ball
Department: HPER Mail Stop: NA Electronic Mail Address: swb10@albion.edu

(2) CO-PRINCIPAL OR STUDENT INVESTIGATOR
Name:
Department:
Electronic Mail Address:

III. CURRENT STATUS OF RESEARCH PROJECT

Please answer questions 1-4 to determine if this project requires continuing review by the HSIRB.

1. The project is closed to recruitment of new subjects.
☐ Yes ☐ No (Project must be reviewed for renewal.)

2. All subjects have completed research related interventions.
☐ Yes ☒ Not Applicable ☐ No (Project must be reviewed for renewal.)

3. Long-term follow-up of subjects has been completed.
☐ Yes ☒ Not Applicable ☐ No (Project must be reviewed for renewal.)

4. Analysis of data is complete.
☐ Yes ☒ No (Project must be reviewed for renewal.)

- If you have answered "No" to ANY of the questions above, you must apply for Continuing Review. Please complete numbers 5-12 on page 2. If you need to make changes in your protocol, please submit a separate memo detailing the changes that you are requesting.
- If you have answered "Yes" or "Not Applicable" to ALL of the above questions, please check the Final Report box below and complete questions 5-10 on page 2.
- If your protocol has been open for three years and you still want to collect or analyze data, you must close this protocol by filing a final report using this form and apply for approval of a new protocol using an Application for Initial Review. Please make a Final Report on your project by completing numbers 5-10 on page 2.

IV. ☒ Application for Continuing Review

V. ☐ Final Report

Revised 7/03 WMU HSIRB
All other copies obsolete.
HSIRB Project Number:

5. Have there been changes in Principal or Co-Principal Investigators? □ Yes □ No
   (If yes, provide details on an “Additional Investigators” form (available at the HSIRB web site, http://www.wmich.edu/research/compliance/hsirb/hsirb_2.html))

6. Has the approved protocol been modified or added to with respect to:
   (If yes to any item below, provide the details on an attached sheet.)
   a. Procedures □ Yes □ No
   b. Subjects □ Yes □ No
   c. Design □ Yes □ No
   d. Data collection □ Yes □ No

7. Has any instrumentation been modified or added to the protocol? □ Yes □ No
   (If yes, attach new instrumentation or indicate the modifications made.)

8. Have there been any adverse events that need to be reported to the HSIRB? □ Yes □ No
   (If yes, provide details on an attached sheet.)

9. Total number of subjects approved in original protocol: 00012

10. Total number of subjects enrolled so far: 4
    If applicable: Number of subjects in experimental group: __________ Number in control group: __________
    • If this is a FINAL REPORT you may stop here and return the form electronically.
    • If this is an APPLICATION FOR CONTINUING REVIEW continue with numbers 11-13 below.

11. Estimated number of subjects yet to be enrolled: 00004

12. Verification of Consent Procedure: Provide copies of the consent documents signed by the last two
    subjects enrolled in the project. Cover the signature in such a way that the name is not clear but there is
    evidence of signature. If subjects are not required to sign the consent document, provide a copy of the most
    current consent document being used.

13. If you are continuing to recruit subjects for this project, please remember to include a clean original
    of the consent documents to receive a renewed approval stamp.

[Signatures and dates]

Approved by the HSIRB:

[Signature and date]

Western Michigan University
Human Subject Institutional Review Board -- Mail Stop 5456
(269) 387-8293 research-compliance@wmich.edu

Revised 7/03 WMU HSIRB
All other copies obsolete.
APPENDIX G
Informed Consent

Western Michigan University
Department of Health, Physical Education, and Recreation

Principal Investigator: Timothy J. Michael, Ph. D.
Student Investigator: Steven W. Ball, BA, CSCS

You have been invited to participate in a research project "The Effects of Acute Resistance Training on Resting Metabolic Rate in Men." This study will fulfill the thesis requirement for a Masters Degree in Exercise Science for Steve Ball. This consent document will explain the purpose of this research project, the time commitments, the procedures used, and the risks and benefits of participating in this research project.

Study Purpose

Resting metabolic rate (RMR) is the pace at which an individual uses calories without doing any physical activity. This is an important factor in maintaining a healthy weight and also attempting to lose weight.

Weight lifting or resistance training can maintain or increase muscle mass. Increased muscle mass leads to an elevated RMR due to the larger muscles using more calories. Therefore, RMR is elevated as a result of weight training. Most weight training programs suggest lifting weights 2-3 times per week with a minimum of 48 hours between bouts. However the question remains, will this frequency keep RMR elevated throughout the rest period? Is it more beneficial for to do 2 full-body weight lifting bouts per week or to do 4 split-body weight training bouts per week?

The purpose of this study is to determine whether doing 4 split-body weight lifting bouts is more beneficial than doing 2 full-body weight lifting bouts for maintaining an elevated RMR.
Qualifications to Participate in this Research

To be able to participate in this research project, you must meet the following criteria:

- Male, 18-35 years of age.
- Must have weight lifted at least twice per week for the past 6 months.
- Nonsmoker.
- No known cardiovascular problems.
- No known muscle, bone, or joint problems.
- Must NOT be taking any dietary supplements or performance enhancing drugs (a daily multivitamin is acceptable).
- Must be willing to stop all exercise outside of the research study for the duration.
- Must be willing to donate approximately 1-2.5 hours of your time on four or five consecutive mornings, for two separate trials.

Duration of the Study

You will be asked to come to the Exercise Physiology Laboratory of Western Michigan University located on the first floor of the Student Recreation Center ten times. The first visit will be an “Orientation” visit and the remaining visits will be for the “Investigation Trials”.

The “Orientation” visit will take approximately 90 minutes. The “Investigation Trial” visits will take approximately one to two and a half hours.

Your participation in this study will last a minimum of 12 days.

Study Procedures

You will be asked to attend thirteen sessions with Steve Ball, Certified Strength and Conditioning Specialist (CSCS), in the Exercise Physiology Laboratory located in the Student Recreational Center on the campus of Western Michigan University. The first session will be an “Orientation” visit and the remaining three will be the “Investigation Trials”. You will not have to change your diet during the study. However, you will be asked to not exercise outside of the “Investigation Trials” for the duration of the study. We will also ask that you do not drink any alcohol or take any caffeine the day before and the day of your visits to the laboratory. We also ask that you do not ingest any food or beverage other than water after 9:00 pm the night before visiting the laboratory.

The student investigator will call you the evening prior to your appointment to remind you about the time and location of the study.
Orientation Visit

When you arrive to the laboratory for the "Orientation" visit, the student investigator will go over this consent form with you and explain the study and all of its procedures, risks, and benefits to you. You will be encouraged to ask any questions that you may have. If you decide to participate, one of the investigators will ask you to sign this consent form. We will ask you to wear a t-shirt and shorts for this visit. This meeting will last approximately 90 minutes.

You will also complete a health history questionnaire. The investigators will use this information to classify your "risk level" for exercise based on guidelines established by the American College of Sports Medicine. You can participate in this study only if your "risk level" is "Low-Risk". This risk-level procedure will be explained to you.

You will also have your anthropometric measurements assessed. This means that we will measure your height, weight, and percentage body fat. Body fat percentage will be measured using skinfold calipers.

You will also participate in a predicted one repetition maximum testing (1RM) for each lift (for list of the lifts used see Weight Lifting Protocol section). 1RM is the maximal amount of weight that you can lift only one time.

A practice RMR will be done so you can get a feel for the metabolic cart mouthpiece and nose clip that will be used to collect air samples, as well as the dental chair and environmental chamber you will be sitting in.

Investigation Trials

The following table illustrates when you will be in the lab and what you will be doing. The lifting protocols are explained in the following section. Order of trials will be randomized and there will be a minimum of 3 days between trials for your RMR to return to a pre-lifting level. It is acceptable for there to be more than a week between trials as long as you do not exercise for 3 days prior to the start of the next trial. Once a trial has begun you must return for three or four more consecutive days to complete the trial.
<table>
<thead>
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**Weight Lifting Protocol**

This is the weight lifting protocol that you will be following for the study.

**Protocol A:** 2 sets of 10 repetitions at 75% of 1RM
- Dumbbell Incline Press
- Dumbbell Flys
- Lateral Raises
- Triceps Extension
- Dumbbell Squats
- Toe Raises

**Protocol B:** 2 sets of 10 repetitions at 75% of 1RM
- Bent over row
- Upright row
- Bent arm pullovers
- Biceps Curl
- Forward Lunges
- Lateral Lunges

All lifts will be done as a superset with the adjacent lift, meaning you will do a set of the first lift followed immediately by a set of the second lift and then a set of the first lift again, thus getting the rest for the first lift while you are doing the second lift.
Possible Risks of Your Participation in This Study

Risks and inconveniences associated with intense exercise include muscular fatigue and possibly muscle soreness on the following day. The exercise will be stressful but is generally easily tolerated by individuals and is not dangerous for healthy individuals. The investigators are trained in performing exercise tests and are familiar with emergency procedures.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken. Both the primary investigator and the student investigator are certified in CPR.

Benefits of Your Participation in this Study

There may be no direct benefit to you besides learning about your fitness level and your RMR value. The investigators will explain all of the results to you. You will also benefit by learning about research and some of the laboratory procedures used in collecting research data. You will be compensated for your time spent in the lab. You will receive $3 per visit (not including the orientation visit) for the first eight visits and $26 for the final visit.

Conditions of Participation in the Study

There are conditions that must be met in order for you to participate in this study. One is having weight lifted at least twice per week for the past 6 months. You must be between the ages of 18-35 years. You must not be taking any dietary supplements or performance enhancing drugs (a daily multivitamin is acceptable).

We also ask that you follow all of the study guidelines, such as not drinking alcohol, and not taking any caffeine for the day before and the day of your visits to the laboratory for the "Investigation Trials." We also ask that you cease all exercising outside of the "Investigation Trials" until the research study is complete. We also ask that you not ingest anything besides water after 9:00 pm the night before coming into the lab.

Because the data collected could be affected if you do not follow these guidelines, we ask that you tell us if you did not follow any of the guidelines. You will not suffer any penalties from the investigators if you do not follow the guidelines, but it is important for us to know. In this case, we can reschedule one of your appointments or you can choose not to participate in the study any longer. If you choose not to participate in the study any longer you will be compensated $3 per session you spent in the lab (not including the orientation visit).
Confidentiality of Your Results

In order to maintain confidentiality, the study will be focused on group data and an identification code (rather than the participant's name) will be used to record data. This will be kept on a master list with the name and personal data until the completion of the study. At the completion of the data collection the master list will be destroyed so only the code will be connected to the personal data and your confidentiality will be maintained. Following the study, the primary investigator and the research committee will have access to the original data. The original data will be retained in a locked cabinet for a minimum of three years after the completion of the study in Dr. Michael's office (SRC 1052).

If the results of the study are published in a journal or presented at a conference, no names will ever be used.

Withdrawal from the Study

You can choose to stop participating in the study at anytime for any reason. You will not suffer any prejudice or penalty by your decision to stop your participation. You will experience NO consequences either academically or personally if you choose to withdraw from this study.

The study investigators can also decide to stop your participation in the study without your consent. If you choose not to participate in the study any longer you will be compensated $3 per session you spent in the lab (not including the orientation visit).

Should you have any questions prior to or during the study, you can contact the student investigator, Steve Ball at 517-525-1608, or the primary investigator, Dr. Tim Michael at 269-387-2691. You may also contact the Chair, Human Subjects Institutional Review Board at 269-387-8293 or the Vice President for Research at 269-387-8298 if questions arise during the course of the study.
This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

"I have read this informed consent. The risks and benefits have been explained to me. I agree to take part in this study."

Please Print Your Name

Participant’s Signature Date

Permission obtained by: Signature of Investigator Date
A review of literature on the topic of resting metabolic rate (RMR), also referred to as resting energy expenditure (REE), and sometimes measured as basal metabolic rate (BMR), has uncovered many articles with many different theories and questions about elevating RMR. BMR has been replaced in much of the literature with RMR, because BMR conditions are difficult to maintain and verify. BMR is a much more strict measurement than is RMR. In articles that use the term BMR, the protocol was very meticulous. Measurements were taken immediately after awakening after a 12 or more hour fast, often times the subject was driven to the lab. They were free from fever and anxiety and had not exercised. RMR can be measured any time of day and a few hours after a bout of exercise or a light meal (this definition is not specified in the literature). Currently, RMR is the most widely used term, however, much of the methodology in the literature mimics that of BMR (16). It is common among researchers studying BMR to use a ventilated hood as a measurement tool. A ventilated hood covers the entire head, it is more comfortable than a facemask (covers the nose and mouth) or a one-way mouthpiece and noseclip. For longer duration measurements a ventilated hood is often used so the subject does not become uncomfortable, irritable, and stressed. However, in shorter duration RMR measurements, which are most common, researchers will use any of the three above-mentioned measurement tools. Segal tested all three RMR measurement tools in similar conditions. A 30 minute rest period was followed by a 20 minute measurement period, in which two 5 minute samples were taken. Subjects lay at
a 30° above the horizontal reclined position. There was no significant or practical
difference between any of the three measurement tools (21).

Some researchers have discovered that with a severely restricted diet (when the
body is in negative energy balance) RMR decreases significantly. Molé reviewed many
studies on RMR and BMR; his analysis of underfeeding studies concluded that with
starvation and semistarvation, BMR declined 15-30%. However, this did not occur for
several days, whereas overfeeding enhanced BMR after 24 hours (16). A study by
Lazzer et al. investigated the effect of a weight reduction program on the RMR of obese
adolescents. 26 severely obese adolescents ages 12-16 participated in a nine-month diet
and exercise program. Subjects exercised twice a week, 40 minutes each time and were
on moderate caloric restriction. Fat-free mass was preserved, although RMR was not.
RMR declined significantly while in negative energy balance (14). Another study by
Gornall and Villani investigated the effects of a short term very-low calorie diet and
resistance training on RMR. Twenty overweight women either dieted without resistance
training or dieted and resistance trained for four weeks. The resistance training did not
prevent a decline in fat-free mass or RMR (11).

There are discrepancies among studies on whether RMR decline with caloric
restriction can be slowed by resistance training. Geliebter et al. investigated 65 subjects
in three groups. One group dieted with resistance training, another dieted with endurance
training, and another only dieted. As opposed to Gornall and Villani, Geliebter et al.
found that strength was significantly increased in the resistance training group and fat-
free mass reduction was slowed significantly. However, the RMR decline was not stopped by resistance training, which is similar to the findings of Gornall and Villani (10). Bryner et al. found RMR and fat-free mass to be preserved during caloric restriction with resistance training. Twenty subjects were assigned to one of two groups, a diet plus aerobic training group or a diet plus resistance training group. The decline in RMR and fat-free mass that was seen in the aerobic training group was not seen in the resistance training group (4).

It has been seen in some of the research that not all exercise is of adequate intensity to elicit an increase in RMR or maintain it during severe caloric restriction. Molé observed in his review that many studies did not show a change in RMR because their exercise protocol was inadequate (16). Weight loss studies that produced the greatest amount of weight loss were those that were intensive or longer in duration. However, the low intensity long duration exercise programs would not significantly raise RMR (13). Geliebter et al. used a slow resistance training protocol in which the weight was raised and lowered for five seconds each direction. The weight being lifted needed to be reduced significantly for this slow pace to be constant for eight repetitions. Gornall and Villani did not use a repetition maximum test to determine intensity of training, so intensity may not have been sufficient for all subjects. Lazzer et al. did not mention the intensity of resistance training in their research. It is unlikely that any of these studies had adequate intensity to alter RMR.
Williamson and Kirwan studied twelve older men (age 59-77). In this study, a three repetition maximum was used (3RM) to determine intensity. Subjects resistance trained at 75% of their 3RM, for 16 sets of 10 repetitions. RMR was significantly increased up to 48 hours post-exercise. Bryner et al. (4) used three sets of eight to twelve repetitions with 60 seconds rest, after a 1RM determination. Dolezal et al. investigated RMR after eccentric training in 18 subjects. Eight sets of leg press were completed at a six repetition maximum, with a four second eccentric phase of the lift. RMR was significantly elevated up to 48 hours post exercise (9). In a separate study Dolezal and Potteiger determined that after a 10 week training program of three sets of 10-12, 8-10, and 4-8 repetitions, thirty subjects increased strength and RMR (8). This study also discovered that resistance training raised RMR more so than endurance training. This is was also the case in other studies (4,18,19).

Byrne and Wilmore investigated the effects of exercise on RMR in 19 sedentary, moderately obese women. These women trained for 20 weeks using either resistance training or a combination of resistance training and walking. The researchers used a 3RM to determine intensity for 14 exercises. A four day split-body protocol was used at three sets of 6-12 repetitions. Both groups increased their fat-free mass, but only the resistance training group increased their RMR. The resistance plus walking group decreased their RMR. The researchers suggested the reason was heat acclimation from the walk training (7).
A similar study by Dolezal and Potteiger, investigated RMR with concurrent resistance and endurance training. 30 physically active men were assigned to one of three, 10 week training groups. An endurance trained (3 days/week jogging and/or running), resistance trained (3 days/week resistance training), or combined endurance and resistance training. The endurance training was 25 minutes at 65% of maximal heart rate for two weeks, 35 minutes at 65-75% of maximal heart rate for the next four weeks, and 40 minutes at 75-85% of maximal heart rate for the last four weeks. The resistance training group used both free weights and machines. Upper body was exercised on Monday, lower body on Wednesday and both upper and lower body on Friday. All major muscle groups were used including: bench press, lat pulldown, shoulder press, biceps curl, triceps pushdown, back squat, leg extension, leg curl, clean pulls, incline dumbbell press, leg press, seated row, and upright row. During the first two weeks, subjects performed 3 sets of 10-15 repetitions to failure (failure was defined as the point at which the exercise could not be executed correctly through its full range of motion). During the last 8 weeks, subjects performed 10-12 repetitions on the first set, 8-10 on the second, and 4-8 on the third. The combined group completed both endurance and resistance training on the same day, with resistance training completed first. Both the resistance trained group and the combined group had a significantly elevated RMR. The endurance trained group had a RMR lower than baseline. The combined trained RMR was slightly lower than the resistance trained RMR. When all three groups were analyzed together a strong correlation was shown between fat-free mass and RMR. This is in agreement with the other studies that fat-free mass is a major determinant of RMR (8). However, in this study subjects were in energy balance. In other studies the subjects were in negative
energy balance, so RMR was not significantly elevated, but it was preserved, and the usual decline in RMR from negative energy balance was not seen. It can also be seen in the results from Dolezal and Potteiger that RMR will be raised significantly more with resistance training than with endurance training. This study also concurs with the previous study, in that the aerobic training prevented the usually high increase in RMR from resistance training. RMR did not decrease however, most likely because the low intensity walking in the former study would burn kilocalories without causing any RMR perturbations, therefore the body would be further in negative energy balance causing a decline in RMR rather than an increase. In the later study, endurance training was a more intense 65-85% of maximal heart rate, therefore RMR was effected slightly by the endurance training, but more so by the resistance training.

A study by Melby et al. showed that along with an increase in RMR due to resistance training, there is also a decreased respiratory exchange ratio (RER) showing greater fat mobilization and oxidation. In this study subjects resistance trained using a superset routine (meaning a set of one exercise was done and then a set of another before the second set of the first exercise; exercises were in pairs). Six sets of 10 exercises were done at 70% of one repetition maximum, for 8-12 repetitions. RMR was measured in the morning and then again in the afternoon after breakfast had been eaten and immediately before exercise, then again the next morning 15.5 hours after exercise. They also completed a secondary experiment in which there was a control condition with no exercise. In both experiments RER was significantly decreased after the resistance exercise in an opposite manner that RMR had increased. Melby et al. suggested that this
increased fat oxidation post-resistance exercise is most likely due to the carbohydrate sparing. During strenuous exercise the body will utilize primarily phosphocreatine and carbohydrate for energy, resulting in substantial fat oxidation during recovery (15).

BIBLIOGRAPHY


