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Self-Control as Measured by Delay Discounting is Greater Among Successful Weight Losers Than Controls

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Introduction

Considerable evidence has shown that individuals who are obese exhibit poorer self-control than controls across a variety of personality and behavioral measures (Chamberlain et al. 2015; Elfhag and Morey 2008). One dimension of reduced self-control, the inability to delay gratification with excessive discounting of future reward has been observed repeatedly in individual who are obese (Amlung, Petker, Jackson, Balodis, & MacKillop, 2016; Bickel et al., 2014; Fields, Sabet, & Reynolds, 2013; Weller, Cook, Avsar, & Cox, 2008). However, whether those who have successfully lost and maintained appreciable amount of weight report greater, lesser or no differences in self-control compared to control participants is not known. Here, we report a study comparing self-control, as measured by performance in delay discounting tasks, among those who have successfully lost and maintained weight versus controls, and examine this in both participants who are obese and non-obese.

Delay discounting refers to the decline in value of a reinforcer as a function of delay to its receipt. Discounting is intuitive in that most would prefer, for example, a $100 now versus the same $100 at a later time (e.g., six months); that is, the later $100 is worth less or discounted. To measure the extent of discounting of future reinforcers, a psychophysical approach is employed where choices are presented between an immediate smaller amount and a later larger amount with the magnitude of the immediate amount manipulated to ascertain the point of subjective equivalence. This subjective equivalence is obtained at several timepoints to create a discounting curve from which the rate of discounting of delayed rewards can be calculated via a hyperbolic delay discounting equation (see Equation 1 in the data analysis methods section).

Evidence to date suggests that excessive discounting of delayed rewards is observed in multiple disorders and has been described as a trans-disease process. For example, excessive

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discounting can be observed in a variety of disorders including various forms of addiction, excessive gambling, risky sexual behavior, and obesity (Bickel, Jarmolowicz, Mueller, Koffarnus, & Gatchalian, 2012). Relevant to obesity, a recent meta-analysis of 39 studies examining the results of 10,278 participants found that excessive discounting was observed among the people who were obese with a medium effect size and, in that paper, the authors concluded that "[s]teep discounting… [is] a robust feature of obesity" (Amlung et al., 2016, p. 2423). To date, the degree of discounting of delayed reinforcers among those who have sustained weight loss has not been studied.

To address this gap in the literature, we have compared the delay discounting in those who have successfully lost weight and maintained it with control participants. Specifically, we invited participants from the National Weight Control Registry (NWCR), a registry composed of those who have lost 30 pounds or more and kept it off for a year or longer, to participate in a study in which they completed an web-accessible delay discounting task and compared that to discounting obtained from crowd-sourced individuals.

Methods

Demographic characteristics (see Table 1) and two delay discounting tasks were collected online from a sample of individuals in the NWCR and a control sample of Amazon's Mechanical Turk (MTurk) workers.

Participants

Participants in the successful weight loss group were enrolled in the NWCR which is a registry of individuals 18 years or older who have maintained weight loss of 30 pounds or more for at least one year. Individuals were recruited to the NWCR through local and national media sources, physician and dietitian referrals, mailings sent by commercial weight loss programs to members, and articles placed in health-related newsletters and magazines. Individuals could join the NWCR by calling a toll free number or visiting the study website. Participants provided consent approved by the Miriam Hospital IRB and questionnaire packets were sent to participating individuals. For the present study, we contacted 650 NWCR members who had joined the registry since 2002, had consented to be contacted regarding completion of online questionnaires, and had not had bariatric surgery. Five hundred and fifty-two participants completed at least one of the delay discounting tasks and provided updated demographic information. There was no compensation for participation in the registry.

Control participants were required to be at least 18 years old and completed the delay discounting tasks as members of Amazon's Mechanical Turk (MTurk) website. MTurk provides payment for participants to complete surveys online. The control participants were required to be in the United States and to complete at least 90% of their previous Human Intelligence Tests (HITs) or tasks on MTurk and were recruited by posting a flyer about the available HIT on the MTurk website. Control participants were compensated $4 for completion of the task. Participants were provided with an overview of the study and implied consent was obtained when participants indicated they understood the information and chose to continue. Completion of study participation took approximately 30 minutes.

Participants provided self-reported height and weight which was used to calculate Body Mass Index (BMI) using the standard equation: BMI = (Weight in Pounds/(Height in inches x Height in inches)) x 703. Due to previously reported differences in rates of delay discounting in individuals who are obese (Bickel et al. 2014; Amlung et al. 2016)(Bickel et al., 2014), both the NWCR and control samples were divided into those who had currently BMI of less than or greater than 30 (non-obese and obese, respectively).

Delay Discounting Task

Computerized titrating discounting procedures were used to assess the indifference points of each individual at delays of 1 day, 1 week, 1 month, 6 months, 1 year, 5 years, and 25 years, presented in randomized order, for $100 and $1000 magnitudes of hypothetical monetary values (see procedures initially presented in Du, Green, & Myerson, 2002). Indifference points were calculated for each of these delays at each of the magnitudes and then fit to the predominant model of human delay discounting (MacKillop et al. 2011; Amlung et al. 2016):

$$V = A/(1 + kD) \quad \text{Equation 1 (Eq. 1)}$$

where V is the subjective value of the objective monetary amount A, to be delivered after some delay, D (Mazur, 1987). The outcome variable of interest, k, provides an estimate of the rate of discounting where higher k values indicate higher discounting of future rewards. Participants with non-systematic discounting, as evidenced by an indifference point that was more than 20% of the magnitude greater than the prior indifference point, were excluded from the analyses. The k values were subsequently natural log transformed to better approximate the assumption of normality, which underlies parametric statistical analysis. With the log transformed values, larger negative numbers indicate less discounting of future rewards or more self-control.

Statistical Analyses

To address the possibility that other variables might affect the association between discounting and group status, an exhaustive model selection routine was used to determine which covariates to model alongside the group status and reward magnitude in the delay discounting tasks. The purpose of this exercise was to determine which participant characteristics are associated with delay discounting, statistically control for those, and then compare rates of delay discounting after accounting for these other characteristics. The following candidate predictors were considered: age, BMI, education, employment, sex, income, and race. Bayesian Information Criterion (BIC) was used as a metric to decide which of the available demographic predictors best describe delay discounting. Briefly, BIC uses an exhaustive search strategy to weigh the likelihood of a candidate model for a given set of data while including a penalty term for complexity, so that a model with fewer parameters would be chosen over a more complex model if the predictive ability of both models was similar. The *bestglm* package in R (McLeod & Xu, 2010) was used.

After selecting covariates using the BIC, the chosen variables were added to a mixed effect model alongside group (obese NWCR, non-obese, obese control, and non-obese control), discounting magnitude ($100 and $1000), the interaction of group and discounting magnitude, and the random factor of participant ID. Variables of interest to compare differences in rates of discounting across groups were assessed using model-based contrasts of least squares means following a Tukey HSD correction for multiple comparisons. As a secondary analysis, the model-based least squares means of within-group differences in discounting by weight status were compared.

Results

With the ultimate goal of comparing rates of delay discounting between the NWCR and the control groups, we first accounted for sometimes notable differences in demographic variables between groups using model selection to identify covariates to include in the primary analyses. A model selection routine was employed to determine which covariates to model alongside group and magnitude of delay discounting task. From the full model, age, education, and BMI were retained as the optimal model. The top five models are provided in Table 2. NWCR participants were older (t=30.59, p<0.001), were more educated (t=19.70, p<0.001), and had a lower BMI (t=−5.87, p<0.001). By modeling selected covariates alongside the primary variables of interest (i.e., NWCR and control groups), the groups can vary freely with regard to delay discounting while also accounting for possible variance due to covariates. The overall mixed model included age, education, BMI, discounting task magnitude, group (obese NWCR, non-obese NWCR, obese control, and non-obese control) and participant ID. A significant effect of group (F(3,1035)=14.99, p<0.001), magnitude ($100 or $1000) of the delay discounting task (F(1,973)=447.61, p<0.001), education (F(1,1036)=19.20, p<0.001), and the interaction of group and magnitude (F(1,970)=3.44, p=0.02) was observed. In the mixed effect model, no significant difference was detected for age (F(1,1035)=0.03, p=0.87, *ns*) or BMI (F(1,1030)=3.66, p=0.06, *ns*).

The primary goal of this analysis was to compare delayed discounting between the NWCR participants that had lost 30 pounds or more and maintained the weight loss for at least one year and control participants. Following Tukey HSD correction, the control participants discounted significantly more than the NWCR participants regardless of current weight status of obese (t=5.38, p<0.001) or non-obese (t=5.24, p<0.001). The significant interaction between group and discounting showed a consistent pattern across the two magnitudes to delay discounting tasks (i.e., $100 and $1000). Specifically, the lower rate of delay discounting in the NWCR participants compared to the control participants was observed in both the $100 and $1000 magnitude delay discounting tasks. In the $100 magnitude delay discounting task, control participants discounted significantly more than the NWCR participants, with significant differences in both obese (t=5.48, p<0.001) and non-obese (t=5.87, p<0.001) group comparisons. Comparable findings were observed in the $1000 magnitude delay discounting task where both obese (t=4.73, p<0.001) and non-obese (t=4.27, p<0.001) control participants discounted significantly more than the NWCR participants. No significant differences were observed in either the NWCR or control between the non-obese and obese participants (t=−0.26, p=0.99; t=0.66, p=0.91, respectively).

Discussion

In this study, we compared delay discounting, a measure of self-control, at two monetary magnitudes, in a sample of individuals who have successfully lost weight and maintained weight loss from the National Weight Control Registry and a control online sample of obese and non-obese individuals from the crowd sourcing resource, Amazon's Mechanical Turk. After statistically adjusting for selected demographic differences, we found that those who had successfully lost weight and maintained weight loss discounted delayed reinforcers at a lower rate compared to the comparison group. Similar effects were seen when we compared discounting in the obese NWCR and the obese controls, or alternatively, in the non-obese NWCR and the non-obese control participants.

The finding that the NWCR discounted future monetary rewards significantly less than controls (i.e, exhibit an enhanced ability to delay gratification) and that this difference was observed in the total sample and in both the non-obese and obese subgroups, suggests that successful weight loss maintenance may be associated with greater self-control than in controls. Overall, this finding is consistent with other observations made from the NWCR suggesting that they exhibit high levels of self-control. NWCR members have been shown to engage in a variety of behaviors to support the maintenance of weight loss that suggest self-control such as controlling dietary fat, engaging in strenuous physical activity, and frequently monitoring weight (McGuire, Wing, Klem, & Hillf, 1999). Moreover, using fMRI responses to food cues, McCaffery et al. (2009) demonstrated greater activation in inhibitory control areas of the brain in successful weight losers compared to normal weight or obese controls, suggestive of their greater self-control. While prior work supports the interpretation that sustained weight loss is associated with an increase in self-control across a variety of measures, these findings could also reflect other differences between NWCR and the comparison group that were unmeasured and therefore not adjusted for in the models.An important question raised by this study is whether successful weight losers have high degrees of future orientation before they lose and maintain their weight (and this trait enables them to be successful) or whether this future orientation develops as a consequence of their efforts and success at weight control. A recent study using a task where participants made hypothetical choices between highly desired, but less healthy foods versus less desired, but healthier items showed marked differences between participants who were normal weight and obese with greater self-control in the former (more frequent selection of the less desired, but healthier items; Demos et al., 2017). Moreover, participation in a weight loss program led to significant changes on this task, with evidence of greater self-control after weight loss (but still not equal to non-obese). Perhaps with larger weight losses and more sustained efforts to maintain these losses, individuals become increasingly future oriented and more able to exert self-control.

Interestingly, the current study did not find greater discounting in obese individuals as compared to non-obese individuals which is in contrast to previous studies showing differences in discounting based on weight status (see Amlung et al. 2016 for meta-analysis). With regard to the NWCR group, perhaps the long-term weight loss maintenance resulted in a diminishing of differences in impulsivity between non-obese and obese individuals. However, this does not account for the similarity in discount rates between

weight statuses observed in the control group. Amlung et al. (2016) found that several study characteristics moderate the discounting effect, including some that pertain to the current study. For example, sampling adults as opposed to children or adolescents and using monetary rewards as opposed to food in the discounting task are associated with a smaller differences between rates of discounting in non-obese and obese individuals. These study characteristics may have limited the ability to detect differences between weight status. This study has several limitations including differences in demographic characteristics between the NWCR sample and the sample from Amazon's Mechanical Turk. A model-selection technique was employed to select covariates resulting in age, BMI, and education being included as covariates in the analyses. Education, but not age or BMI, was significantly associated with the rate of discounting. Cross-sectional studies have shown that more educated individuals have a lower rate of discounting than those with less education (Jaroni, Wright, Lerman, & Epstein, 2004; Reimers, Maylor, Stewart, & Chater, 2009). In the current study, the NWCR participants were significantly more educated than the control sample. The case may be that these results would not be as robust if the samples were matched on education level and other demographic variables. Second, it is possible that some of the control group had a history of successful weight loss. While the control group reported current weight and height, history of weight change was not assessed. However, a study surveying overweight or obese individuals in the US found that only 17.3% had achieved long-term weight loss maintenance of 10% or more, or about 34 pounds (Kraschnewski et al. 2010) suggesting that it is unlikely that the comparison group included many who had sustained large weight losses. Third, our two samples are from individuals who have access to the internet which may limit the applicability of the sample. As a final point, the measure of delay discounting was hypothetical and results may be different if actual monetary amounts were employed. However, direct comparison of real and monetary delay discounting have shown the same results both behaviorally and neurally (Bickel, Pitcock, Yi, & Angtuaco, 2009).

In conclusion, this study is the first to compare delay discounting in those who have successfully lost and sustained weight loss with control individuals. The results indicate that individuals who successfully maintained weight loss discounted future monetary reinforcers at a lower rate than controls. These results suggest either that in the process of weight loss and maintenance may help individuals to become more future oriented and better able to delay gratification or that individuals who are successful at weight loss and maintenance are lower discounters than controls to begin with and that this may contribute to their success. These results warrant additional future study to replicate findings following sustained weight loss.

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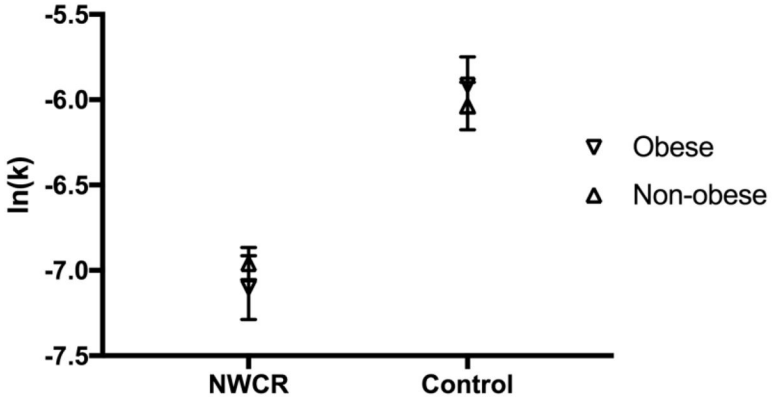

Figure 1.

Delay Discounting Rates Across Groups.

Model adjusted mean ± SE of delay discount rates in NWCR and control groups including both currently participants who were obese and non-obese. Significant differences were observed between all comparisons of NWCR and control groups.

Table 1

Demographic variables.

	Obese NWCR	Non-obese NWCR	Obese Control	Non-obese Control
N	152	605	207	236
Age †	50.82 (11.80)	51.01 (12.39)	33.19 (11.26)	28.49 (8.84)
BMI †	34.82 (4.36)	24.57 (2.70)	36.17 (6.73)	23.16 (3.76)
Education				
Some high school	0 (0%)	1 (0.01%)	2 (1%)	1 (0.01%)
High school diploma/GED	6 (4%)	22 (4%)	32 (15%)	22 (9%)
Trade school	3 (2%)	10 (2%)	10 (5%)	5 (2%)
Some college	11 (7%)	31 (5%)	51 (25%)	81 (34%)
Associate's degree	13 (9%)	31 (5%)	26 (13%)	22 (9%)
Bachelor's degree	41 (27%)	150 (25%)	56 (27%)	87 (37%)
Some post-grad work	13 (9%)	65 (11%)	13 (6%)	6 (3%)
Master's degree	46 (30%)	194 (32%)	17 (8%)	11 (5%)
Doctoral degree	19 (13%)	101 (17%)	0 (0%)	1 (0.01%)
Employment				
Full Time	89 (59%)	363 (60%)	86 (42%)	102 (43%)
Part Time	18 (12%)	46 (8%)	26 (13%)	30 (13%)
Self-employed	13 (9%)	68 (11%)	26 (13%)	25 (11%)
Unemployed	4 (3%)	18 (3%)	34 (16%)	39 (17%)
Retired	25 (16%)	99 (16%)	6 (3%)	1 (0.01%)
Student	2 (1%)	6 (1%)	20 (10%)	36 (15%)
Other	1 (0.5%)	5 (1%)	9 (4%)	3 (1%)
Gender				
Male (%)	35 (23%)	147 (24%)	96 (46%)	156 (66%)
Income				
Under $25,000	9 (6%)	11 (2%)	52 (25%)	39 (17%)
25,000 – 34,999	7(5%)	19 (3%)	35 (17%)	27 (11%)
35,000 – 49,999	9 (6%)	42 (7%)	0 (0%)	0 (0%)
50,000 – 74,999	30 (20%)	81 (13%)	71 (34%)	105 (44%)

	Obese NWCR	Non-obese NWCR	Obese Control	Non-obese Control
75,000 – 99,999	26 (17%)	87 (14%)	19 (9%)	25 (11%)
100,000 – 124,999	22 (14%)	102 (17%)	15 (7%)	21 (9%)
Above $125,000	35 (23%)	198 (33%)	0 (0%)	0 (0%)
Prefer not to answer	14 (9%)	65 (11%)	15 (7%)	19 (8%)
Race				
Asian/Pacific	0 (0%)	7 (1%)	9 (4%)	36 (15%)
Black	4 (3%)	9 (1%)	11 (5%)	14 (6%)
White	140 (92%)	569 (94%)	177 (86%)	176 (75%)
Other	8 (5%)	20 (3%)	10 (5%)	10 (4%)

Demographic characteristics of participants.

†All demographics are reported as frequencies and percent with the exception of age and BMI which are reported as the average and standard deviation.

Table 2

BIC Model Selection for Covariates.

Model	Age	Sex	Education	Race	Income	Employment	BMI	BIC
1	+		+				+	2140.49
2	+		+			+	+	2142.23
3	+	+	+				+	2147.12
4	+	+	+			+	+	2148.63
5	+		+	+			+	2149.16

The top five models to predict delay discounting are shown where + indicates variables that were included in each model. The model with the lowest BIC was selected as the best model and used in subsequent analyses.