Relative Energy Expenditure May Prove Beneficial When Prescribing Exercise to Phase II Cardiac Rehabilitation Patients

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ABSTRACT

Shultz BD, Kamphoff CS, Dalleck LC. Relative Energy Expenditure May Prove Beneficial When Prescribing Exercise to Phase II Cardiac Rehabilitation Patients. JEPonline 2010;13(5):1-8. The purpose of this study was to determine if there is a relationship between weekly energy expenditure relative to body mass (kcal·kg⁻¹·wk⁻¹) and change in cardiovascular disease (CVD) risk factors during Phase II cardiac rehabilitation. An observational study design was employed. Participants included 109 individuals who were eligible for and completed Phase II cardiac rehabilitation. Multiple linear regression was used to determine the independent relation of relative energy expenditure and baseline risk factor values with the change in individual CVD risk factor scores from baseline to post-program. The level of statistical significance was set at p < 0.05 for all analyses. Relative energy expenditure (kcal·kg⁻¹·wk⁻¹), after partialling out the effect of baseline risk factor value, was independently associated (p < 0.05) with changes in four CVD risk factors: fasting blood glucose, HDL cholesterol, triglycerides, and cardiorespiratory fitness in both men and women. Findings from the present study demonstrate that CVD risk factor modification is related to relative weekly energy expenditure. These results suggest weekly energy expenditure goals for cardiac disease patients should be established while considering client body mass.

Key Words: Dose-Response, Physical Activity, Cardiovascular Disease Risk Factors, Secondary Prevention.
**INTRODUCTION**

Cardiac rehabilitation (CR) is a three-stage program designed to aid those who have had a heart attack or heart surgery, recover and improve cardiovascular health (7). This three-phase program educates patients on cardiovascular disease (CVD) management, and helps design a heart-healthy lifestyle by incorporating supervised exercise while reducing other risk factors, such as high blood pressure, cholesterol levels, body mass index and insulin resistance (9, 13). In fact, scientific research has demonstrated that there is a dose-response relationship between exercise and multiple health outcomes, including cardiovascular fitness, risk of coronary artery disease (CAD) and all-cause mortality, obesity, dyslipidemia, type II diabetes, and colon cancer (2-3). Based on these dose-response relationships, both the American College of Sports Medicine (ACSM) and U.S. Surgeon General have noted that the health benefits of an exercise program are associated with the total weekly energy expenditure (2, 18).

Gross (total) energy expenditure includes both the resting metabolic rate and the energy expenditure attributable to the exercise itself (net caloric expenditure) (2). The ACSM has recommended that the overall volume of exercise for cardiac patients should initially exceed 1000 kcal⋅wk\(^{-1}\) because energy expenditure below this level was associated with progression of coronary artery disease (CAD) in one study (10). Ultimately, it has been suggested that to maximize the possibility for CAD stabilization and regression, energy expenditure should be advanced to a total volume of 1500 to 2100 kcal⋅wk\(^{-1}\) (10). Yet, one shortcoming of this broad recommendation is a failure to account for individual differences in body mass, which may potentially lead to significant over- or under-estimation of energy expenditure goals. Indeed, it was reported in one study of cardiac rehabilitation participants that only 43% and 19% of participants achieved the energy expenditure goal of 1500 kcal⋅wk\(^{-1}\) and 2100 kcal⋅wk\(^{-1}\), respectively (4).

While there is compelling evidence to support the absolute energy expenditure recommendations of 1000, 1500, and 2200 kcal⋅wk\(^{-1}\) by the ACSM, it is important to note that the calories expended during the same exercise session will be dissimilar among individuals of differing body mass. Table 1 illustrates two individuals of different body masses following a similar exercise routine. While this exercise program yields a weekly energy expenditure of 750 kcal for individual one, the same program leads to an energy expenditure of 1,250 kcal per week for individual two. The primary reason for the difference in weekly energy expenditure is the variation in body mass. Accordingly, it has been noted that greater attention should be given to individual differences (e.g., body mass, age, sex) when determining overall physical activity requirements (14, 17).

An alternative approach to setting overall energy expenditure goals is to establish the weekly requirements relative to differences in body mass (e.g., kcal⋅kg\(^{-1}\)⋅wk\(^{-1}\)). Recently, separate studies have demonstrated a dose-response relationship between energy expenditure relative to body mass and numerous health outcomes, including cardiorespiratory fitness, lipid parameters, body

<table>
<thead>
<tr>
<th>Individual #1 (55kg)</th>
<th>Training Program</th>
<th>Individual #2 (91kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 days/wk</td>
<td>Frequency</td>
<td>3 days/wk</td>
</tr>
<tr>
<td>5.0 mph (8.6 METs)</td>
<td>Intensity</td>
<td>5.0 mph (8.6 METs)</td>
</tr>
<tr>
<td>30-min/day</td>
<td>Time</td>
<td>30-min/day</td>
</tr>
<tr>
<td>8.3 kcal/min</td>
<td>Caloric Equivalent</td>
<td>13.7 kcal/min</td>
</tr>
<tr>
<td>Treadmill</td>
<td>Type</td>
<td>Treadmill</td>
</tr>
<tr>
<td>750 kcal/wk</td>
<td>Energy Expenditure</td>
<td>1250 kcal/wk</td>
</tr>
</tbody>
</table>
composition measurements, and insulin sensitivity (6, 11-12, 15). These studies involved middle-age adults with numerous risk factors (sedentary lifestyle, overweight/obese, and dyslipidemia) and postmenopausal women. To our knowledge, there is no previous research focused on the topic of relative energy expenditure and risk factor modification in cardiac diseased individuals. Therefore, the purpose of this study was to determine if there was a relationship between weekly energy expenditure relative to body mass (kcal⋅kg\(^{-1}\)⋅wk\(^{-1}\)) and change in CVD risk factors during Phase II cardiac rehabilitation.

METHODS

Subjects
Participants included 109 individuals who were eligible for Phase II cardiac rehabilitation, including those participants who were post coronary artery bypass graft surgery, myocardial infarction, percutaneous transluminal coronary angioplasty, and/or post valve surgery. Clinical indications and contraindications for outpatient phase II cardiac rehabilitation, as outlined by ACSM (2), were used for inclusionary and exclusionary criteria. Participants performed phase II cardiac rehabilitation at a traditional urban cardiac rehabilitation program between January 2008 and December 2009. The study was approved by the appropriate ethics committees and all participants provided their written informed consent.

Procedures
An observational study design was employed. Participants had scheduled appointments at baseline, mid-program (usually 6-weeks), and post-program (generally after 3-months). Prior to any appointments all participants initially attended an orientation session where an explanation of the cardiac rehabilitation program was provided, paperwork was distributed, and time was allotted for questions. At the conclusion of the orientation session participants scheduled their baseline appointment.

Baseline appointment
The baseline appointment began with an exercise physiologist whom was responsible for measuring and/or recording each participant’s cardiovascular disease risk factors, including resting blood pressure, anthropometric measurements (height and weight), lipid profile, functional capacity, and current physical activity levels. Participant body mass was determined by measuring weight to the nearest 0.1 kg using an electronic scale (Taylor Precision Products, New Mexico, USA). Participant height was determined by measuring height to the nearest cm using a standard tape measure. Waist circumference measurements were acquired via a spring-loaded tape measure (Creative Health Products, Ann Arbor, MI). A horizontal measurement was obtained at the narrowest circumference of the torso, at an anatomical point above the umbilicus and falling beneath the xiphoid process. Waist circumference measurements were repeated until two were within ±1 cm. ACSM guidelines were followed for obtaining resting blood pressure (2). Participants were seated quietly for five minutes in a chair with arms rested and relaxed at heart level. Blood pressure was measured twice on the left arm brachial artery with the use of a sphygmomanometer. Measurements were separated by one minute and the mean of the two measurements was recorded. Lipid testing was performed by an external laboratory and exercise physiologists recorded the values provided by this facility following analysis. The exercise physiologist then performed a graded, exercise test with the participant to establish baseline functional capacity. Individualized walking protocols were performed with treadmill speed held constant, while treadmill grade was increased 1% each minute until volitional fatigue was attained. Maximal oxygen uptake (VO\(_2\)\(_{\text{max}}\)) was predicted according to metabolic equations (2) using the last stage (speed + grade) each participant completed. Information from the exercise test was also used to establish a safe and effective starting exercise duration and intensity for each participant. Current energy expenditure was determined by first establishing the frequency, intensity, time, and
type of exercise for each participant and subsequently using ACSM metabolic equations to estimate caloric expenditure. To conclude the baseline appointment, participants met with a cardiologist to discuss their medical condition, possible limitations, and to mutually identify individualized goals for the Phase II cardiac rehabilitation program. At the conclusion of the baseline appointment, participants scheduled their exercise orientation.

**Exercise program**

At the exercise orientation appointment, participants met with an exercise physiologist. The exercise physiologist employed evidence-based guidelines available from the ACSM and American Association for Cardiovascular and Pulmonary Rehabilitation (AACVPR) to guide the design, implementation, progression, and monitoring of the exercise program for each participant (1-2). Exercise programs were also designed with the consideration of participant preferences and values. Supervised exercise took place each Monday, Wednesday, and Friday between 8am to noon and 1pm to 5pm. During the phase II cardiac rehabilitation program, participants were supervised during all exercise sessions and monitored via portable telemetry, pulse oximetry, blood pressure, and rating of perceived exertion (1-10 scale). The machines used for exercise included recumbent steppers, arm ergometers, cycle ergometers, elliptical cross trainers, and treadmill. Metabolic equivalents (16) and the ACSM metabolic equations (2) were used to calculate weekly energy expenditure. Relative energy expenditure was determined by dividing participant body mass into weekly energy expenditure.

**Mid-point evaluation**

At the mid-point phase of the cardiac rehabilitation program participants visited again with a cardiologist. This appointment consisted of a review of the participant’s medical condition(s). Additionally, the cardiologist and participant discussed the progress being made toward individual goals; specifically the management of cardiovascular disease risk factors that had contributed to the cardiac event.

**Post-program appointment**

The post-program appointment duplicated the procedures of the baseline appointment. Participants again had meetings with an exercise physiologist and cardiologist. All cardiovascular disease risk factors measured at baseline were also determined at the post-program appointment in order to quantify the effectiveness of the program. At the conclusion of the post-program appointment, during the meeting with the cardiologist, a plan was formulated to transition the participant into a home-based exercise program or supervised phase III cardiac rehabilitation program.

**Statistical Analyses**

All analyses were performed using Statistical Package for the Social Sciences, Version 12.0. Measures of centrality and spread are presented as mean ± SD. Mean differences in risk factors between baseline and post-program were assessed using paired t-tests. To determine the independent relation of relative energy expenditure and baseline values with the change in individual CVD risk factor scores from baseline to post-program, we used multiple linear regression analyses (enter method). For each model, a CVD risk factor was entered as the dependent variable, while baseline values and relative energy expenditure were entered as independent variables. Part correlation coefficients from the regression analyses were used to determine the independent association of relative energy expenditure to individual CVD risk factor change scores while controlling for baseline values. Residual analyses to test the validity of regression model assumptions were performed for all developed regression models. The level of statistical significance was set at p < 0.05 for all analyses.
RESULTS

The physical and physiological characteristics for all participants by sex are presented in Table 2. Paired t-tests revealed significant (p < 0.05) changes from baseline to post-program for all values in men with the exception of body mass (p = 0.12), body mass index (p = 0.07), diastolic blood pressure (p = 0.19), LDL cholesterol (p = 0.07), and total cholesterol (p = 0.43). Similarly, women had significant changes (p < 0.05) from baseline to post-program values in all areas except body mass (p = 0.06), body mass index (p = 0.07), diastolic blood pressure (p = 0.35), LDL cholesterol (p = 0.06), and total cholesterol levels (p = 0.13).

### Table 2. Physical and physiological characteristics at baseline and post-program by sex.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Women (n=49)</th>
<th>Men (n=60)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Baseline</td>
<td>Post-Program</td>
</tr>
<tr>
<td>Age (yr)</td>
<td>59.2 ± 11.0</td>
<td>---</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>80.5 ± 17.4</td>
<td>80.1 ± 17.6</td>
</tr>
<tr>
<td>Waist Circumference (cm)</td>
<td>92.8 ± 15.6</td>
<td>90.4 ± 14.8*</td>
</tr>
<tr>
<td>Body Mass Index (kg/m²)</td>
<td>29.1 ± 5.9</td>
<td>28.8 ± 6.1</td>
</tr>
<tr>
<td>VO2max (mL·kg⁻¹·min⁻¹)</td>
<td>28.2 ± 7.7</td>
<td>32.8 ± 8.8*</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>121.8 ± 10.2</td>
<td>117.8 ± 12.0*</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>75.8 ± 8.2</td>
<td>74.8 ± 8.2</td>
</tr>
<tr>
<td>Total cholesterol (mg/dL)</td>
<td>215.8 ± 34.9</td>
<td>208.2 ± 34.9</td>
</tr>
<tr>
<td>HDL cholesterol (mg/dL)</td>
<td>41.8 ± 12.4</td>
<td>45.4 ± 12.0*</td>
</tr>
<tr>
<td>LDL cholesterol (mg/dL)</td>
<td>137.2 ± 37.0</td>
<td>131.2 ± 31.7</td>
</tr>
<tr>
<td>Triglycerides (mg·dL⁻¹)</td>
<td>145.0 ± 91.1</td>
<td>124.7 ± 91.1*</td>
</tr>
<tr>
<td>Blood Glucose (mg/dL)</td>
<td>104.9 ± 20.9</td>
<td>97.1 ± 13.9*</td>
</tr>
<tr>
<td>Absolute EE (kcal/wk)</td>
<td>450.7 ± 487.8</td>
<td>1324.9 ± 526*</td>
</tr>
<tr>
<td>Relative EE (kcal/kg⁻¹·wk⁻¹)</td>
<td>6.0 ± 7.9</td>
<td>16.4 ± 5.3*</td>
</tr>
</tbody>
</table>

Values are mean ± SD; *within-group change is significantly different from baseline, p < 0.05.

Relative energy expenditure (kcal·kg⁻¹·wk⁻¹) and CVD risk factor associations are presented in Table 3. Relative energy expenditure, after partialling out the effect of individual baseline value of risk factor, was independently associated (p < 0.05) with changes in four individual (fasting blood glucose, HDL cholesterol, triglycerides, and cardiorespiratory fitness) CVD risk factors. Relative energy expenditure was not (p > 0.05) independently associated with changes in any other CVD risk factors.

DISCUSSION

This study indicates that weekly energy expenditure relative to body mass (kcal·kg⁻¹·wk⁻¹) is associated with positive modifications to several major risk factors for cardiovascular disease in phase 2 cardiac rehabilitation participants. After accounting for individual baseline risk factor levels, weekly energy expenditure relative to body mass was found to be independently related to the change in VO2max, HDL cholesterol, triglycerides, and fasting blood glucose. Based on the dose-response relationship between overall energy expenditure and health outcomes, it has been suggested that the overall energy expenditure is the most important consideration of the exercise...
Comparing the training responses following programs of similar absolute energy expenditure volumes becomes problematic because the relative energy expenditure will vary depending on body mass differences. For example, if an absolute caloric expenditure of 1500 kcal·wk\(^{-1}\) has been set as the weekly goal, a 100-kg individual in relative terms will be expending 15 kcal·kg\(^{-1}\)·wk\(^{-1}\). In comparison, a 50-kg individual would be expending 30 kcal·kg\(^{-1}\)·wk\(^{-1}\) in relative terms. Although each individual is following a similar caloric value in absolute terms, the second individual in relative terms is performing twice as much exercise. This raises the question of whether or not these individuals are actually following a similar volume exercise program. We would propose that the exercise programs from an exercise volume standpoint are markedly different and that consequently dissimilar training adaptations may possibly be experienced. Though not common, previous research has examined the dose-response relationship between relative weekly energy expenditure and CVD risk factors. For example, the Studies of a Targeted Risk Reduction Intervention through Defined Exercise (STRRIDE) examined the effect of different weekly relative energy expenditure values (14 and 23 kcal·kg\(^{-1}\)·wk\(^{-1}\)), while holding exercise intensity constant, on various CVD risk factors in middle-age (40 to 65 yr) men and women who were sedentary, overweight/obese, and mildly dyslipidemic (11, 12, 15). In a dose-response manner, it was reported that changes in cardiorespiratory fitness, various lipid parameters, numerous body mass and body composition measurements, and insulin sensitivity, were greater in the group completing 23 kcal·kg\(^{-1}\)·wk\(^{-1}\) compared to the group performing 14 kcal·kg\(^{-1}\)·wk\(^{-1}\). Similar findings were reported in the Dose-Response to Exercise in Postmenopausal Women (DREW) study, which examined the effect of performing 50% (4 kcal·kg\(^{-1}\)·wk\(^{-1}\)), 100% (8 kcal·kg\(^{-1}\)·wk\(^{-1}\)), and 150% (12 kcal·kg\(^{-1}\)·wk\(^{-1}\)) of the National Institutes of Health physical activity recommendation on cardiorespiratory fitness in obese and sedentary postmenopausal women with high blood pressure (6). In a dose-response manner, changes in cardiorespiratory fitness were greater when moving from the low-amount (4.2%) to moderate-amount (6.0%) to high-amount (8.2%) groups.

Several limitations to the present study warrant discussion. The fact that our research design was observational in nature must be carefully considered when interpreting the findings. Future research should examine this issue using a randomized, controlled research design. Data collection was performed by three different exercise physiologists at baseline and post-program, though each followed the same standardized procedures. Energy expenditure was estimated and not directly measured. Dietary intake was also not considered or accounted for in the present study. Lastly, exercise was progressed at different rates across participants in the present study according to medical conditions, fitness levels, and personal preferences. As such, some patients achieved higher relative energy expenditure earlier in their rehabilitation program compared to others.
Conclusion

The dose-response relationship between exercise volume and CVD risk factors has led to the suggestion that total weekly energy expenditure should be the primary focus of cardiac rehabilitation exercise program design. Traditionally, this approach has followed an absolute recommendation insensitive to individual differences, particularly body mass. An absolute energy expenditure recommendation may increase the likelihood of over- or under-estimating individual participant needs. Overestimating the energy expenditure for a participant may lead to an unreasonable goal, increasing the chance of adverse cardiac events, injury, and/or less program adherence. Conversely, underestimating the energy expenditure could result in less than optimal health benefits, which might also lessen program adherence and contribute to disease progression. Findings from the present study demonstrate that CVD risk factor modification is related to relative weekly energy expenditure. These results suggest weekly energy expenditure goals for cardiac disease patients should be established while considering client body mass. However, future research is required to formulate evidence-based relative energy expenditure guidelines.

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