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The Effect of a High Intensity Interval Exercise Bout on Addictive Behaviors in Overweight/Obese Adults

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THE EFFECT OF A HIGH INTENSITY INTERVAL EXERCISE BOUT ON ADDICTIVE BEHAVIORS IN OVERWEIGHT/OBESE ADULTS

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Addictive snacking can contribute to excessive caloric intake having an adverse effect on body weight and the obesity pandemic. Studies have reported that moderate intensity exercise decreases chocolate consumption. However, the effect of high intensity interval exercise (HIIE) on addictive snacking is unknown. This study aimed to investigate the effects of a brief HIIE bout on cravings, affect (affective valence and affective activation), and attentional bias to chocolate. Twelve regular chocolate eaters (10 premenopausal females; 2 males; mean age: 30.5 ± 7.37 years, mean BMI: 28.67 ± 4.5 kg/m^2) abstained from chocolate consumption for 24 h prior to evaluation. Participants were randomly assigned to one of two conditions involving either a 26 min bout of HIIE or quiet rest followed by two stress-inducing tasks; a computerized Stroop task and a chocolate-handling task. Chocolate cravings and affect were measured immediately after treatment. Attentional bias to chocolate images was assessed using an adapted dot probe task post-treatment at each session. Paired sample t-tests revealed a significant reduction in cravings and an increase in affective activation (physiological arousal) following HIIE compared to quiet rest conditions. There were no significant changes in affective valence or attentional bias. This was the first study to use HIIE as an exercise intervention for curbing addictive chocolate behaviors in an overweight/obese population. Our findings have important clinical implications for reducing addictive behaviors in vulnerable populations.

KEYWORDS: Exercise; Food craving; Inhibition; Physical activity; Self-regulation; Snacking; Chocolate; Addiction

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Chapter 1: Introduction

Obesity has been on the rise since the seventies, with addictive snacking behavior implicated as a contributing factor (Bes-Rastrollo et al., 2010). Research shows that 97% of women and 68% of men in Canada (Weingarten & Elston, 1991) and 58% of women in New Zealand (Gendall, Joyce, & Sullivan, 1997) experience food cravings for energy dense foods, making it a significant problem. Chocolate is one of the most commonly craved foods (Rozin, Levine, & Stoess, 1991). Reports have suggested that chocolate is addictive due to its content of biologically active constituents (methylxanthines, biogenic amines, and cannabinoid-like fatty acids), fat and sugar content, texture, and aroma (Bruinsma & Taren, 1999). Satisfying the urge to consume chocolate can improve well-being in the short term (Bruinsma & Taren, 1999), but can also have negative consequences in the long-term, such as weight gain and obesity. Finding an alternative option to hedonic eating may be essential to physical health and can be accomplished by understanding the events that occur right before chocolate consumption takes place, such as negative mood, cravings, and increased attention bias (AB) toward chocolate (Oh & Taylor, 2014; Taylor & Oliver, 2009).

Negative mood is one component of affect, a measure of self-reported mood, which is characterized by two components, affective valence (positive or negative mood) and affective activation (high or low levels of physiological arousal) (Feldman Barrett & Russell, 1998). Negative mood may reduce self-regulation of health behaviors that can lead to the consumption of chocolate in an attempt to improve mood (Thayer, 2001). Cravings and increased attentional bias (AB) given to chocolate images can similarly contribute to substance seeking behavior according to the Incentive-Sensitization Theory

(Robinson & Berridge, 1993) and Elaborated Intrusion (EI) Theory(Kavanagh, Andrade, & May, 2005). These theories posit that substance-related conditioned stimuli acquire the ability to grab attention and elicit cravings prior to substance-seeking behaviors. While the precipitating events, negative mood, cravings, and increased AB to chocolate, may predict chocolate consumption, exercise has been suggested to minimize the aforementioned high risk events and therefore curtail chocolate snacking.

Many studies have examined the effects of exercise on hunger, however, there are a paucity of studies examining the effect of exercise on addictive snacking behavior and the events preceding it, irrespective of hunger levels. In one study, a 15-min brisk walk improved affect and decreased chocolate cravings that were induced by two stress-inducing tasks (Taylor & Oliver, 2009). The stressful tasks used to stimulate cravings involved a cognitively challenging computer task, called the Stroop Color Word Interference Task (Renaud & Blondin, 1997), and another task in which participants were asked to unwrap but not eat a chocolate bar. In a study by Oh et al. (2013), a 15-min brisk walk in average and overweight subjects reduced both initial AB (IAB), the immediate shift in attention when chocolate was in sight (e.g. 100-500 ms), and maintained AB (MAB), the sustained attention given to chocolate for a longer period of time (e.g. 500-1000 ms). Another study reported reduced IAB in response to a 15-min bout of steady state vigorous intensity cycling exercise performed at 70%-75% of heart rate reserve (HRR) (Oh & Taylor, 2014). Unfortunately, only average weight subjects were used, limiting the ability to generalize findings to a more heterogeneous group of individuals. It has been reported that body mass index (BMI) influences AB, and that women with a higher BMI possess greater IAB to food compared with normal weight women

(Castellanos et al., 2009). Furthermore, a recent review reported that baseline AB to food cues is higher in overweight/obese compared to average weight subjects (Hendrikse et al., 2015). Therefore, examining overweight/obese individuals with a BMI ≥ 25 may provide a better understanding of the effects of exercise on AB in those individuals who may benefit most. Furthermore, previous studies have only examined continuous steady state exercise performed at low, moderate, or vigorous intensity levels. To our knowledge, no study has investigated the effects of high intensity interval exercise (HIIE) on addictive behaviors. Since HIIE has become a very popular mode of training for improving performance and cardiometabolic health in a shortened time period (Foster et al., 2015), this type of exercise may be important to include in any study examining the health benefits of exercise.

In light of the absence of studies evaluating HIIE and addictive behaviors, the present study will examine the effects of one bout of HIIE following stress inducing tasks, on affect, cravings, and IAB/MAB to chocolate in overweight/obese chocolate cravers.

Hypotheses

Hypothesis 1: A 26-min bout of HIIE will result in significantly better scores of affect than a 26-min resting condition following stress inducing tasks in overweight/obese chocolate abusers.

Hypothesis 2: A 26-min bout of HIIE will result in significantly lower craving scores than a 26-min resting condition following stress inducing tasks in overweight/obese chocolate abusers.

Hypothesis 3: A 26-min bout of HIIE will result in significantly lower AB scores to images of chocolate than a 26-min resting condition following stress inducing tasks in overweight/obese chocolate abusers .

Chapter 2: Methods

Recruitment

Participants were recruited through public messages and posted flyers on the University of Miami campus. Twenty prospective subjects responded to the flyers. All subjects were subsequently screened by telephone to ensure they met eligibility criteria for the study. Eight subjects were excluded because they did not meet the study's eligibility criteria. Reasons varied from being outside age requirements, being left-handed, not being overweight/obese, suffering from premenstrual syndrome (PMS) symptoms to failure to possessing a heightened interest in chocolate. A total of 12 participants (10 females, 2 males), mean age 30.5(7.37) years, met eligibility criteria and completed all testing and training requirements. All testing and training procedures were approved by the University of Miami Institutional Review Board, and subjects completed signed informed consent forms prior to participating in the study.

Participants

Inclusion criteria for all participants were:

- 18-45 years old
- BMI≥25
- Eat at least 3.5 oz (100g) chocolate (i.e. 2 bars/day)
- Be premenopausal
- Not suffer from PMS

- Score at least 33 out of a possible 36 on the Handedness Questionnaire to include right handed subjects only (Coren, 1992).
- No contraindications to exercise, using PAR-Q
- Score greater than 12 out of a possible 18 on interest in chocolate questionnaire (Oh & Taylor, 2013).

The questions on the interest in chocolate questionnaire were: “How would you describe the experience of eating chocolate?”; “I often have cravings for sweets”, and “I often have cravings for chocolate” using a 6-point Likert scale (1=*very unpleasant or strongly disagree*, 6= *very pleasant or strongly agree*). An upper age limit of 45 years was set to delimit women to premenopausal status and minimize risk associated with a HIIE bout when working with obese subject.

Delimitations:

This study is delimited to:

- Subjects between the ages of 18-45 years of age.
- Premenopausal subjects who are not experiencing premenstrual syndrome (PMS).
- Subjects with a BMI ≥ 25.
- Subjects who eat at least 3.5 oz (100 g) of chocolate (i.e. 2 chocolate bars) per day.

- Subjects whose total score is greater than 12 out of a possible 18 when asked about their interest in chocolate.
- Subjects who are capable of exercising based on Physical Activity Readiness Questionnaire (PAR-Q).
- Subjects who score at least 33 out of a possible 36 on the Handedness Questionnaire.
- A 3-day chocolate diary to indicate habitual chocolate consumption.
- A 24-hour dietary recall to indicate general dietary pattern.
- The Feeling Scale to indicate affective valence.
- The Felt Arousal Scale to indicate affective activation.
- The State Food Chocolate-Craving Questionnaire to indicate the existence and magnitude of chocolate cravings.
- A visual dot probe task to indicate AB to chocolate.
- The Stroop task and a chocolate handling task to elicit stress-related chocolate cravings.

Limitations:

This study is limited by:

- The use of subjects between the ages of 18-45 years old to accurately represent the adult population.

- The use of premenopausal subjects who are not experiencing premenstrual syndrome.
- The recruitment of overweight/obese subjects to indicate those individuals with increased AB to chocolate.
- The use of subjects eating 2 chocolate bars per day to indicate those individuals addicted to chocolate.
- The use of a chocolate interest questionnaire to identify subjects who are addicted to chocolate.
- The ability of the PAR-Q to accurately assess the subjects' level of readiness for physical activity.
- The use of right-handed subjects to standardize the two computer tasks.
- The ability of a 3-day chocolate diary to accurately measure habitual chocolate consumption.
- The ability of a 24-hour dietary recall to accurately measure dietary history.
- The ability of the Feeling Scale to accurately measure affective valence.
- The ability of the Felt Arousal Scale to accurately measure affective activation.
- The ability of the State Food Chocolate-Craving Questionnaire to accurately measure state chocolate cravings.

- The ability of the visual dot probe task to capture AB to chocolate.
- The ability of the Stroop task and the chocolate handling task to elicit stress-related chocolate cravings.
- The subjects' honesty and accuracy in completing the PAR-Q, the 3-day chocolate diary, the 24-hour dietary recall, the Felt Arousal Scale, the Feeling Scale, the State Food Chocolate-Craving Questionnaire, and the self-report 7-day recall measure of physical activity.
- The ability of subjects to complete all study requirements and procedures.

Study Design

A counterbalanced, within-subject randomized study was conducted on two separate days in the Laboratory of Clinical and Applied Physiology at the University of Miami to determine the effect of a single HIIE bout on affect, cravings, and AB toward chocolate.

Based on a previous study by Oh et al. (2014) showing an effect size of 1.42 with vigorous intensity exercise, we calculated our power requirements accordingly. Based on the statistical power of 0.8 and $\alpha=0.05$, we calculated that for a within-subject randomized clinical trial, a sample size of at least seven subjects would be necessary to detect differences in AB to chocolate images. To account for a large dropout rate, we aimed to recruit 12 subjects.

Procedures

Instructions

In accordance with previous study procedures, participants were instructed to record a 3-day chocolate diary and abstain from eating chocolate on the fourth day prior to reporting to testing (Oh & Taylor, 2013). They were also required to refrain from exercise, alcohol and/or caffeine 24 h before and on the mornings of the study visits. In addition, subjects were instructed to fast for 10 h (water was permitted *ad libitum*) before both visits to the laboratory for testing. Compliance was verbally confirmed upon arrival to the laboratory. Subjects were required to record everything they ate and drank on the day before and the morning of study days. Subjects were also required to list three types of chocolate they typically crave before attending the first visit. This was done to personalize their chocolate interest and improve the effectiveness of the chocolate handling task used to elicit stress and cravings for chocolate.

Shown in Figure 1 is a timeline of our study activities presented below.

Testing

Subjects reported to the laboratory at 8 AM at which time the chocolate diaries, diet records, height, weight, heart rate (HR), systolic and diastolic blood pressure (SBP and DBP) were collected. BMI was calculated as weight in kilograms/height in meters^2. Body composition was measured using the InBody 520 machine (Seoul, Korea). Subjects also completed the 7-d Physical Activity Recall Questionnaire (Sallis et al., 1985) to determine physical activity level during the past week. Subjects were then randomly assigned to start their first visit as either exercise or control condition. The interval between visits was a minimum of 24 hours and a maximum of 7 days to ensure a consistent washout period and also keep in line with similar studies (Oh & Taylor, 2013; Taylor & Oliver, 2009). At the end of study procedures, all subjects received numerical compensation along with their results for participating in the study.

Stress-Inducing Tasks

On both study visits, participants initially sat quietly for 10 min before completing a Stroop task (Stroop, 1935; Taylor & Oliver, 2009) as well as the chocolate handling task, separated by a 10 min rest period. Both tasks served to elicit stress-induced cravings. The chocolate bars presented in the latter task were tailored to the personal preferences of the participants. The stress-inducing tasks were preceded and followed by HR, SBP, and DBP measurements.

Exercise Treatment

The exercise condition consisted of a HIIE bout on a stationary bicycle ergometer beginning with a 3-min warm-up and ending with a 3-min cool-down. The exercise consisted of one min of high intensity alternating with one min of low intensity exercise repeated 10 times for a total of 20 min. The first three HIE bouts were performed at 80% of estimated maximum heart rate (80% HR_{max}), followed by four bouts at 85% HR_{max}, and finally three bouts at 90% HR_{max} (Roy, 2013). Maximum HR was estimated using an age-predicted equation: 220 minus age. The recovery intervals were performed at 45% HR_{max}. Exercise's HRs were measured continuously throughout each exercise session using a Polar F1 monitor (Polar Electro Oy, Kempele, Finland) to ensure that participants were training at the prescribed exercise intensity.

Passive Treatment

During the rest condition, participants sat quietly at a desk, instead of exercising, for the same 26 min with no electronic access, reading materials, or food related stimuli. Under resting conditions, all pre- and post-testing measurements took place in the absence of exercise. This included HR, SBP, and DBP measurements taken after the passive treatment condition.

Outcome Measures

Cravings

A validated State Food Cravings Questionnaire (FCQ-S)(Cepeda-Benito, Gleaves, Williams, & Erath, 2000), adapted for chocolate by Rodriguez et al. (2005, 2007), was administered after treatment conditions in order to measure the intensity of acute chocolate cravings. The FCQ-S includes five dimensions of three questions each for a total of 15 questions. The total score ranges from 1 to 75 with a lower score indicating greater chocolate cravings. This questionnaire has been shown to be a valid and reliable tool with a test-retest reliability of $r=0.56$ for measuring cravings (Cepeda-Benito et al., 2000).

Affect

After each treatment, the Feeling Scale (FS) was used to measure affect (Hardy & Rejeski, 1989) while the Felt Arousal Scale (FAS) was used to measure affective activation (Svebak & Murgatroyd, 1985). The FS was an 11-point scale evaluating mood ranging from -5 indicating low pleasure/displeasure to +5 indicating high pleasure/positive mood. The FAS was a 6-point scale evaluating physiological arousal ranging from +1 indicating low activation/arousal to +6 indicating high activation/arousal. The FS and FAS have been successfully used in previous studies to measure affect (Oh & Taylor, 2014).

Attention Bias

Following completion of the FCQ-S, subjects' AB was assessed on a computer using a modified visual dot probe task (Kemps & Tiggemann, 2009) with chocolate-related pictures. Neutral images consisted of office supplies images. The chocolate and office supply images were matched for their shape, size, color and luminescence. Each trial began with a central black fixation cross on a white background for 1000ms, followed by a pair of images, which were presented for either 200ms (to measure IAB) or 1000ms (to measure MAB). After five practice trials, 60 critical trials were displayed. Each block contained two buffer trials and 60 images: 20 critical pairs (chocolate/neutral images) for 200 ms, 20 critical pairs (chocolate/neutral images) for 1000 ms, 20 filler pairs (neutral/neutral images) for 200 and 1000 ms. Paired images were presented side by side but randomly displayed on the left or right. After the pair of images disappeared, a black circular dot (called a probe) appeared randomly from behind one of the previous images. The probe was displayed until a response was made. The participants were then required to respond as quickly as possible to the probe by pressing a designated key on a computer keyboard for left and right. The reaction times (RT) from the perception of the stimulus (chocolate vs. neutral images) to the mechanical response (pressing the appropriate directional key) were recorded using e-Prime software (Psychology Software Tools, Pittsburgh, PA). Incorrect responses were recorded independently of RT and were eliminated from all data analyses. Only correct responses and responses with RTs between 200 and 2000 ms or ±2SD of the mean were included in the analysis. The IAB and MAB scores were calculated by subtracting RT to probes replacing chocolate images (congruent trial) from RT to probes replacing neutral images (incongruent trial). The procedure was followed for both exercise and passive conditions.

Data Analysis

All data were analyzed using SPSS (version 25). Descriptive data of subjects' characteristics were reported using means and standard deviations (SD). Data were initially screened for normality of distribution by calculating skewness and kurtosis with values ± 2.00 deemed normal. Because the baseline values for HR and BP were normally distributed, initial paired samples t-tests were used to identify any differences between the exercise and control conditions. Repeated measures analyses of variance (ANOVA; 2 [Group] x 4 [Time]) were used to evaluate the effects for group, time, and the interaction between group and time for HR and BP.

To examine the effect of condition (exercise, control) on the three outcome measures (affect, cravings, and IAB/ MAB), normally distributed data such as FS, FCQ-S total score and dimensions two to four, IAB and MAB were analyzed using paired sample t-tests. Non-normally distributed data such as FAS and FCQ-S dimensions one and five were analyzed using Wilcoxon signed rank t-tests.

The significance level was set at $p<0.05$ for all statistical tests with Bonferroni corrections applied for all outcome measures.

Chapter 3: Results

Subjects

Subject characteristics are shown in Table 1. A total of 12 participants (two males and 10 females) with a mean (SD) age of 30.5(7.37) years ranging from 20 to 45 years participated in the study. The mean (SD) BMI of participants was 28.67(4.5) kg/m^2, however, values were as low as 25 and as high as 38.23 kg/m^2, indicating the inclusion of overweight, grade I, and grade II obesity participants. Subjects' participation in moderate and vigorous intensity physical activity in the past week averaged 6.39(7.17) hours. Baseline SBP and DBP averaged 117/76 (11/8.2) mmHg while chocolate consumption averaged 6.15(3.32) oz per day. Washout-period ranged from 1 to 7 days with a mean of 3(2.57) days.

Heart Rate and Blood Pressure Continuum

Figure 2 shows the significant interaction effect between the exercise and control conditions for HR, F (1.63, 13.01)=86.17, p <.01, η^2=.92. Upon further analysis, there was a significant increase in post-condition HR in the exercise condition compared to the control condition, F(1,8)=382.32, p<.01, η^2=.98.

Figure 3 shows the significant interaction effect between the exercise and control conditions for mean arterial pressure (MAP) (F(3,15)=17.95,p<.01, η^2=.78). Upon further analysis, there was a significant increase in post-condition MAP in the exercise condition compared to the control condition, F(1,8)=69.61, p<.01, η^2=.93.

Cravings

Figure 4 shows the mean FCQ-S scores for exercise and control conditions. A paired sample t-test revealed that the total FCQ-S score was significantly higher after the exercise condition, $t(11)=2.62$, $p<0.05$. Furthermore, Cohen's $d=1.35$, 95% CI [2.62, 30.38] indicated a large effect size. Upon further analysis, paired sample t-tests revealed that scores for dimensions two, $t(11)=2.6$, $p<0.05$, three, $t(11)=3.02$, $p<0.05$, and four, $t(11)=2.75$, $p<0.05$, were significantly higher after exercise compared to the control conditions. Related samples Wilcoxon signed rank tests revealed that scores for dimension one ($p<0.05$) were significantly higher after the exercise compared to control condition, whereas scores for dimension five (p=NS) were not significantly different between the two conditions.

Affect

As shown in Figure 5 were the affective valence and affective activation for exercise and resting conditions. Since mean scores were positive, the negative scale was not presented in figure form. For affective valence, paired sample t-tests revealed no significant differences between exercise and control conditions, $t(11)=0.72$, $p=.487$. This was supported by a small effect size, Cohen's $d=0.26$, 95% CI [-1.2, 2.37]. For affective activation, a related Wilcoxon signed-rank test indicated that physiological arousal was significantly higher in the exercise compared to the control condition, $p=0.028$. Using Pearson's correlation to calculate effect size for non-parametric statistics, $r=0.45$, indicating a medium effect size.

Attentional Bias

Shown in Figure 6 are the IAB and MAB scores for exercise and control conditions. Paired sample t-tests revealed no significant differences in IAB, $t(11)=0.41$, $p=0.692$. This was supported by a small, insignificant effect size, Cohen's $d=0.14$, 95% CI [-14.46, 21.01]. There were also no significant difference between exercise and control conditions for MAB, $t(11)=0.90$, $p=0.386$. This was, again, supported by a small Cohen's $d=0.42$, 95% CI [-19.08, 45.64].

Summary of Significant HIIE Effects on Addictive Behaviors

Shown in Table 2 are a summary of all the significant findings regarding addictive behaviors following exercise and control conditions. Our results indicate significant differences for two outcome measures related to chocolate cravings, cravings and affective activation. Cravings were significantly higher after the exercise condition compared to the control condition (46.67 versus 30.17; $p<0.05$), indicating lower desire for chocolate. Affective activation was significantly higher following exercise compared to control conditions (3.92 versus 2.08; $p<0.05$), indicating a higher level of physiological arousal. There were no significant changes in any other outcome variables related to chocolate addiction.

Chapter 4: Discussion

Chocolate snacking represents an addictive behavior preceded by worsening mood, cravings for chocolate and increased attention paid to chocolate images. In the present study, we used a HIIE bout to determine whether exercise can modify addictive markers of chocolate consumption in overweight/obese volunteers following two stress inducing tasks. The computerized Stroop task and the chocolate handling task were used to induce stress-related cravings to approximate an office environment characterized by stressful computer tasks and widespread chocolate availability. Typically one would expect both HR and BP to increase in response to stress, however, we did not observe that in our study (see Fig. 2 and 3). Research shows that stress can be experienced without increases in HR and BP using a non-verbal Stroop task (Boutcher & Boutcher, 2006). HR and BP did not change pre to post Stroop because the Stroop task used in this study did not require verbal response. This may have occurred because the motor response of regular Stroop tasks is responsible for autonomic reactivity. It is possible that speaking activates neurons in sympathetic centers to deliver metabolic support for the facial muscles that are about to be used (Boutcher & Boutcher, 2006). Thus, when facial muscles are not activated, it may reduce autonomic reactivity, i.e. no increase in HR and BP. Participants reported an average of 6.39 hours per week of moderate or vigorous physical activity, indicating a moderately active population (U.S. Department of Health and Human Services and U.S. Department of Agriculture, 2015).

Our study found a 35.3% reduction in cravings following a brief HIIE bout, which was significant. This was supported by a very large effect size, indicating that exercise was shown to result in a substantial decrease in cravings, despite a relatively small sample size. This is significant in light of the fact that a reduction in cravings signals the dissolution of habit circuits. Lower cravings are associated with reduced activity in the brain area strategic to habit learning and action initiation (Volkow et al., 2006). Specifically, a reduction in craving is mediated through a diminished release of dopamine from the substantia nigra pars compacta in the ventral striatum (Haber & Fudge, 1997) to the dorsal striatum (caudate and putamen). This has been recently reported to affect habit learning and the promotion of addictive behaviors (White & McDonald, 2002). Thus, HIIE may be used to attenuate or weaken the habit of chocolate snacking that, in the long term, may sustain an unhealthy weight. Cravings were significantly reduced on almost every measured dimension of the FCQ-S questionnaire from “an intense desire to eat” to “obsessive preoccupation with food or lack of control over eating” following the HIIE bout. In fact, only hunger (dimension 5 on the FCQ-S questionnaire) was unchanged following an HIIE bout supporting the multidimensional nature of chocolate cravings and confirming that cravings can operate independently of hunger (Rodriguez, Fernandez, Cepeda-Benito, & Vila, 2005). Although exercise tends to blunt hunger (Vatansever-Ozen, Tiryaki-Sonmez, Bugdayci, & Ozen, 2011), this typically occurs only after high intensity exercise lasting for at least one hour. Given that our HIIE was performed at 80% of estimated HR_{max} for a portion of the 26 min, this would not be long enough to blunt hunger. Our findings confirm those of previous studies using moderate exercise (i.e. brisk walking) that HIIE can reduce chocolate cravings in normal and overweight subjects in the presence of hunger (Oh & Taylor, 2013, 2014; Taylor & Oliver, 2009).

Affect may contribute to addictive behaviors as it reflects an emotional state that can predispose or shield one from impulsive behaviors. Affective activation reflects one's state of arousal with lower levels of arousal facilitating addictive snacking behaviors and higher levels blunting these behaviors. A deficit in physiological arousal is observed in those with substance use disorders who exhibit impulsive behaviors (Metcalf & Pammer, 2014). HIIE in the present study increased affective activation by 46.9%, supported by a medium effect size and an increase in our subjects' HR and BP. Both signs reinforce a greater level of arousal that confers protection against addictive snacking. In contrast, affective valence, which indicates mood, did not change as a result of HIIE, and that was supported by the small effect size observed between exercise and control conditions. Given the large variance observed for affective valence (Figure 5), it would be difficult to find significant differences. However, if the exercise is too intense, a feeling of well-being may not occur acutely (Ekkekakis, Parfitt, & Petruzzello, 2011). Since HIIE may be performed at too high an intensity, it may be considered too stressful to improve mood. Research supporting the transient hypofrontality hypothesis (Dietrich, 2006) shows that any imbalance between oxygen supply and demand in the prefrontal cortex may have adverse consequences on mood via activation of the amygdala (Ekkekakis et al., 2011). Each high intensity work interval was performed at >80% of age-predicted HR_{max}, and the repetition of 10 of these intervals in one bout may have been stressful and uncomfortable for the participants. Our results support the circumplex model of affect which proposes that affective activation can change independently of mood.

The brief HIIE bout used in this study reduced chocolate cravings and increased physiological activation, and these effects support the arousal theory of motivation. The aforementioned theory builds upon the drive-reduction theory of motivation which proposes that humans are motivated by their need to maintain biological homeostasis in their body. The arousal theory specifically focuses on maintaining an optimal level of physiological arousal and dopamine levels. It explains how changes in physiological arousal levels are potential motivators of certain behaviors that could restore the balance. For example, low levels of physiological arousal can motivate a person to consume chocolate that would increase arousal by raising dopamine levels whereas low levels of arousal would suppress sweet cravings. Thus, the individual is constantly motivated to seek an optimal level of physiological arousal to maintain dopaminergic homeostasis. This study showed that exercise can raise physiological arousal levels, thereby rendering chocolate consumption unnecessary for maintenance of optimal physiological activation. Therefore, exercise can be used instead of chocolate consumption for increasing physiological arousal and dopamine levels.

Interestingly, our study showed no effects of exercise on AB. This was supported by insignificant and small effect sizes for IAB and MAB, respectively, signifying no change in attention to chocolate. The large variances in combination with small sample size increase the chances of committing a type two error, making it more difficult to find significance. This may be due to the recruitment of subjects who were less addicted to chocolate, as people with higher dependency levels are more likely than those with lower dependency to have AB changes following exercise (Field & Cox, 2008). Since it may be less challenging for our participants to avoid thoughts about chocolate, exercise may be a less significant contributor to changes in AB. Our findings are in contrast to what has been reported by Oh (2013, 2014) showing positive effects of exercise on AB. However, those studies may have artificially increased the focus on chocolate by placing the visual dot probe task both before and after the treatment condition (exercise or quiet rest). In our study, subjects completed the visual dot probe task only once after the condition, thereby minimizing repeated exposure to chocolate images and the potential for inflating the focus on chocolate. Our procedure did not artificially inflate focus on chocolate presenting a more accurate assessment of AB to chocolate. Based on our study, AB was not influenced by exercise.

There were several limitations that should be noted in this study. First, the passive condition involved sitting quietly without any distractions. In addition to simply having a passive comparison group, there should be a third condition that includes a distraction task such as watching a video. This would have allowed a better baseline against which to compare the effects of exercise (passive condition, distraction task condition). Second, food diaries were self-reported, which may lead to inaccurate reporting of food and chocolate consumption. Requiring subjects to take pictures of their food would have provided a more accurate measure of the amount of chocolate consumed. Third, using a glucometer to check fasting blood glucose levels would have ensured subjects were fasted during the study visits. Non-fasting conditions introduce potential confounding factors to outcome variables including a decreased capacity to detect AB and craving changes. Fourth, the FAS (affective activation) and FS (affective valence) were used only once after each of the two conditions (exercise and rest) rather than being administered both before and after the stress-inducing tasks. That limited our ability to determine whether stressful tasks elicited stress-induced responses capturing acute increases in physiological arousal and negative mood states. However, it also superficially augments

AB to chocolate by increasing the focus on mood states and physiological arousal levels. Therefore, we chose to avoid the confounding influence of increased focus on mood and energy levels on AB in our study. Fifth, since there were five times as many females as males, it is possible that there was a gender effect that may have confounded our results. Although the Stroop tasks have traditionally been used to elicit stress, one would question their ability to significantly increase stress given the high amount of daily stress people tend to report in their everyday lives. The gold standard for stress induction is electric shock administration, however, we chose not to use this method of inducing stress. Finally, the distribution of the questionnaires and the visual dot probe task were administered in the same order for both exercise and seated conditions. It would be important to randomize the distribution of questionnaires and visual dot probe tasks to avoid any bias introduced by the order effect.

In summary, our findings showed that a HIIE bout can successfully reduce chocolate addiction in overweight/obese subjects. The significant reduction in cravings concomitant with higher levels of affective activation may translate into decreased consumption of calorically dense foods, e.g. chocolate, using HIIE. Given the popularity of HIIE, it would be interesting to examine different types of HIIE such as resistance interval training, sprint interval training, and Tabata on addictive behaviors. Future studies should examine the effects of chronic exercise using HIIE programs over an extended period of time for long-term management of addictive snacking behaviors. Finally, examining females and males independently may elucidate potential gender differences in addictive behaviors as a result of exercise.

Conclusion

Our study showed that exercise resulted in decreased cravings for chocolate and increased physiological arousal (affective activation). This was the first study to use HIIE as a training method for influencing addictive behaviors in an overweight/obese population. Our exercise findings may have important clinical implications for reducing addictive behaviors in vulnerable populations. Future studies may wish to examine different types of HIIE programs to better manage addictive behaviors in at risk populations.

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FIGURES

FIGURE 1. Flow diagram for study visit structure.

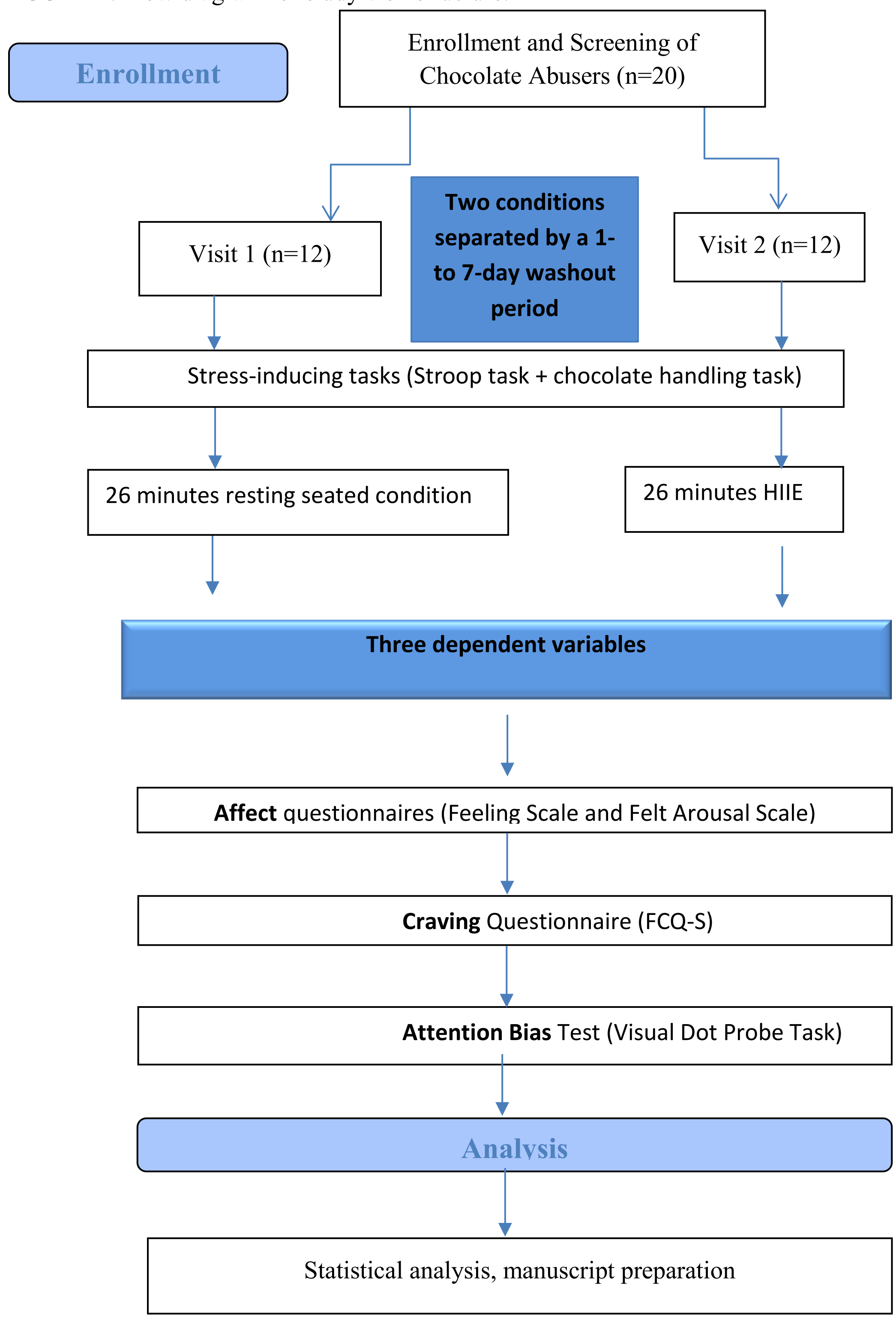


FIGURE **2.** Heart rate (HR) changes over time before and after stress inducing tasks (pre- and post-Stroop) for exercise and control conditions. *Significantly different than control condition post exercise at p<0.05.

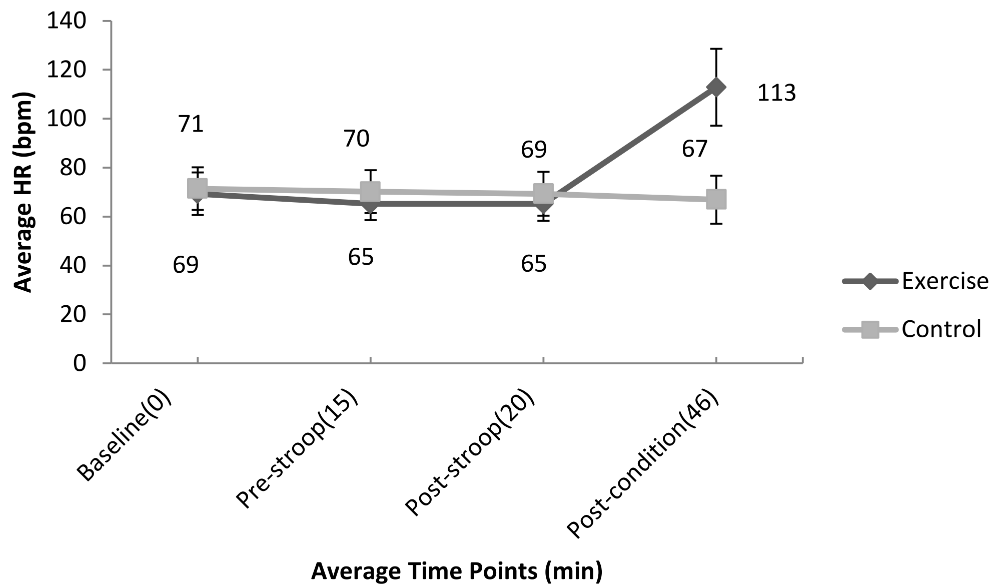


FIGURE 3. Mean arterial pressure (MAP) changes over time before and after stress inducing tasks (pre- and post-Stroop) for exercise and control conditions. *Significantly different than control condition post exercise at p<0.01.

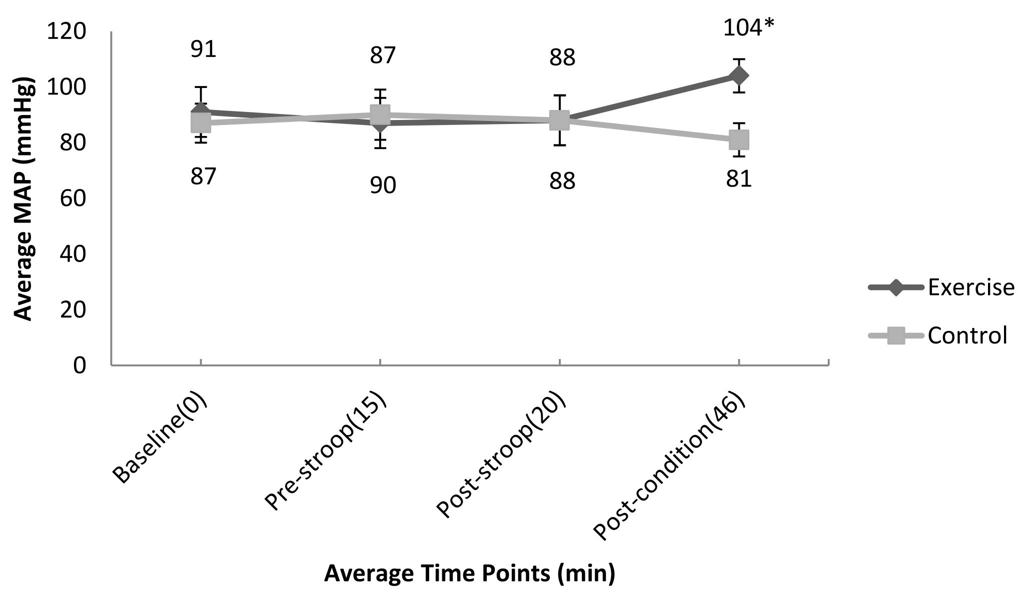


FIGURE 4. Food Craving Questionnaire-State (FCQ-S) (modified for chocolate). Scale is from 0-75, with higher scores indicating lower cravings. Dimension 1: an intense desire to eat; dimension 2: anticipation of positive reinforcement that may result from eating; dimension 3: anticipation of relief from negative states and feelings as a result of eating; dimension 4: obsessive preoccupation with food or lack of control over eating; and dimension 5: craving as a physiological state or "hunger". *Significantly different than control, p<0.05

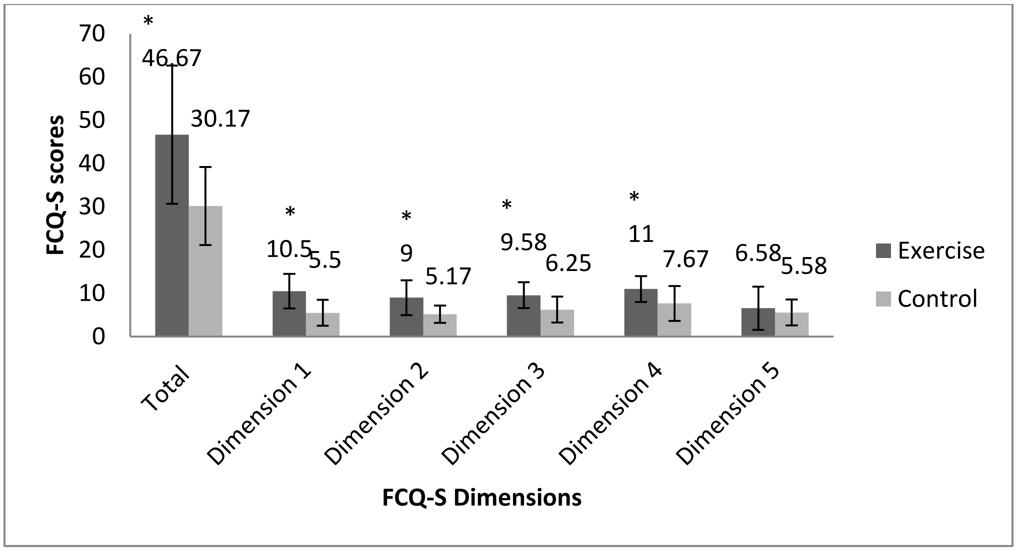


FIGURE 5. Feeling Scale (FS) and Felt Arousal Scale (FAS) scores for exercise and control conditions. *Significantly different than control, p<0.05

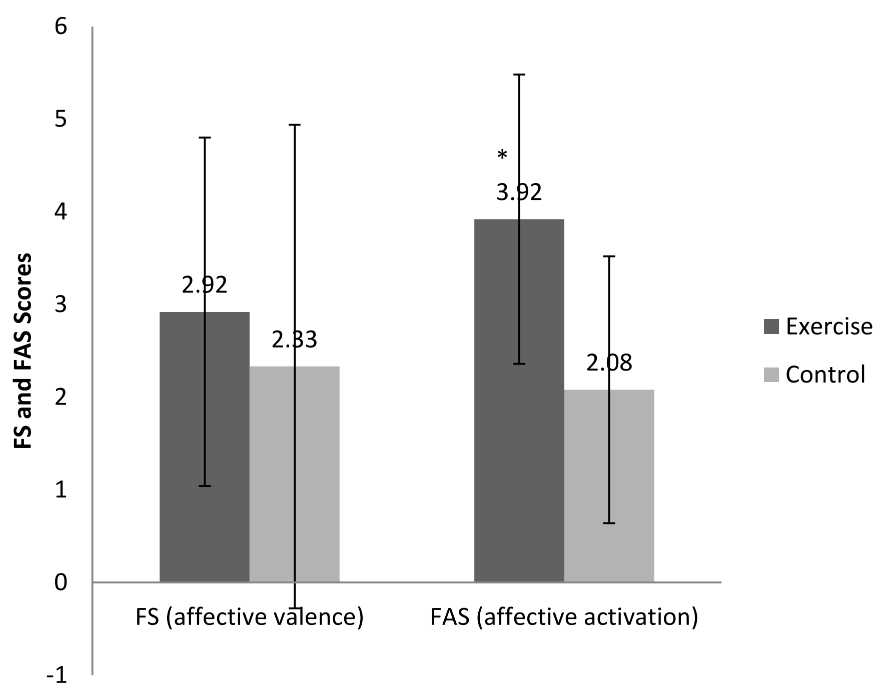
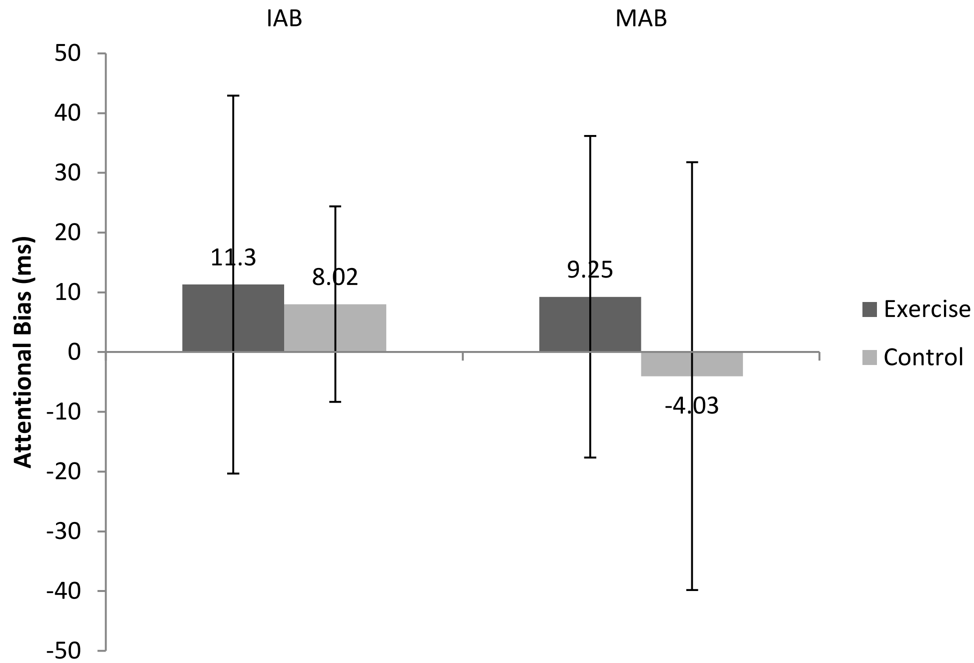


FIGURE 6. Initial attention bias (IAB) and maintained attention bias (MAB) data for exercise and control conditions.



TABLES

TABLE 1

Subject characteristics (n=12).

Variable	**Means (SD)**
Males (%)	17
Females (%)	83
Age (yr)	30.5 (7.37)
BMI (kg/m^2)	28.67 (4.5)
Body fat percentage (%)	36.17 (8.5)
Moderate and vigorous physical activity(hr/wk)*	6.39 (7.17)
Baseline mean SBP/DBP (mmHg)	117/76 (11/8)
Mean chocolate consumption (oz)	6.15 (3.32)
Mean washout-period (days)	3 (2.57)

SD, Standard Deviation

*Calculated using the 7-day physical activity recall questionnaire.

TABLE 2

Summary of Significant Effects of High Intensity Interval Exercise (HIIE) on Addictive Behaviors

	Condition	
Addictive Behaviors	HIIE	Control
Cravings[1]	46.67(15.89)*	30.17(8.6)
Affective Activation[2]	3.92(1.56)*	2.08(1.44)

[1]Cravings evaluated using FCQ-S questionnaire, examining total score ranging from 0-75.
[2]Affect evaluated using FAS, examining total score on a 1-6 Likert scale.
*$p < 0.05$