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Relationship of physical activity and weight loss in women with Class II and Class III obesity: Mediation of exercise-induced changes in tension and depression

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ABSTRACT. Exercise is a predictor of both weight loss and mood improvement. Because of the minimal energy expenditure associated with exercise in obese persons due to their poor cardiovascular fitness, it has been suggested that exercise-induced mood change may mediate the relationship of exercise with weight loss for them. In the current experimental study, women with Class II and III obesity ($N = 75$) participated in a 24-week moderate exercise and nutrition education program at southeastern U.S. Young Men's Christian Association (YMCA) centers. As expected, exercise session attendance was significantly associated with weight loss (β=-.47), but directly accounted for only an estimated 17% of the loss in weight. Using the Baron and Kenny approach, significant partial mediation was found for changes over 24 weeks in both tension and depression scores. This suggested that exercise indirectly affected weight change through psychological pathways, and supported tenets of social cognitive theory. After replications and extensions, findings may help to improve explanatory theory and weight management treatments.

KEYWORDS. Exercise. Mood. Weight loss. Obesity. Experiment.

RESUMEN. El ejercicio físico predice tanto la pérdida de peso como la mejora en el estado de ánimo. Debido al gasto energético mínimo relacionado con el ejercicio en personas obesas y a su pobre estado cardiovascular se sugirió que el cambio en el estado

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de ánimo inducido por el ejercicio puede mediar la relación de éste con la pérdida de peso. En el presente estudio experimental, mujeres con obesidad de Clase II y III (*N* = 75) participaron en un programa de ejercicio moderado y educación en nutrición durante 24 semanas en centros de la Asociación Cristiana de Jóvenes (YMCA) en el sudeste de Estados Unidos. Tal como se esperaba, la participación en las sesiones de ejercicio se relacionó con la pérdida de peso (β = -.47), pero, de forma directa, representaron solamente un 17% de la pérdida de peso. Utilizando la aproximación de Baron y Kenny, se encontró una mediación parcial significativa para los cambios en 24 semanas en las puntuaciones de tensión y depresión. Esto sugiere que el ejercicio afectó indirectamente al cambio de peso mediante vías psicológicas y apoyó los principios de la teoría social cognitiva. Después de la replicación, los resultados pueden ayudar a mejorar las teorías explicativas y los tratamientos de control de peso.

PALABRAS CLAVE. Ejercicio. Estado de ánimo. Pérdida de peso. Obesidad. Experimento.

Approximately 46% of American women (and 60% of women who are either overweight or obese) are trying to lose weight, with caloric restriction (dieting) being the most frequent method (Bish *et al.*, 2005). It is now clear that after a brief period, the strategy of solely restricting caloric intake for weight loss is ineffective for all but a very small percentage (Mann *et al.*, 2007). Exercise predicts weight loss in obese persons (Fogelholm, Stallknecht, and Van Baak, 2006), and is the strongest predictor of maintaining loss of weight (Miller, Koceja, and Hamilton, 1997). The relationship between exercise and psychological improvements, mainly depression and anxiety (also referred to as tension)[2], has also been established (Jiménez, Martínez, Miró, and Sánchez, 2008; Landers and Arent, 2001). Because of the limited volumes of exercise typically completed by deconditioned adults beginning exercise programs (American College of Sports Medicine, 2009), it has been suggested that weight loss for them may be better explained by an association between exercise-induced improvements in mood and maintenance of calorie-restricted eating, than energy actually expended through physical activity itself (Jakicic, Wing, and Winters-Hart, 2002). It is consistent with social cognitive theory (Bandura, 1986,1997), and a model of indirect effects of physical activity on weight loss proposed by Baker and Brownell (2000), that exercise-induced changes in mood will affect weight loss behaviors through an association of emotional factors with perceived capabilities and perseverance (Bandura, 1998). Direct testing of this premise is, however, lacking, and has been specifically suggested (Jakicic *et al.*, 2002).

Depression and tension have been viewed as both proximal and distal antecedents (immediate triggers and predisposing factors, respectively) to overeating (Waller, 2002). There may be subtle differences between tension and depression regarding their effects on eating behavior. Although research confirms that individuals who are generally more

[2] Consistent with the measurement instrument used within this report (Profile of Mood States; McNair, Lorr, and Droppleman, 1992), tension and anxiety are used interchangeably.

depressed and anxious will tend to have more episodes of low mood and anxiety (Endler and Magnusson, 1976), overeating responses may be more frequent with acute anxiety. Thus, it is likely that overall (chronic) feelings of tension make acute triggers to stress-induced eating increasingly likely, while overall feelings of depression may be associated with a general tendency to overeat to improve dysthymia (Christensen, 1993; Cooper, 1995). This implies a distinction on how and when tension and depression may act to influence caloric consumption and weight gain (Linde *et al.*, 2004; Weinstein, Shide, and Rolls, 1997). Because direct measurement of changes in caloric intake has been difficult, and is often inaccurate (Favé, Beckmann, Draper, and Mathers, 2009; Williamson *et al.*, 2007), it may be possible to make indirect estimates based on energy expenditure and weight change over time – especially within field research.

Because exercise is reliably related to weight loss (Catenacci and Wyatt, 2007), but the amount of weight loss observed is greater than would be expected based on the relatively low amount of caloric expenditure associated with exercise in deconditioned persons (American College of Sports Medicine, 2009), the present investigation was conducted to assess the possibility of mediation of the exercise-weight loss relationship by exercise-induced changes in tension and depression. Due to the possible temporal differences in the effects of tension and depression on eating, analyses of mediation of these psychological changes were conducted separately. Severely to morbidly obese women were selected for testing because of the great need for understanding behavioral mechanisms of weight loss in this at-risk subgroup. It was expected that exercise session attendance would be significantly related to change in body mass index (BMI), but account for only a small portion (less than 25%) of the weight loss. It was also expected that significant changes in both tension and depression would mediate the relationship between exercise and BMI change. It is hoped that a better understanding of the indirect effects of exercise on weight loss will improve explanatory theory and, ultimately, improve behavioral weight management treatments.

Method

Participants

Women from the southeast U.S. responded to solicitations in a local newspaper for an exercise and nutrition education program. Inclusion criteria were a) age of 21-65 years, b) Class II or III obesity at a BMI of 35-45 kg/m^2, c) no regular exercise completed in the previous year, and d) reporting a goal of weight loss. Exclusion criteria were a) inadequate health for exercise, b) pregnant or planning to become pregnant within 1 year, c) taking medications for weight loss or a psychological problem, and d) completed or planned surgery for weight loss. Institutional review board approval, written consent from participants, and written physician's clearance to participate, was obtained. There was no cost or compensation for participation.

The mean age of participants was 43.60 years (*SD* = 9.90), with a mean BMI of 41.10 kg/m^2 (*SD* = 3.90). The racial make-up was 47% African American, 45% White, and 8% other racial/ethnic groups. Most participants were in the lower-middle to middle class.

Measures

- Tension and Depression. The Profile of Mood States–Short Form (McNair *et al.,* 1992) scales of *Tension* (*e.g.,* anxious, tense) and *Depression* (*e.g.,* sad, gloomy) each had five, one-word items, and required responses from 0 *(not at all)* to 4 (*extremely*) to indicate «how you have been feeling during the past week including today». For women, internal consistency was reported at .88 for the *Tension* scale and .95 for the *Depression* scale, and test-retest reliability (over 20 days) was .70 and .74, respectively (McNair *et al.*, 1992). The factor analytic structure was consistent across asymptomatic and psychiatric samples. Concurrent validity was demonstrated with a variety of accepted affective measurement instruments (McNair *et al.*, 1992). The intercorrelation of *Tension* and *Depression* scores in the present sample was .24.
- Exercise session attendance. Consistent with previous research (Annesi, 2007), Exercise session attendance was the ratio of sessions actually completed divided by the «ideal» number of sessions or 72 (3 sessions assigned / week *x* 24 weeks), expressed as a percentage. Exercise sessions were recorded electronically at a kiosk in the study's exercise areas, or through the Internet. This method was indicated as valid through strong correlations (r = .42 - .55) with changes in measures of cardiorespiratory function (*e.g.,* $VO_{2\ max}$, blood pressure, and resting heart rate) in previous research (Annesi, 2000).

Procedure

Participants were provided access to Young Men's Christian Association (YMCA) centers that included a variety of cardiovascular exercise apparatus and areas for walking and running. A standardized exercise support program that emphasized goal setting, enjoyable exercise, and self-regulatory skills (Annesi, 2003) was administered by trained wellness specialists monthly in 60-min individual sessions. This program was standard practice for all adults beginning an exercise program in the present YMCA centers. Wellness specialists administering the program were not aware of the research design or goals of the research.

For each participant, three exercise sessions per week of moderate-intensity cardiovascular exercise (progressing from a minimum of 20 minutes to a maximum of 30 minutes per session) were assigned. Intensity was monitored using the Borg Rate of Perceived Exertion Scale (Robertson and Noble, 1997), and kept moderate; between 13 *(somewhat hard)* and 14 *(between somewhat hard and hard)*. Participants were trained how to use the computerized mechanism for tracking exercise. Recording of exercise completed outside of the YMCA was done through the Internet. Participants were not placed into groups to exercise, nor were they supported by a wellness specialist during their exercise sessions. Thus, the possibility of biasing results due to expectation or social support effects was minimized.

Registered dietitians provided six bi-monthly, 1-hour nutrition information sessions in groups of 15-25 participants. The standardized protocol was supported by a workbook that was given to participants to keep (Kaiser Permanente Health Education Services, 2002). The emphasis was placed on healthy eating. Curriculum components included a)

understanding carbohydrates, protein, and fats; b) using the U.S. Food Guide Pyramid; c) developing a plan for appropriate snacking; and d) healthy food preparation. No specific caloric or fat restrictions were imposed.

Surveys were administered in a private area at baseline and at Week 24. To minimize biasing of results, persons involved in direct administration of the treatment were not present. If a participant was not present for the scheduled assessment at program end, up to three email and phone communications were attempted to prompt measurement at an alternate time.

Data analysis

The study incorporated an experimental design (Montero and León, 2007; Ramos-Álvarez, Moreno-Fernández, Valdés-Conroy, and Catena, 2008). Consistent with previous related research (Jakicic *et al.*, 2002; Napolitano *et al.*, 2008), an intention-to-treat design was incorporated where missing data due to a participant's missing measurements at program end was imputed using the last observation carried forward approach. Missing data at Week 24 occurred in 12 participants (16% of the sample). These 12 women did not significantly differ ($ps > .20$) in age, BMI, race/ethnicity, tension, or depression, from all other participants. Missing data associated with non-response of survey items were imputed using the expectation maximization approach. Expectation maximization is an iterative method that alternates between computation of expectation with respect to the distribution of the data, and computation of parameters which maximize likelihood from the expectation step (Schafer, 1999). This was required in only a few instances.

Dependent *t* tests were first conducted to assess if there were significant within-group changes in BMI, depression, and tension scores over 24 weeks. Next, the linear relationship between exercise session attendance and change in BMI was calculated. Based on estimates of caloric expenditure from participants' weight and exercise types, durations, intensities, and frequencies (Katch, Katch, and McArdle, 1996),[3] the percentage of weight change accounted for by the exercise completed was then calculated. This was based on recent research suggesting that an estimated 3500 kcal difference is required for a .45 kg (1.00 lb) of weight change to occur (in persons in the present BMI range) (Hall, 2008).

The mediation procedure described by Baron and Kenny (1986), incorporating the Sobel-Goodman test for significance (Goodman, 1960), was then used to assess if the direct relationship between exercise session attendance (the independent variable) and change in BMI (the dependent variable) (Path c) was significantly reduced by entry of changes in depression and tension scores (mediators) (Path c') into separate equations. Research suggests that changes in psychological factors, rather than their values at a single point, are most important for the prediction of weight change (Baker and Brownell, 2000). Because extremely high and low scores (ceiling and floor effects) were not

[3] The typical type of exercise completed was walking. It was done for an average of 27.50 min. at a speed of approximately 4.80 km/hour (3.0 miles/hour). The average estimated caloric expenditure per session of exercise was, thus, 185 kcal.

present, and it was of practical interest to include changes associated with a naturally occurring array of initial mood and BMI scores in the present subgroup, similar to previous research (Annesi, 2007; Jakicic *et al.*, 2002), actual score changes (rather than scores controlling for baseline values) were used. Relationships between exercise and each mediator (Path a), and each mediator and BMI change (Path b), are also given.

Because the relationship of tension scores with caloric consumption (the assumed causal factor for weight change beyond exercise) may have been more the result of an accumulation of acute occurrences of anxious states than was the case with depression scores (that may have been associated with more stable and persistent low mood) (Linde *et al.*, 2004; Weinstein *et al.*, 1997), it was thought that tension and depression might not have acted on the resultant BMI changes concurrently. Thus, although simultaneous testing of both of the mediators (changes in tension and depression) would have increased statistical power somewhat (Napolitano *et al.*, 2008), we did not believe that it should be used here given the possible temporal differences in their respective effects on the dependent variable. Thus, separate analyses were conducted. Statistical significance was set at $\alpha = .05$ (two-tailed), with a sequential Bonferroni correction (Jaccard, 1998) applied to adjust for multiple tests, while maintaining the highest statistical power possible (Kromrey and Dickinson, 1995).

Results

Mean exercise session attendance was 48.95% (*SD* = 30.84). Change in BMI over 24 weeks was significant (Table 1), and equated to a mean change of -4.98 kg (-10.98 lbs). Exercise session attendance was significantly related to change in BMI, $\beta = -.47$, $p < .001$. Only approximately 17% of the mean weight loss (-.85 kg; -1.87 lbs) was, however, attributable to caloric expenditure from exercise.

TABLE 1. Within-group changes in tension, depression, and BMI over 24 weeks ($N = 75$).

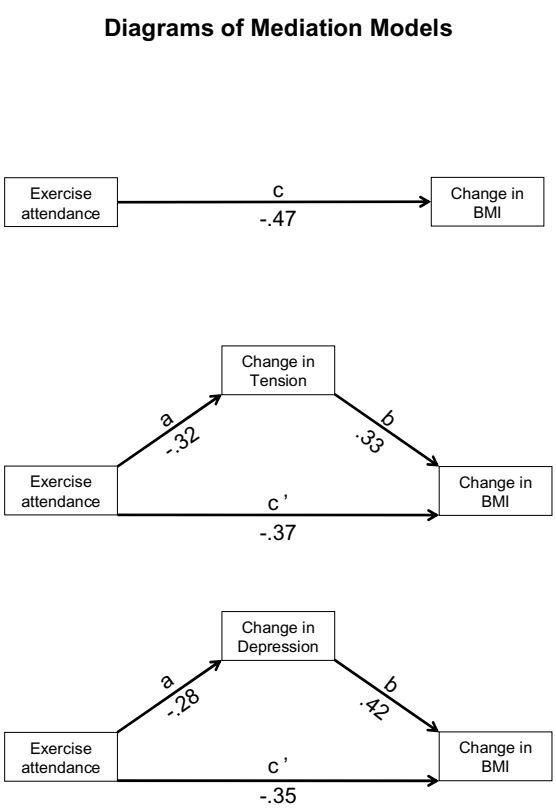
Measure	*Baseline M (SD)*	*Week 24 M (SD)*	$t_{(74)}$	*p*	*95% CI*	*d*
BMI	41.13 (3.86)	39.28 (4.17)	3.77	<.001	.40, 1.29	.48
Tension	3.36 (2.47)	2.62 (2.22)	2.66	.009	.18, 1.28	.30
Depression	3.55 (1.75)	3.01 (1.49)	2.11	.038	.03, 1.04	.30

Notes. *d* = Cohen's measure of effect size, BMI = body mass index.

Changes in both tension and depression scores were significant (Table 1). In testing the mediating effect of change in tension on the relationship between exercise session attendance and change in BMI where Path a was $\beta = -.32$, $p = .005$, and Path b was $\beta = .33$, $p = .002$, a reduction from $\beta = -.47$ (Path c) to $\beta = -.37$, $p < .001$ (Path c'), was found (see Figure 1). The Sobel-Goodman test statistic indicated significant partial mediation, $z = 2.19$, $p = .028$.

In a separate test of the mediating effect of change in depression on the relationship between exercise attendance and BMI change where Path a was β = -.28, p = .014, and Path b was β = .42, p = .001, a reduction from β = -.47 (Path c) to β = -.35 p = .001 (Path c'), was found (see Figure 1). The Sobel-Goodman test statistic indicated significant partial mediation, z = 2.23, p = .025.[4]

FIGURE 1. Unmediated and mediated models of the relationship of exercise session attendance and change in BMI.



[4] The mediation analyses were also calculated using change scores adjusted for baseline scores. Findings were only marginally different. In analysis of the mediating effect of change in tension on the significant relationship between exercise attendance and BMI change where Path a was b = -.41, p < .001, and Path b was b = .37, p < .001, a reduction from b = -.47 (Path c) to b = -.34, p < .001 (Path c'), was found. The Sobel-Goodman test statistic indicated significant partial mediation, z = 2.64, p = .008. In analysis of the mediating effect of change in depression on the relationship between exercise attendance and BMI change where Path a was b = -.26, p = .022, and Path b was b = .42, p < .001, a reduction from b = -.47 (Path c) to b = -.36, p < .001 (Path c'), was found. The Sobel-Goodman test statistic indicated significant partial mediation, z = 2.27, p = .023.

Discussion

As expected, significant within-group improvements in weight, tension, and depression were found in the present sample of women with Class II and III obesity. The pattern of adherence to the assigned regimen of moderate exercise (a mean of 1.5 sessions/week, with wide variation) was similar to previous related research on samples that were not exclusively obese (Annesi, 2003). Also, as expected, the volume of exercise completed was significantly related to the large range of change in the participants' weight over 24 weeks, but, understandably, only a small portion of the weight loss was directly attributable to energy expenditure associated with the low volumes completed.

In assessments of indirect pathways of the relationship between exercise attendance and weight loss, exercise-induced changes in both tension and depression were found to be significant partial mediators. It could be interpreted that, for the present sample, even the low volume of exercise completed was associated with improvements in mood, which, in turn, positively affected caloric consumption. This is based on the realization that weight loss is largely explained through the combination of caloric expenditure (through physical activity) and caloric intake (through consumption of food). Proponents of behavioral explanations of the exercise-mood change relationship posit that psychological improvements (*e.g.,* in self-concept and self-efficacy) related to participation in an exercise program predict mood change better than exercise-induced biochemical changes (*e.g.,* in endorphin and serotonin levels) that may require volumes of exercise in excess of those found here (Dunn, Trivedi, Kampert, Clark, and Chambliss, 2005). Thus, it was behavioral explanations that were partially supported here.

Research suggests the importance of exercise for weight loss (Fogelholm *et al.*, 2006), that participation in exercise is associated with mood improvements (Landers and Arent, 2001), and that changes in mood affect caloric consumption (Waller, 2002). This investigation extended research on these interrelations, and contributed to research on the premise that exercise may be indirectly associated with weight loss through psychological pathways (Baker and Brownell, 2000). Although this study was conducted with a specific sample, without a control group, in a field setting that may have reduced experimental control, it had the advantage of evaluating effects in a high-risk subgroup within a practical context. The need for research that accepts some loss in experimental control in order to conduct analyses with at-risk persons in realistic settings has recently been emphasized (Glasgow, 2008). It should also be noted that alternate explanations could be proposed for the relationships found. For example, improvements in weight may induce positive mood changes, rather than the reverse (as was suggested). Adherence to the development of testable hypotheses based on accepted theoretical frameworks will continue to be important to add clarity. It is hoped that replications over longer periods with different samples, and extensions of the present design, will increase confidence in findings and, ultimately, serve to improve behavioral weight loss treatments.

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