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Perception of exercise difficulty predicts weight regain in formerly overweight women

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Abstract

It has been previously reported that overweight and obese individuals perceive exercise as more difficult than their lean counterparts, and this difference may not be solely attributed to physiological differences. Therefore, we tested the hypothesis that individual differences in the perception of exercise difficulty during exercise, independent of concurrently measured physiological markers of exertion, are predictive of weight regain, after completion of a weight loss program. One-hundred and thirteen formerly overweight women who had previously completed a weight loss program to achieve a normal body weight (BMI <25) underwent a sub-maximal aerobic exercise task while measures of physiological and perceived exertion (RPE) were recorded. Weight gain was assessed following a subsequent 1-year free-living period. Average weight regain 1 year following the intervention was 5.46 ± 3.95 kg. In regression modeling, RPE ($\beta = 0.21$, $P = 0.01$), but not physiological exertion ($\beta = 0.02$, $P = 0.81$) was positively associated with 1-year weight regain following weight loss in premenopausal women, independent of measured confounding variables. The association between RPE and weight regain suggests that perception of exercise difficulty is an important predictor of weight regain following a weight loss intervention.

Keywords

Weight Loss; Physical Activity; Perceived Exertion; Exercise

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Introduction

Success rates for long-term weight loss maintenance through traditional lifestyle strategies are poor, with high recidivism rates being the norm.[1–3] This is in part attributable to individual-level barriers that may prevent weight-reduced individuals from achieving the amount of daily physical activity necessary to prevent weight regain.[4–8] Daily physical activity has been consistently shown to be a critical factor in maintaining long-term weight loss.[4–8] However, achieving the necessary quantity and quality of physical activity to prevent weight regain after successful weight loss has remained challenging. The preponderance of physical activity research has focused on frequency, intensity, and duration of physical activity needed to facilitate weight loss and prevent weight regain, but research identifying individual-level barriers to achieving these recommendations is still very much inchoate.

It has been previously reported that overweight and obese individuals perceive exercise as more difficult than their lean counterparts. Perception of exercise difficulty during exercise is measured with the highly validated Borg rating scale of perceived exertion (RPE). The tool is predicated on the signaling connection between the physiological response to exercise and the subsequent perception in higher brain centers of these physiological perturbations. Ratings of perceived exertion have been consistently correlated with individual markers of physiological exertion, such as heart rate, blood lactate, percent $VO_{2max,}$ VO_2, ventilation, and respiration rate.[9–14] In addition, psychological constructs have been reported to affect perceptual responses to exercise as well, [15, 16] and it is commonly assumed that perception of exercise difficulty in overweight individuals is solely reflective of the physiological demands of the additional body weight.[17, 18] It appears plausbile to suggest that an amalgam of physiological and psychological stimuli serve as a composite sensation to produce the perceived effort sense of exercise, as others have reported.[19–21] If perception of exercise difficulty is not solely explained by physiological or metabolic parameters, then credence is lent to the proposition that “perception” of exercise difficulty might be a salient factor in long-term weight loss maintenance.

The purpose of this study was to explore whether ratings of perceived exertion recorded during a submaximal aerobic exercise test in formerly overweight women were related to 1-year weight regain. This question was explored among formerly overweight women who had lost weight via an investigator-administered lifestyle intervention program with the goal of reducing body weight to the normal range on the body mass index scale (BMI < 25kg/m^2). We hypothesized that perceived exertion measured during a submaximal aerobic exercise task in formerly overweight women would be positively associated with weight regain during a 1-year free-living period, and this relationship would be independent of concurrently measured physiological markers of effort.

Methods

Participants

Participants in this study were selected from premenopausal previously overweight (mean ± SD; initial BMI, 28 ± 1.32; initial weight; 76.8 ± 6.95; weight lost during intervention, 12 ± 2.42 kg) women who had completed a weight loss intervention to achieve a BMI < 25 kg/m^2. Those eligible for inclusion in this study had also completed a one-year follow-up weight maintenance assessment. All women were nonsmokers and reported experiencing menses at regular intervals.

Procedure

Following the weight loss program, women underwent 4-weeks of supervised weight maintenance, and baseline testing for the present analysis was conducted during the last 2 weeks of this period. Participants were weighed 3–5 times per week and there was < 0.5% weekly weight variation for the two weeks prior to evaluation. Participants also underwent submaximal and maximal exercise testing to evaluate physiological and perceptual responses to exercise in a weight-reduced state and then entered the long-term follow-up free-living period. Measurements of weight and height were obtained prior to, following, and one-year after the weight loss intervention.

Procedures followed were in accordance with the ethical standards of the institution committee on human experimentation. Before participating in the study, the women provided informed consent to the protocol, which was approved by the Institutional Review Board and Human Services Regulation for Protection of Human Research Subjects.

Submaximal Aerobic Exercise Test

In the morning following an overnight fast, submaximal ventilation (VE), oxygen uptake (VO_2), carbon dioxide production (VCO_2), respiratory exchange ratio (RER), heart rate (HR), and rating of perceived exertion (RPE) were obtained while walking at 3 mph on a calibrated treadmill for 5 minutes. Ventilation, VO_2 and VCO_2 were determined by open-circuit spirometry using a MAX-II metabolic testing system (PHYSIO-DYNE, Quogue, New York). Heart rate was monitored by a Polar Vantage XL heart rate monitor (Polar Beat, Port Washington, NY). Three mph was selected since it is a common walking velocity for which steady state oxygen uptake can be achieved.[22] The average of the third and fourth minutes was used as the steady state VO_2. All subjects underwent at least two previous treadmill walks to insure familiarity with the treadmill. A rating of perceived exertion for “whole body effort sense” was obtained during the last minute of the walk using the Borg Scale at the same time the physiological variables used in the composite physiological variable.

Maximal Oxygen Uptake (VO_2max)

In the morning following an overnight fast, VO_{2max} was determined by indirect calorimetry on a treadmill using a modified Bruce Protocol to exhaustion. Ventilation, pulmonary gas exchange, heart rate, and RPE were determined as described previously.

Composite Physiological Exertion

The physiological response to the submaximal aerobic exercise test was evaluated by three common variables measured during exercise: Heart Rate (HR); Ventilation (VE); Respiratory Exchange Ratio (RER). Relative physiological effort during the submaximal walk was calculated by dividing the absolute submaximal walking values by maximal values obtained during the VO_{2max} test: 1) $\%HR_{max}$ = submaximal HR/HR_{max}; 2) $\%VE_{max}$ = submaximal VE/VE_{max}; 3) $\%RER_{max}$ = submaximal RER/RER_{max}. Z-scores were then calculated for each of the physiological effort variables (% effort/standard deviation). In order to obtain a composite relative measure of physiological stress during the 3 mph walk test, we averaged the Z-scores for $\%HR_{max}$, $\%VE_{max}$, and $\%RER_{max}$. Percent of VO_{2max} was not included in the composite variable because it is known to affect each of the other variables and thus would be redundant.[9–14]

Statistics

Descriptive characteristics are reported as means and standard deviations. Simple Pearson correlations were used to identify potential predictors of 1-year weight regain. Age, race,

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cardiorespiratory fitness (both VO_{2max} and % VO_2 during the submaximal aerobic exercise test), composite physiological measure of exertion during the submaximal aerobic exercise test, RPE during the submaximal aerobic exercise test, BMI prior to weight loss (we postulated that those that presented with a higher initial BMI might be predisposed to regain more weight during the follow-up period), and the number of days required to achieve a BMI < 25 kg/m^2 (the initial weight loss program was open-ended, and the subjects had no set time point to lose the goal weight; we thought it might be plausible that individuals who had greater difficulty losing weight, would have a more difficult time keeping the weight off in the follow-up period). Potential predictors of 1-year weight regain were then analyzed using multiple linear regression.

Results

Fifty-one European-American and 62 African-American women, aged 34.6 ± 6.2 years were included in the present analysis. Summary characteristics are reported in Table 1. Average weight regain 1 year following the intervention was 5.46 ± 3.95 kg. The results of the post weight loss sub-maximal aerobic exercise test are reported in the lower half of Table 1. Simple Pearson correlations revealed four potential predictors of 1-year weight regain: days to initial weight loss goal ($r = 0.49$, $p < 0.001$); pre-weight loss BMI ($r = 0.26$, $p < 0.01$), perceived effort measured during the submaximal aerobic exercise test ($r = 0.18$, $p = 0.03$) and the composite physiological effort variable measured during the submaximal aerobic exercise test ($r = 0.06$, $p = 0.26$). Although the composite physiological effort variable was not associated with 1-year weight regain, we included it in the regression analysis to determine if the perception variable was independent of the concurrently measured physiological response. The percentage of the VO_{2max} (fitness level) utilized during the submaximal aerobic exercise test was not correlated with ($r = 0.05$, $p = 0.3$) or predictive of 1-weight regain ($p = 0.69$).

Table 2 reports the results from the regression model. Participants who took a long time to achieve their weight loss goal during the initial intervention subsequently gained more weight during the 1-year follow-up period, independent of their baseline BMI prior to weight loss. As hypothesized, RPE, but not physiological exertion, during the submaximal aerobic test was associated with weight regain, independent of BMI prior to weight loss and number of days needed to achieve the initial weight loss goal. The direction of the association between RPE and weight regain suggests that perception of exercise difficulty during a standardized submaximal aerobic exercise task is an important predictor of weight regain following a weight loss intervention. Accounting for other variables, each ~.5 increase in RPE during the 3 mph walk test resulted in a 1 kg weight regain at 1-year. This finding was observed regardless of whether the physiological variables were summed as a composite of physiological exertion or analyzed independently as indices of physiological exertion (i.e. HR, VE, RER, VO_2).

Discussion

The results of this investigation provide support for our hypothesis that perception of exercise effort during a common, submaximal aerobic exercise modality is an important predictor of weight regain following a weight loss program. The fact that perceived exertion was compared to a composite of physiological exertion, rather than to heart rate alone, attenuates the possibility that the inaccuracy between the physiological and perceptual responses is due to the sensing of other physiological signals of exertion. To our knowledge, this is the first report that heterogeneity of perceptual responses to an exercise challenge has been associated with recidivism in weight-reduced, formerly overweight women.

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In our cohort the RPE during the submaximal walk test was ~9 ± 1.8 (range 6 to 13), which is below the reported RPE (12–14) to be associated with the lactate threshold and suggests that psychological constructs may be the likely explanation for any potential over perception of effort during the submaximal exercise test.[21, 23] This is congruous with Ekkekakis's dual mode hypothesis that states that at lower intensities of exercise, such as our walk test, the primary driving forces in the perceived exertion of exercise are anchored in cognitive factors and as exercise intensity increases interoceptive factors such as blood lactate and ventilation become the salient factors that drive perception of exercise.[24] Furthermore, Williams et al[25] have recently reported that more positive affective responses and lower RPE scores to an acute, moderate-intensity exercise task is associated with greater physical activity participation 6 and 12 months later. Although, affective responses were not measured in the current study, Willams et al work does suggest that affective responses to acute exercise add to the predictive capacity of long-term participation in physical activity, mostly independent of RPE and should therefore be considered two distinct components that deserve further exploration.

With these two bodies of work in mind, it can be reasonably inferred that the formerly overweight participants in our cohort may have experienced diminished affective responses and cognitions that led to higher RPE scores during the submaximal walk test and these cognitions made it less likely that these weight-reduced women would engage in the necessary volume of physical activity to prevent weight regain.[25–31] Indeed, itt seems plausible that the relationship between perception of exercise difficulty and weight regain is related to actual engagement in physical activity. Our group has previously found that RPE tends to be higher during exercise for women with lower levels of free-living physical activity.[32] In addition, in a subset (n = 85) of the women in the present analysis, we observed that RPE recorded during the exercise task was significantly related to reduced self reported time in physical activity between 4 and 5.9 METS ($r = 0.28$, $p < 0.02$) during the 1-year follow-up period. However, it is not known whether the higher RPE is the cause of, or is consequent to, low levels of physical activity. We are limited in our ability to further analyze the physical activity connection, since the original trial was not designed to answer this question. Future research needs to explore whether the association between perception of exertion and weight regain is mediated by engagement in free-living physical activity, and the direction of this relationship.

Although this study was limited in scope to fully elucidate the observed findings, the identification of a factor that appears to impair weight loss maintenance is not insignificant, considering the dismal success rates for long-term weight loss. Importantly, by investigating this phenomenon in a weight-reduced state, we have shown that individual differences in the perception of exercise difficulty may be an underlying phenomenon that persists after weight loss and makes it less likely that long-term weight maintenance will be achieved. This may in part explain differences in weight regain following successful weight loss.

In conclusion, findings from the present analysis suggest that perception of exercise difficulty during a submaximal, aerobic exercise task after weight loss is an important predictor of weight regain during a one-year follow-up period in women who have successfully completed a weight loss program. Elucidating the underlying mechanisms to identify additional treatment targets as well as developing exercise preference tools based on perceptual and affective responses for different exercise modalities/intensities may have a substantial impact on the likelihood that participants will be successful in maintaining a healthy body weight.

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Table 1

Descriptive Statistics (N = 113)

Characteristics	Mean + SD
Age (y)	34.6 ± 6.2
Height (m)	1.65 ± 0.1
Weight (kg)	77.1 ± 6.9
BMI (kg/m^2)	28.2 ± 1.3
Post Weight Loss VO $_{2max}$ (ml/kg/min)	33.0 ± 5.0
Days to Weight Loss Goal (d)	154 ± 71
1-year Follow-up Weight Gain (kg)	5.46 ± 3.95
Post-Weight Loss Sub-Maximal Walk Test	
VO$_2$ (ml/kg/min)	12.00 ± 1.5
Heart Rate (bpm)	108.9 ± 15.9
Ventilation (L/min)	21.8 ± 3.2
Respiratory Quotient	0.80 ± 0.05
% VO$_{2max}$	36.8 ± 6.1
% Heart Rate$_{max}$	59.2 ± 7.7
% Ventilation$_{max}$	24.8 ± 5.0
% Respiratory Exchange Ratio $_{max}$	64.0 ± 0.9
Ratings of Perceived Exertion: RPE (Borg Scale)	9.2 ± 1.9

The bottom half of Table 1 reflects measured values during the standardized 3 mph submaximal walking test after weight loss. Percentage values for the physiological variables were calculated by using each participant's post weight loss maximum values measured during a VO$_{2max}$ stress test.

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Table 2

Simple Pearson correlations (*r*) between for exercise behavior and weight regain in the 1-year follow-up period (N = 113)

Regression model for predicting one-year weight regain in previously overweight women (N = 113)

Measure	Exercise Behavior	1-Year Weight Regain
Age	0.09	0.06
Weight	0.06	0.14
VO_{2max}	0.1	−0.14
Pre-weight loss BMI	0.15	0.24**
Days to weight loss goal	0.18	0.48**
Perceived exertion (Borg Scale)	− 0.19*	0.17 (p<0.07)
Submax VO_2	− 0.12	− 0.08
Submax HR	− 0.05	− 0.07
Submax VE	− 0.07	0.05
Submax RQ	− 0.09	0.04

Pre-weight loss BMI = BMI before entering initial investigator-administered weight loss program; Days to weight loss goal = the initial investigator-administered weight loss program was open ended and participants had no timeline to achieve their goal weight; Perceived exertion = measured during the post-weight loss submaximal walking test; Composite physiological exertion = heart rate, ventilation, and respiratory exchange ratio responses to the post-weight loss submaximal walking test (percentages, based on measured maximal values obtained during the VO_{2max} test, were converted to Z scores and averaged).

* $p < 0.05$

** $p < 0.01$

Table 3

Regression models for predicting one-year weight regain and exercise behavior in previously overweight women (N = 113)

Model	B	R^2	β	P
Model 1: 1-year weight regain		0.292		< 0.001
Intercept	−7.22			
Pre-weight loss BMI	0.275		0.093	0.287
Days to weight loss goal	0.026		0.44	< 0.001
Perceived exertion	0.44		0.206	0.015
Composite physiological exertion	1.714		0.02	0.814
Model 2: 1-year follow-up exercise behavior		0.08		0.09
Intercept	−7.41			
Pre-weight loss BMI	0.341		0.125	0.238
Days to weight loss goal	0.005		0.109	0.304
Perceived exertion	−0.36		−0.181	0.068
Composite physiological exertion	3.309		0.04	0.68