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The reinforcing effect of exercise in anorexia nervosa: Clinical correlates and relationship to outcome

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Abstract

The purpose of the current study was to examine the relative reinforcing effect of exercise compared to a non-monetary alternative reinforcer (leisure activity), and to money, before and after weight restoration in an inpatient population with anorexia nervosa (AN). Sixty-two inpatients with AN completed a progressive ratio (PR) task to earn exercise, leisure activities, or cash at low weight and after weight restoration. Measures of pathology and motivation to exercise were completed and post-treatment discharge weights were collected. Patients worked harder for exercise at low weight than after weight restoration, ($df=46$, $t= 5.50$, $p < .001$). PR task performance was weakly associated with a measure of commitment to exercise (low weight: $r=0.31$, weight restored: $r=0.36$, $p < .05$), but not with other clinical measures or follow-up weights. Contrary to prior suggestions, measurement of the reinforcing value of exercise among individuals with AN via a PR task does not appear valuable in assessing clinical severity or outcome. Other, simpler, self-report measures of commitment to exercise may have greater value in assessing these outcomes.

INTRODUCTION

Anorexia Nervosa (AN) is a serious psychiatric illness marked by self-starvation and overvaluation of shape and weight. Patient reports of excessive exercise in AN have been associated with heightened eating disorder pathology, depression, anxiety (Davis et al., 1997; Davis, Kennedy, Ravelski, & Dionne, 1994; Shroff et al., 2006), and chronicity (Dalle Grave, Calugi, & Marchesini, 2008; Strober, Freeman, & Morrell, 1998). Comparisons of objectively assessed physical activity between groups of individuals with AN and healthy controls have yielded mixed results, such that some studies have found that individuals with AN are more active than controls (El Ghoch et al., 2013; Gianini et al., 2015), while others have found no difference in activity levels (Gümmel et al., 2015; Keyes et al., 2015). While

it is unclear to what extent activity levels in AN differ from those in healthy controls, within AN, activity and drive for activity are linked to pathology and poor prognosis (Bratland-Sanda et al., 2010; Dalle Grave et al., 2008). It has been suggested that exercise may be undertaken in the service of further weight loss, and/or it may serve to regulate unpleasant emotions or raise low body temperature (Carrera et al., 2012; Haynos & Fruzzetti, 2011).

The objective measurement of the motivation to exercise in AN is of potential value, as it may inform the degree to which exercise is related to other features of the disorder and whether it is related to outcome. Behavioral economics examines the role of emotional, social, and cognitive factors in decision-making (Kahneman, 2003). Behavioral economic paradigms have been developed to assess how reinforcing and valuable a behavior is by measuring the willingness of individuals to “work” for it (Lappalainen & Epstein, 1990). One such paradigm used in humans is the progressive ratio (PR) task that typically requires individuals to press a keypad on a computer in order to earn access to a reinforcing object or behavior. Over trials, the task requires increasing amounts of effort, or keypad taps, to earn the reinforcer. The *reinforcing value* of an activity can be determined when that activity is the *only* activity an individual can “work for.” The *relative reinforcing value* of a behavior can be measured when alternative activities that can be “worked for” are presented simultaneously. The “breakpoint” for a stimulus is the number of responses, or keypad taps, completed to earn a reinforcer before an individual stops working for it. This may mean an individual has stopped working for a particular activity (e.g., exercise) and started working for a different activity (e.g., leisure), or they have stopped working for any activity whatsoever. Generally, the more reinforcing a stimulus, the harder individuals work for it and the greater the breakpoint (Hodos, 1961).

Prior studies examining the reinforcing effect of exercise in inpatients with AN have demonstrated that patients were willing to work for exercise via keypad taps (Klein et al., 2010; Schebendach, Klein, Foltin, Devlin, & Walsh, 2007) in a PR task, and from this, a “breakpoint for exercise” is derived. The breakpoint for exercise is a number ranging from 0 to 1,850 indicating how many keypad taps an individual was willing to make in an effort to “earn” increments of time to exercise (Klein et al., 2010; Schebendach et al., 2007). Higher numbers indicate that an individual was willing to press a keypad more times and thus “work harder” in order to earn exercise. In previous pilot studies, breakpoint for exercise was correlated with scores on the Commitment to Exercise Scale (CES; (Davis, Brewer, & Ratusny, 1993))(Klein et al., 2010). In one study, performance on the PR task was also associated with scores on the Beck Depression Inventory, such that those who worked harder to earn exercise reported higher levels of depression (Schebendach et al., 2007), suggesting that breakpoint for exercise on the PR task could signal greater psychopathology in AN.

The current study aimed to expand upon prior studies by exploring the relative reinforcing effect of exercise with regard to a non-monetary alternative reinforcer (leisure activity), and with regard to money, before and after weight restoration in an inpatient population. Leisure was added as an alternative reinforcer to model “real-world” choices that patients make with regard to exercise. Specifically, once discharged from inpatient treatment, patients will often have the option of choosing to engage in exercise or a leisure activity in their everyday lives, and so the addition of this condition to the current study increased the ecological validity of

the task. We also sought to determine whether the reinforcing effect of exercise measured during inpatient treatment was associated with measures of psychopathology, and whether the relative reinforcing effect of exercise was related to weight trajectory in the 12 months following discharge. We hypothesized that the breakpoint for exercise would be higher at low weight (75% Ideal Body Weight as determined by Metropolitan Life Insurance tables (Health & Division, 1983)) than at weight restoration (90% Ideal Body Weight). Furthermore, we hypothesized that greater breakpoints would be associated with a self-report measure of motivation to exercise (CES), heightened affective disturbance and eating disorder pathology, as per our previous findings (Klein et al., 2010; Schebendach et al., 2007). Finally, we hypothesized that elevated motivation to exercise at low weight and weight restoration time points during treatment would be correlated with weight loss during a 12-month follow-up period.

METHODS

Participants

Sixty-two patients hospitalized on the General Clinical Research Unit (GCRU) of the New York State Psychiatric Institute (NYSPI)/Columbia University Medical Center and receiving treatment for AN were enrolled. All participants were women between the ages of 15 and 40 years, and all met *DSM-5* criteria for AN. Diagnoses were made by the Eating Disorder Examination (EDE) and Structured Clinical Interview for DSM-IV administered by trained research assistants, and confirmed via evaluation with Ph.D. or M.D. level clinicians (Cooper & Fairburn, 1987; First, Spitzer, Gibbon, & Williams, 2007). Patients were required to be medically stable and weigh a minimum of 75% Ideal Body Weight (IBW) to participate. Potential participants were excluded if they had significant medical illness, substance dependence in the past 6 months, psychosis, or were at risk for suicide. All patients were free of medications that might impact physical activity (e.g., neuroleptics; stimulants) for a minimum of 2 weeks before the first set of study sessions. All participants provided informed consent before participation in this study, and all study procedures were approved by the NYSPI Institutional Review Board.

Treatment for individuals with anorexia nervosa admitted to the GCRU includes a behavioral protocol aimed at weight restoration to 90% IBW. During hospitalization, physical activity is initially limited to activities of daily living within the confines of the inpatient unit, such as attending groups, individual therapy sessions, and meals. Failure to gain weight at an expected rate results in reduction of activity privileges (e.g., bed rest). As weight gain progresses, patients are permitted to have supervised off-unit time that is limited to select areas within the facility, and these were the typical activity privileges of participants at the low-weight time point. Once stable at or above 90% IBW (weight restored phase), patients are permitted to leave the inpatient unit for up to 24 hours on pass. Formal exercise, including the use of exercise equipment, is not permitted during the weight gain phase of treatment and is highly discouraged after weight has been restored as well. Throughout hospitalization, surreptitious exercise (e.g., in patients' bedrooms) is possible, but discouraged, and interrupted if discovered.

Patients were assessed at two time points (low weight and weight restored) during their inpatient stay. Assessments involved the PR task and questionnaires described below, and were administered by trained bachelor's level research assistants. After discharge from inpatient treatment, participants completed follow-up assessments of weight after 1, 2, 4, 8, and 12 months had elapsed.

Progressive Ratio Task

At low-weight (approximately 75% IBW) and weight restoration (approximately 90% IBW), patients participated in two 40-min PR task sessions, scheduled at least 48 hours but no greater than 2 weeks (mean = 3.7 ± 2.0 days) apart. The timing of the two low-weight sessions depended on when patients achieved the minimum weight for testing and were medically stable. The second set of two sessions was conducted as soon as possible after participants reached 90% IBW (mean of 32.9 ± 10.5 days after first set of sessions). All PR sessions were conducted on a weekday morning (starting between 9:30 and 11:00 am) after patients ate a supervised breakfast at 8:00 am. Neither caloric content nor food content of the meal was standardized across patients.

During one session at each time point (low weight and weight restoration), an individual worked for all or part of a maximum amount of time (30 min) for which she would be permitted to exercise, or for either all or part of a maximum amount of time (30 min) for which she would be permitted to engage in a patient-selected, sedentary, leisure activity. At the other session at the low weight and weight restoration time points, an individual worked for all or part of a maximum amount of time (30 min) for which she would be permitted to exercise, or for all or part of a maximum amount of cash (\$30). Options to work for leisure or money were randomized and counterbalanced across study days at the two weight time points. Work consisted of finger presses on a computer keyboard. Each PR session consisted of 10 trials, with $1/10^{\text{th}}$ the maximum amount of exercise time, leisure time, or cash earned at each trial (\$3 or 3 minutes per trial).

To begin a PR task session, the participant selected a computer screen icon that represented the reinforcer of her choice, opportunity to exercise, or cash, or leisure time. Once this was selected, the participant was required to continue to work for that reinforcer until that trial was completed (or until she stopped working for the session). After completion of a trial, the participant had 8 seconds to decide which reinforcer she would like to work for in the next trial. She could change her selection at the beginning of the trial but not within a trial (i.e., after she had pressed the keypad multiple times). The work required in the first trial for each reinforcer was 50 presses; however, the work requirement increased with each subsequent trial that reinforcer was selected. At the first trial, after a reinforcer was chosen, 50 presses were required. The second time it was selected, 250 presses were required, and then 450; 650; 850; 1,050; 1,250; 1,450; 1,650; and 1,850 presses were required to complete the trial. If the participant selected the alternative reinforcer, it would require 50 button presses, then 250, 450, etc. Thus, the work requirement for each reinforcer increased independently during the session. To earn the maximum amount of exercise, cash, or leisure, the participant had to perform 9,500 keyboard finger presses within the 40-min period. Fewer total presses were required if choices were distributed between the two reinforcers. Patients were

informed before beginning the experiment about the progressive nature of number of taps required for each trial. At the end of each trial, an icon representing the earned reinforcer was displayed on the right side of the computer screen. At the end of the 40-min session, total earnings were displayed.

Possible reinforcers were time to exercise, time for a leisure activity, and cash. For exercise earnings, individuals were allowed access to a treadmill, which was shown to participants before experimental sessions. Exercise earnings were up to 30 min brisk walking at a maximum speed of 4.0 mph. Exercise was monitored by a study physician using an earlobe pulse monitor with target heart rate in the 40–50% maximal heart rate range, consistent with light to moderate exercise (Pollock et al., 1998). Leisure earnings were up to 30 min of a participant-chosen sedentary leisure activity, such as reading a magazine not typically available to them on the inpatient unit, doing crossword puzzles, and/or having a specialty coffee from Starbucks brought to them, and these were provided immediately following the PR session. Potential monetary earnings (cash) were shown to participants before experimental sessions and provided immediately following the PR session. Cash earnings were up to \$30. Choice of leisure or cash as alternative reinforcers was counterbalanced by study session (day). The reason for measuring the reinforcing effect of exercise relative to two different reinforcers (leisure activity or cash) was to determine whether exercise might be perceived as more or less rewarding depending upon the alternative reinforcer available.

Instruments

The following assessments were obtained at low weight and after weight restoration. The Commitment to Exercise Scale (CES; Cronbach's $\alpha = 0.96$ (Davis et al., 1993)) is an 8-item visual analog scale assessing pathological and obligatory aspects of exercise behavior wherein total score on the CES is expressed as a percentage (with 100 the maximum obtainable score). The Beck Depression Inventory (BDI; Cronbach's $\alpha = 0.89$ (Beck, Ward, & Mendelson, 1961)) is a 21-item scale assessing depressive symptoms, with higher scores indicating higher levels of depression. The BDI has demonstrated good concurrent validity and reliability (Beck, Steer, & Carbin, 1988). The Beck Anxiety Inventory (BAI; Cronbach's $\alpha = 0.90$ (Beck, Epstein, Brown, & Steer, 1988)) is a 21-item scale assessing anxiety symptoms, with higher scores indicating higher levels of anxiety. The BAI has demonstrated high internal consistency and test re-test reliability. The Eating Disorder Examination-Questionnaire (EDE-Q; Cronbach's $\alpha = 0.94$ (Fairburn & Beglin, 1994)) is a self-report measure assessing severity of dietary restraint, eating, shape, and weight concerns, with higher scores representing more severe eating pathology. The EDE-Q has demonstrated good convergent validity and acceptable test-retest reliability (Peterson et al., 2007). In-person follow-up weights were collected at intervals of 1, 2, 4, 8, and 12 months following treatment discharge. When possible, these follow-up weights were obtained in-person by research staff. When patients could not attend in-person follow-up visits, weights were provided via self-report, which was verified by an outside clinician (e.g., primary care physician, etc.) when possible.

Statistical Analyses

Paired *t*-tests were used to compare work for exercise between low weight and weight restoration as well as between the money and leisure as the alternative reinforcer conditions at low weight and weight restoration, respectively. Associations between exercise breakpoint variables and CES, BAI, BDI or EDE-Q were examined using Pearson's correlations. The association between exercise breakpoint (during treatment at low weight and weight restoration when leisure was the alternative reinforcer and when money was the alternative reinforcer) and BMIs in the 12 months following treatment discharge was estimated using a linear mixed effects model with random intercepts and random slopes adjusting for demographic variables and measures of depression and anxiety (BAI, BDI) and eating disorder pathology (EDE-Q). A similar model was used to evaluate the association between CES measured at low weight and weight restoration during treatment and follow-up BMI in the year following treatment discharge.

RESULTS

Participant Characteristics

Sixty-two women participated. Fifty-eight participated in at least one study session at low weight and 52 participated in at least one study session at weight restoration. Forty-seven participants completed all four study sessions. Participants were a mean age of 24.6 (*SD*= 6.2) years with average reported duration of illness of 8.5 (*SD*=6.1) years. Participants were an average of 79.2% (*SD*= 3.1) IBW with a BMI of 17.4 (*SD*= 0.7) kg/m² at the first study sessions and 91.4% (*SD*= 2.0) IBW with a BMI of 20.1 (*SD*= 0.5) kg/m² at the second sessions. Follow-up weights were available for 52 participants at month one following discharge, *n* = 54 at month two, *n* = 45 at month four, *n* = 54 at month eight, and *n* = 49 at month twelve. Fifty-seven (91.9%) participants identified as white, 4 as Hispanic (6.5%), and 1 as Asian (1.6%). Thirty-nine (62.9%) individuals indicated they were currently unemployed, 14 (22.6%) reported being employed full-time, and 8 (12.9%) indicated being employed part-time.

Progressive Ratio Task (Table 1)

Greater work for exercise was observed at low body weight compared to weight restoration (*df*= 46, *t* = 5.50, *p* < .001), regardless of the alternative reinforcer (leisure or cash). At low weight, greater work for exercise was observed when leisure was the alternative reinforcer compared with when cash was the reinforcer (*df*= 56, *t* = -3.80, *p* < .001). The same pattern of results was present at weight restoration (*df*= 48, *t* = -4.26, *p* < .001).

Correlates of Exercise Breakpoint

Breakpoint was not associated with BAI, BDI, or EDE-Q at either time point and was weakly associated with CES when leisure was the alternative reinforcer at both low weight and weight restoration (Table 1).

Exercise Breakpoint and Weight After Discharge

Exercise breakpoint under leisure or money reinforcer conditions at low weight or weight restoration was not significantly related to the rate of change in follow-up BMI in the 12 months following discharge from treatment. CES at weight restoration, however, was strongly predictive of the rate of BMI change in the 12 months following discharge adjusting for demographic variables, self-reported measures of depression and anxiety (BDI, BAI) and eating disorder pathology (EDE-Q; weekly rate of change per SD unit of CES = -0.027 ; 95% CI: $-0.047, -0.0071$; $p = .0096$) (Table 2).

DISCUSSION

As predicted, inpatients with AN worked harder for exercise at low weight compared to following weight restoration. This result is consistent with our hypothesis that higher commitment to exercise was a reflection of the psychopathology characteristic of AN, and that desire for exercise decreased as a function of eating disorder recovery. However, it is also possible that this decrease is attributable to the physical activity restrictions placed on these patients while in this inpatient unit. At low weight, all participants' activity was generally restricted to the inpatient unit where exercise was monitored and discouraged. At weight restoration, participants were allowed to leave the hospital for brief passes and it is possible that earning exercise may have been less desirable at weight restoration because patients could walk outside. Furthermore, measures of eating pathology improved with weight restoration but were not associated with performance on the PR task (see further description below). So while effort expended to earn exercise and eating pathology "improved" across study time points, it is possible these improvements were unrelated to each other. Thus, while intriguing, these results are far from definitive and would require replication in a sample in which general activity level was held constant across weight restoration.

Contrary to our hypothesis, effort to earn exercise was only weakly associated with a self-report measure of motivation to exercise and was not significantly related to self-report measures of depression, anxiety, or eating pathology at low weight or upon weight restoration. Effort to earn exercise while in inpatient treatment did not predict BMI trajectory in the 12 months after discharge from inpatient treatment. In contrast, a self-report measure of commitment to exercise administered at low weight and weight restoration time points during inpatient treatment was strongly associated with self-report measures of depression, anxiety, and eating pathology, and was predictive of follow-up BMI trajectory in the 12 months after discharge from inpatient treatment.

The lack of a relationship between performance on the PR task and either measures of psychopathology or weight trajectory following discharge, contrasts to the strong relationship with the self-report measure of commitment to exercise, the CES. Possibly, the exercise that could be earned via the PR task did not offer the nature or intensity of the exercise patients desired, whereas the CES provided a more valid assessment of the desire to exercise vigorously and, more generally, to lose weight, and better predicted actual behavior in a more free-living environment post-treatment discharge. Although an objective measure of motivation to exercise in AN is theoretically appealing, the negative results of the current

study suggest that the specific characteristics of the PR task and the available reinforcers are critical elements, and that, currently at least, the CES is a much simpler but more valid tool.

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Table 1.

Clinical correlates of exercise breakpoints versus money and versus leisure at low weight and weight restoration in Anorexia Nervosa.

		Exercise Breakpoint, Leisure Condition	Exercise Breakpoint, Money Condition	CES
Low Weight	Mean (SD)	Pearson's <i>r</i>		
Exercise Breakpoint, Leisure Condition	914.9 ^{a,b} (682.9)	-		
Exercise Breakpoint, Money Condition	587.7 ^{a,b} (720.9)	0.57 ^{***}	-	
CES	53.1 (33.8)	0.31 [*]	0.19	-
BAI	23.5 ^a (10.7)	0.10	0.03	0.08
BDI	27.5 ^a (11.1)	0.12	0.05	0.28 [*]
EDE-Q	4.3 ^a (1.4)	0.16	0.23	0.46 ^{**}
Weight Restored				
Exercise Breakpoint, Leisure Condition	635.7 ^{a,b} (638.3)	-		
Exercise Breakpoint, Money Condition	337.8 ^{a,b} (624.3)	0.70 ^{***}	-	
Weight Restored	Mean (SD)	Pearson's <i>r</i>		
CES	47.9 (32.2)	0.36 [*]	0.16	-
BAI	19.1 ^a (11.6)	0.15	0.11	0.45 ^{**}
BDI	18.1 ^a (12.2)	0.18	0.26	0.40 ^{**}
EDE-Q	2.5 ^a (1.3)	0.16	0.03	0.63 ^{***}

Note. CES, commitment to exercise scale; BAI, Beck anxiety inventory; BDI, Beck depression inventory; EDE-Q, eating disorder examination-questionnaire;

^aSignificant difference between low weight and weight restoration by paired *t*-test, $p < .05$;

^bSignificant difference between money condition and leisure condition by paired *t*-test, $p < .05$;

* = $p < .05$,

** = $p < .01$,

*** = $p < .001$.

Table 2.Associations between exercise breakpoints, commitment to exercise and follow-up BMI in Anorexia Nervosa^a

	Estimate ^b	95% CI	p value
Low Weight			
Exercise Breakpoint, Leisure Condition	−0.014	(−0.029, 0.001)	0.07
Exercise Breakpoint, Money Condition	−0.005	(−0.020, 0.010)	0.50
CES ^a	0.006	(−0.009, 0.021)	0.44
Weight Restored			
Exercise Breakpoint, Leisure Condition	−0.009	(−0.026, 0.009)	0.31
Exercise Breakpoint, Money Condition	−0.002	(−0.019, 0.015)	0.83
CES ^a	−0.027	(−0.047, −0.007)	0.01 *

Note. CES, commitment to exercise scale; BAI, Beck anxiety inventory; BDI, Beck depression inventory; EDE-Q, eating disorder examination-questionnaire;

^aLinear mixed effects model adjusting for demographic variables and self-report measures of depression and anxiety (BAI, BDI), and eating disorder pathology (EDE-Q);

^bEstimated rate of weekly change in BMI per standard deviation unit increase in exercise break points or CES;

* = $p < .05$.