Original investigation

Change in Body Weight Does Not Mediate the Relationship Between Exercise and Smoking Cessation Among Weight-Concerned Women Smokers

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Abstract

Introduction: Exercise has received attention as a method to prevent or reduce postcessation weight gain. However, little is known about how weight changes following quit attempts contribute to the relationship between exercise and smoking cessation. The present study assessed how exercise relates to cessation and whether initial changes in exercise after quitting smoking promote cessation through attenuated weight gain.

Methods: Weight-concerned women smokers ($N = 342$) receiving cessation treatment provided biochemical validation of cessation, reported weekly exercise activities, and were weighed at 1, 3, and 6 months following treatment initiation. Survival analyses were used to determine time to and risk of relapse among women who reported engaging in varied levels of exercise at baseline. A mediation analysis was used to examine whether the effect of initial changes in exercise on longer-term cessation was driven by change in weight. All analyses were adjusted for relevant covariates.

Results: Women smokers who reported high levels of exercise at baseline were less likely to relapse and returned to smoking more gradually than did women who reported low levels of exercise. Change in weight did not mediate the relationship between exercise and cessation.

Conclusions: Cessation interventions utilizing an exercise component may have to develop exercise regimens of either higher duration or greater intensity to produce beneficial cessation outcomes, particularly when targeting sedentary smokers. Given that change in weight did not mediate the relationship between exercise and cessation, it is likely that other mediational processes are involved.

Introduction

Despite the overall health benefits that accompany smoking cessation, smokers who quit gain an average of 11 pounds during the first year of abstinence.¹ Although there is considerable individual

variability in postcessation weight gain, women consistently gain more weight than do men after quitting.^{2,3} Concern about postcessation weight gain prevents many women smokers from initiating quit attempts and is commonly related to relapse.⁴⁻⁶ Cessation

interventions designed to address postcessation weight concerns among women smokers can improve cessation rates^{7,8} and attenuate postcessation weight gain during treatment,^{8,9} however, such interventions have not consistently been shown to improve rates of sustained abstinence or reduce weight gain in the longer-term.⁷ Thus, additional strategies to address weight concerns and reduce postcessation weight gain among women smokers are warranted.

Exercise is an effective strategy for managing both weight¹⁰ and weight concerns¹¹ and has received increasing consideration as a method to prevent or reduce postcessation weight gain and improve cessation outcomes. A growing body of literature indicates that exercise is inversely related to smoking rates,^{12,13} and numerous randomized controlled trials have examined the efficacy of exercise interventions for smoking cessation. Three randomized controlled trials have shown that smokers who completed an exercise intervention had significantly higher cessation rates at the end of treatment than did controls.^{14–16} However, additional research has demonstrated only marginally significant improvements in cessation rates among smokers participating in an exercise intervention relative to controls,^{17–23} and other studies have found no differences in cessation outcomes between exercise and control conditions.^{24–26} Thus, the efficacy of exercise interventions for smoking cessation remains unclear.

In an effort to clarify the inconsistent findings linking exercise interventions to smoking cessation, additional investigations have sought to elucidate how exercise functions to promote cessation at a mechanistic level. Evidence suggests that the psychobiological effects of exercise can effectively reduce both somatic and affective symptoms of nicotine withdrawal.²⁷ Moreover, brief bouts of exercise decrease cravings for cigarettes at rates comparable to nicotine replacement therapy.²⁸ Thus, exercise is capable of directly ameliorating symptoms of nicotine withdrawal and reducing cigarette cravings, which are factors commonly related to relapse.²⁹ However, despite the rationale for using exercise as a strategy to reduce postcessation weight gain, the effect of exercise on weight gain after smoking cessation remains unclear. Indeed, limited prospective evidence has detailed the relationship between exercise and postcessation weight gain, with the majority of studies demonstrating that exercise is ineffective at attenuating weight gain during cessation treatment.³⁰

Accordingly, we sought to investigate whether baseline exercise habits differentially affect smoking outcomes among weight-concerned women smokers receiving cessation treatment. Because exercise may alleviate symptoms of nicotine withdrawal, decrease cigarette cravings, and reduce postcessation weight gain, we hypothesized that women who reported engaging in higher levels of exercise at the beginning of a cessation treatment would have greater odds of remaining abstinent than more sedentary women. Additionally, given that exercise interventions for smoking cessation presume that heightened levels of exercise will promote abstinence, we were interested in determining whether changes in exercise within the first month of quitting smoking were related to cessation outcome. Because weight-concerned women smokers have been shown to gain the greatest amount of weight within the first 3 months of quitting smoking,⁷ we further reasoned that initial increases in exercise would aid in attenuating weight gain during this period by counteracting the immediate shifts in both metabolic functioning and eating behaviors that accompany quitting smoking and promote weight gain.^{31–33} Thus, we hypothesized that increased exercise within the first month of quitting smoking would promote abstinence at the

end of a cessation treatment and that this effect would be mediated by lower weight gain within the first 3 months of quitting smoking.

Methods

Participants and Procedures

Data for the current study were drawn from a randomized controlled trial investigating the efficacy of combining a cognitive behavioral therapy for smoking-related weight concerns and bupropion among weight-concerned women smokers.⁷ Participants were 342 women smokers with complete baseline data. Women were between 18 and 65 years of age, were motivated to quit smoking, smoked a minimum of 10 cigarettes per day, and endorsed concern about postcessation weight gain as assessed by the following two questions: (a) “How concerned are you about gaining weight after quitting?” and (b) “How concerned would you be if quitting smoking caused you to permanently gain 10 to 15 pounds, the amount typically gained by weight-concerned women after quitting?” Response options ranged from 1 (not at all) to 100 (extremely), and women were required to score 50 or higher on at least one of these questions to be eligible.⁸ Women were randomly assigned to receive either cognitive behavioral therapy for smoking-related weight concerns or standard abstinence treatment with no focus on weight. No counseling on exercise was provided in either intervention. Women were further randomized to receive bupropion or placebo, resulting in a total of four treatment groups. A target quit date was scheduled to occur 10–14 days after study medication was initiated, and women completed assessments at 1, 3, and 6 months following their target quit date. Baseline participant characteristics are displayed in Table 1.

Measures

Demographic Information and Smoking Behaviors

Women reported demographic information at study enrollment. Women also provided information on the number of cigarettes smoked per day, reported the number of years they had been smoking, and completed the Fagerstrom Test of Nicotine Dependence.³⁴

Exercise

At study enrollment and at each assessment following the target quit date, women reported the number of city blocks they walked, flights of stairs they climbed, and the frequency and duration of any sports or recreational activities they participated in during the previous week using the Paffenbarger Physical Activity Questionnaire.³⁵ The metabolic equivalents for each activity were summed to create an

Table 1. Baseline Characteristics (*N* = 342)

Characteristic	Mean	SD
Age	41.96	10.21
Weight (pounds)	160.96	32.97
Body mass index	27.33	5.49
Years smoking	24.00	10.25
Cigarettes per day	20.67	8.37
Nicotine dependence	5.18	2.20
Exercise energy expenditure (kilocalories)	1542.84	1847.53
% Caucasian	86.3	
% College graduate	23.4	

estimate of total exercise energy expenditure in kilocalories (kcal) during the past week.

Weight

Women were weighed in street clothing without shoes prior to each assessment. Precessation weight was determined by computing the average weight of the three assessments prior to the target quit date and body mass index (BMI) was computed by taking weight in kilograms divided by height in meters squared.

Point-Prevalence Abstinence

Women were interviewed at each assessment following the target quit date about smoking using the time-line follow-back method. In addition, expired-air carbon monoxide (CO) was collected using a Vitalograph Breath CO monitor (Vitalograph Inc.) and saliva samples were procured. Point-prevalence abstinence was defined as the self-report of no smoking during the previous 7 days, a CO reading of 8 ppm or less, and a cotinine level of 15 µg/L or less. Smoking for less than 7 consecutive days was not considered to be a relapse unless biochemical markers indicated smoking. Women who dropped out of treatment were considered to have relapsed as of the day following the last visit on which abstinence was verified. In cases when cotinine did not confirm abstinence based on the combined self-report of no smoking during the previous 7 days and a CO reading of 8 ppm or less ($n = 15$), women were coded as having relapsed. Over the course of treatment, 41.8%, 29.2%, and 22.8% of women met criteria for point-prevalence abstinence at the 1, 3, and 6 month assessments, respectively.

Analytic Plan

Two sets of analyses were conducted using SAS 9.3 to examine (a) how baseline exercise related to smoking status over the course of treatment and (b) to determine whether the relation between 1-month change in exercise and 6-month point-prevalence abstinence was mediated by 3-month change in weight. The first set of analyses was evaluated on an intent-to-treat basis, regardless of medication adherence, treatment received, or non-attendance at follow-up visits. Baseline characteristics were initially used to describe the sample and statistical assumptions for each analysis were tested and satisfied.

Kaplan-Meier and Cox proportional-hazard models were used to determine time to and risk of relapse among women who reported engaging in varied levels of exercise at baseline. As in prior research,^{36,37} the continuous baseline exercise data were split into tertiles with 114 women in each tertile. The three tertiles included individuals who expended less than 650 kcal from exercise per week (low exercise), between 650 and 1,650 kcal from exercise per week (moderate exercise), and greater than 1,650 kcal from exercise per week (high exercise). The survival time was censored if a woman relapsed to smoking after her last day in the study. Baseline levels of nicotine dependence, years smoking, and cigarettes per day were considered covariates in the models. In addition, because treatment group was associated with smoking status,⁷ we controlled for group assignment. To evaluate differences in duration of abstinence across the three exercise groups, Kaplan-Meier curves of number of weeks to relapse were plotted and compared using the log-rank test. Crude and adjusted Cox proportional-hazard models were computed to assess risk of relapse, and pairwise comparisons between each of the three exercise groups were implemented.

To examine whether the effect of 1-month change in exercise on 6-month point-prevalence abstinence was driven by 3-month change in weight, a series of models were run. First, change scores for exercise and weight were computed to determine how modification to these factors early in treatment affected smoking status at the end of treatment. Specifically, the change score for exercise was computed by subtracting the exercise energy expenditure reported at baseline from the exercise energy expenditure reported at the 1-month assessment, such that positive scores indicated an increase in exercise. In addition, the change score for weight was computed by subtracting precessation weight from weight measured at the 3-month assessment, such that positive scores indicated weight gain. To focus on modeling the mediational process, only the cases with complete data ($n = 149$) were included in the mediation analysis. Independent samples t tests and chi-square tests indicated that women included in the mediation analysis were more likely to be Caucasian ($\chi^2 = 4.21$; $p = .04$) compared to those who had incomplete data, but there were no differences on any other baseline characteristic. Race was subsequently considered as a potential covariate but was not found to be significant in any of the models and therefore was excluded.

The mediation analysis followed the procedures outlined by Baron and Kenny.³⁸ This multistage approach to testing mediation included three tests (Figure 2), and all models were adjusted for treatment group, nicotine dependence, years smoking, and cigarettes per day. A logistic regression equation was first used to regress 1-month change in exercise on 6-month point-prevalence abstinence (path c). A linear regression equation was then used to regress 1-month change in exercise on 3-month change in weight (path a). A final logistic regression equation, controlling for 1-month change in exercise, was used to regress 3-month change in weight on 6-month point-prevalence abstinence (path b). The mediation effect of 3-month change in weight on the relation between 1-month change in exercise and 6-month point-prevalence abstinence (path c') was then assessed. Given the conservative nature of the Baron and Kenny³⁸ approach, we further assessed the mediation effect using the bias-corrected bootstrap method, which has been shown to be more powerful than other tests.³⁹ Specifically, the statistical significance of the indirect effect (paths ab) was determined by examining the 95% bias-corrected confidence interval derived from 1,000 bootstrapped resamples.

Results

Baseline Exercise and Smoking Cessation

BMI was higher ($p = .01$) among women in the low exercise group ($M = 28.55$; $SD = 6.08$) compared to women in the high exercise group ($M = 26.49$; $SD = 4.91$) but did not differ ($p = .08$) from women in the moderate exercise group ($M = 26.95$; $SD = 5.25$). There were no additional differences in demographic characteristics or smoking behaviors across the exercise groups. At the end of the 6-month treatment period, 57% and 52% of women in the low and moderate exercise groups had relapsed compared to 44% of women in the high exercise group (Figure 1). The median time to relapse was 10.57, 12.86, and 22.00 weeks among women in the low, moderate, and high exercise groups, respectively. Women in the low exercise group resumed smoking significantly earlier than did those in the high exercise group ($\chi^2 = 4.31$; $p = .04$). Women in the moderate exercise group did not differ from women in the low ($\chi^2 = .83$; $p = .36$) or high ($\chi^2 = 1.35$; $p = .25$) exercise groups in time to relapse.

Figure 1. Kaplan-Meier curves of time to relapse by weekly exercise levels at baseline. *Note:* Women in the low exercise group had significantly faster time to relapse than did those in the high exercise group ($\chi^2 = 4.31$; $p = .04$). Women in the moderate exercise group did not differ from women in the low ($\chi^2 = .83$; $p = .36$) or high ($\chi^2 = 1.35$; $p = .25$) exercise groups in time to relapse.

As shown in Table 2, adjustment for covariates augmented the hazard ratios slightly but did not alter the overall effect of exercise level on risk of relapse. Women in the low exercise group were at 1.58 fold increased risk of relapse compared to women in the high exercise group ($p < .05$). Women in the moderate exercise group did not differ from those in the low ($p = .26$) or high ($p = .20$) exercise groups in relapse risk.

Weight Change as Mediator of Exercise and Smoking Outcome

On average, women increased their exercise by 240.00 kcals per week ($SD = 1,171.43$; Range = -2886.32 to 6713.47) by the 1-month assessment and had gained 3.78 pounds ($SD = 5.82$; Range = -15.33 to 19.67) by the 3-month assessment. As shown in Figure 2, 1-month change in exercise was not significantly related to 6-month point-prevalence abstinence ($p = .07$; path c). However, 1-month change in exercise was negatively related to 3-month change in weight ($p = .03$; path a), such that women who increased exercise 1-month following the target quit date gained less weight by 3-months. After controlling for 1-month change in exercise, 3-month change in weight was negatively related to 6-month point-prevalence abstinence ($p = .03$; path b), such that women who gained more weight 3-months following the target quit date were less likely to relapse by 6-months. Indeed, women who remained abstinent at the end of treatment had gained an average of 4.77 ($SD = 5.77$) pounds across the first 3-months of treatment compared to a weight gain of 3.18 ($SD = 5.86$) pounds among women who had relapsed ($t(148) = 1.68$; $p = .09$). Finally, the effect of 1-month change in exercise on 6-month point-prevalence abstinence ($p = .03$; path c') was significant when 3-month change in weight was included in the model, indicating that there was no mediation effect. This finding was further confirmed using

Table 2. Crude and Adjusted Hazard Ratios for Smoking Relapse According to Weekly Exercise Levels at Baseline

Level of exercise energy expenditure	Crude HR (95% CI)	Adjusted HR ^a (95% CI)
High exercise (>1,650 kilocalories)	1.0 (REF)	1.0 (REF)
Moderate exercise (650–1,650 kilocalories)	1.25 (.86, 1.82)	1.29 (.88, 1.89)
Low exercise (<650 kilocalories)	1.47 (1.01, 2.12) ^b	1.58 (1.09, 2.30) ^b

CI = confidence interval; HR = hazard ratio; REF = reference group.

^aAdjusted for treatment group, years smoking, cigarettes smoked per day, and nicotine dependence.

^bSignificant difference from reference group at $p < .05$.

Note: All models adjusted for treatment group, years smoking, cigarettes smoked per day, and nicotine dependence; coefficients are standardized. $p < .05$

Figure 2. The mediating effect of change in weight on the relationship between change in exercise and 6-month point-prevalence abstinence.

the bias-corrected bootstrap method. The bias-corrected confidence interval for the indirect path was found to include zero ($ab = 5.85e-05$; 95% CI = $-6.64e-07$ to $1.68e-4$). Hence, we are more confident to conclude that the relationship between 1-month change in exercise and 6-month point-prevalence abstinence was not mediated by 3-month change in weight.

Conclusions

Exercise is an effective aid for smoking cessation and may promote abstinence by reducing postcessation weight gain.^{14–16} The role of exercise in promoting successful smoking cessation may therefore be particularly important among smokers concerned about post-cessation weight gain. However, there has been limited prospective documentation of the relationship between exercise and smoking cessation and no prior research has investigated whether this relationship is mediated by weight. Accordingly, the present study sought to assess how exercise prospectively relates to smoking cessation and to determine whether initial changes in exercise after quitting smoking promotes cessation by attenuating weight gain among a sample of weight-concerned women smokers receiving cessation treatment.

Results indicated that weight-concerned women smokers who reported engaging in high levels of exercise at the initiation of a cessation treatment were less likely to relapse and returned to smoking more gradually than did women who engaged in low levels of exercise. However, women who engaged in moderate levels of exercise did not differ in cessation rates relative to women who engaged in either low or high levels of exercise, suggesting that exercise may

need to be performed for greater durations or at higher intensities to protect against smoking relapse successfully. Indeed, women who engaged in high levels of exercise reported expending more than 1,650 kcals from exercise per week, which equates to more than 1 hr of moderate intensity exercise per day or more than 30 min of vigorous intensity exercise per day.⁴⁰ These findings are consistent with those of previous studies, which have shown that higher intensity exercise is more efficacious at promoting smoking abstinence^{14,15} than moderate intensity exercise.^{21,24–26} However, both moderate and vigorous intensity exercise are capable of acutely alleviating symptoms of nicotine withdrawal^{41,42} and dampening cigarette cravings.^{43,44} Moreover, recent findings have shown that women who adhered to a moderate intensity exercise regimen had 61% greater odds of achieving prolonged abstinence than did women participating in a wellness control group.²³ Thus, moderate intensity exercise may be sufficient to produce beneficial effects on smoking cessation if compliance is maintained.

Although we did not find differences in demographic characteristics or smoking behaviors across the three exercise groups, it is worth noting that physically active smokers may differ from sedentary smokers. Indeed, physically active smokers tend to have lower nicotine dependence and are more likely to attempt cessation than sedentary smokers.⁴⁵ Thus, physically active smokers may be less vulnerable to nicotine withdrawal and more motivated to achieve cessation than sedentary smokers. It further remains unclear whether physically active and sedentary smokers benefit similarly from exercise during quit attempts. For instance, physically active smokers may be more sensitized than sedentary smokers to the positive effects of exercise on cigarette cravings and nicotine withdrawal. Rather, physically active smokers may develop positive expectancies about the utility of exercise in aiding quit attempts, resulting in greater smoking cessation self-efficacy and lower need to further increase exercise during quit attempts.⁴⁶ However, because the present study was not designed to assess how exercise differentially affects physically active and sedentary smokers following smoking cessation, future work in this area is needed.

Contrary to our hypothesis, 3-month change in weight did not mediate the effect of 1-month change in exercise on 6-month point prevalence abstinence. Rather, increasing exercise during the first month of quitting smoking was related to less weight gain across the first 3-months of treatment, which in turn increased the likelihood of relapse at the end of a 6-month cessation treatment. Thus, increasing exercise shortly after quitting smoking may attenuate short-term weight gain but does not appear to promote longer-term smoking cessation. It is likely that the relationship between weight gain and smoking cessation occurred because women who remained abstinent gained more weight than did women who relapsed, a finding consistent with extant literature.^{1,3} Of note, increased exercise was significantly related to higher odds of smoking cessation only when change in weight was included as a covariate in the model, indicating that changes in exercise and weight are related but ultimately independent predictors of smoking cessation.

Taken together, these results demonstrate that attenuated post-cessation weight gain is not the mechanism through which exercise promotes smoking cessation. Rather, it may be that initial increases in exercise following a quit attempt are particularly effective at counteracting cigarette cravings and symptoms of nicotine withdrawal, which subsequently increase the likelihood of remaining abstinent. Indeed, exercise has been shown to attenuate responses to cigarette cues and increase time between *ad libitum* smoking,^{27,28} suggesting

that exercise may function to reduce cigarette cravings partly by decreasing the attention paid to smoking-related cues. Exercise also reduces the depressed mood, anxiety, irritability, tension, restlessness, and concentration difficulties characteristic of nicotine withdrawal.⁴² Thus, exercise may promote cessation through its positive effects on cigarette cravings and symptoms of nicotine withdrawal rather than by reduced postcessation weight gain as initially hypothesized.

The current study had several limitations. First, the study was not designed to test the effect of exercise on smoking cessation. Second, we excluded over half of the study participants when conducting the mediation analysis. This limits our power to detect significant effects and may introduce concern regarding sample bias. However, women included in the mediation analysis only differed from those who were excluded in that they were more likely to be Caucasian. Third, we used a subjective report of exercise, which can be less accurate when compared to objective measurement.⁴⁷ However, the Paffenbarger Physical Activity Questionnaire³⁵ used in the present study provides energy expenditure estimates that are moderately correlated with objective measures of energy expenditure, suggesting it to be a reliable and valid tool to assess overall exercise energy expenditure.⁴⁸ Finally, the study participants consisted of weight-concerned women smokers. Although we reasoned that weight-concerned women smokers may receive particular benefit from exercise as an aid for smoking cessation given its potential to reduce postcessation weight gain, our findings may not be generalizable to other populations of smokers for whom the role of weight gain on relapse may be different.

Despite these limitations, the present study demonstrates that exercise functions as an important aid for smoking cessation among weight-concerned women smokers. However, for exercise to successfully promote smoking cessation, it may have to be performed at higher durations or greater intensities. Although multiple behavior changes can be difficult to achieve, some evidence suggests that encouraging individuals to quit smoking while simultaneously increasing physical activity is more effective at achieving change in at least one behavior than addressing the behaviors sequentially.⁴⁹ Nonetheless, many women smokers making a quit attempt may be unable or unwilling to adopt and maintain a vigorous intensity exercise program. Thus, cessation interventions utilizing an exercise component should consider exercise regimens that promote adherence while sufficiently aiding in cessation. Although weight change did not mediate the relationship between exercise and smoking cessation, a temporal relationship between these factors was evident. Specifically, initial increases in exercise predicted lower weight gain, which in turn predicted higher odds of relapse, indicating that the attenuated weight gain related to increased exercise after quitting smoking may not be sufficient to promote smoking cessation. Instead exercise may promote smoking cessation through additional mediational processes, such as by reducing cigarette cravings and alleviating symptoms of nicotine withdrawal or improving affective, cognitive, and somatic responses to quitting smoking.

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Declaration of Interests

None declared.

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