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Neuroimaging studies of factors related to exercise: Rationale and design of a 9 month trial ☆

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ABSTRACT

The prevalence of obesity is high resulting from chronic imbalances between energy intake and expenditure. On the expenditure side, regular exercise is associated with health benefits, including enhanced brain function. The benefits of exercise are not immediate and require persistence to be realized. Brain regions associated with health-related decisions, such as whether or not to exercise or controlling the impulse to engage in immediately rewarding activities (e.g., sedentary behavior), include reward processing and cognitive control regions. A 9 month aerobic exercise study will be conducted in 180 sedentary adults ($n = 90$ healthy weight [BMI = 18.5 to 26.0 kg/m^2]; $n = 90$ obese [BMI = 29.0 to 41.0 kg/m^2]) to examine the brain processes underlying reward processing and impulse control that may affect adherence in a new exercise regimen. The primary aim is to use functional magnetic resonance imaging (fMRI) to examine reward processing and impulse control among participants that adhere (exercise >80% of sessions) and those that do not adhere to a nine-month exercise intervention with secondary analyses comparing sedentary obese and sedentary healthy weight participants. Our results will provide valuable information characterizing brain activation underlying reward processing and impulse control in sedentary obese and healthy weight individuals. In addition, our results may identify brain activation predictors of adherence and success in the exercise program along with measuring the effects of exercise and improved fitness on brain activation.

1. Introduction

Exercise is recommended for weight management by virtually all public health organizations [1–4]. Adherence to an exercise routine is one of the strongest differentiators between those who are able to maintain previously lost weight and those who regain weight [5–10]. However, approximately 50% of adults who initiate an exercise program drop out during the first 6 to 12 months; a figure which has remained constant

Abbreviations: BMI, Body Mass Index; DEXA, dual energy x-ray absorptiometry; fMRI, functional magnetic resonance imaging; HW, healthy weight; NDS-R, Nutrition Data System for Research; MPA, moderate physical activity.

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since publication of the first studies on exercise adherence over 25 years ago [11–14].

Impulsivity appears to play a role in health-related behaviors (e.g., exercise) such that individuals who prefer immediately available small rewards over delayed larger rewards have difficulty making health promoting decisions that may be most beneficial in the future [15–18]. Obesity has been associated with increased levels of impulsivity, which is believed to influence unhealthy eating behavior due to the inherently reinforcing properties of food [19–21]. Obesity has also been associated with increased impulsivity and reward sensitivity [22], and measures of impulsivity have been shown to predict eating volume following fasting in obese participants [19,23]. In addition to eating behavior, evidence suggests that impulsivity plays a role in exercise adherence [24,25].

Impulsivity likely influences daily decision-making, impacting exercise behavior because sedentary activities are more immediately reinforcing than physical activities, especially among the obese [26,27]. The greater reinforcing value of sedentary activities compared to exercise may be particularly true among obese individuals because they are more likely to experience physical exertion as unpleasant. Although acute exercise typically improves affect (short-term feeling states including aspects of hedonic tone, e.g. pleasure vs. displeasure, and level of energy) an individual must be willing to endure exertion and potential negative affect *during* the exercise bout before these benefits are felt. Affect during exercise worsens with increasing intensity, and most sedentary obese individuals are inaccurate in regulating exercise intensity [28]. For example, obese women have been shown to reach relative exercise intensities much higher than expected [29] and are thus more likely to experience heightened feelings of displeasure during exercise compared to normal weight sedentary women [30]. In addition, obese sedentary adults often have more negative cognitions about exercise (e.g., lower self-efficacy; [31]), which are known to moderate the exercise–affect relationship and heighten feelings of displeasure [32,33].

Little is known regarding underlying neural mechanisms associated with exercise adherence and the relationship between the neural systems of reward and exercise adherence. Furthermore, the degree to which the ability to delay gratification is reversible in obesity is also not known. We hypothesize that brain processes, underlying reward processing, and impulse control contribute to obesity and to adherence in a new exercise regimen. We propose to scan sedentary obese and sedentary healthy weight (HW) participants with two Functional Magnetic Resonance Imaging (fMRI) tasks before and after a nine-month exercise intervention. The first fMRI task will focus on brain responses that will provide insight about the relationship between general processing of reward/punishment stimuli and exercise adherence. In this Reward Prediction paradigm, participants are scanned as they anticipate and receive predicted and unpredicted monetary rewards and punishments. The second task will focus on brain responses during impulsive decision-making (i.e., delay discounting) that will provide insight about the relationship between immediate compared to long-term decision-making (i.e., choosing a smaller monetary reward immediately versus a larger monetary reward later) and exercise adherence. Together, these tasks will characterize brain activation underlying reward processing and impulse control in individuals that adhere to exercise versus those that do not, examine differences between obese and HW individuals, identify brain activation predictors of adherence and success in the exercise program and evaluate the effects of exercise and improved fitness on brain activation. Findings from this study will have significant implications for understanding brain processing mechanisms contributing to exercise adherence, and may ultimately lead to more effective interventions.

2. Methods

2.1. Study overview

We will conduct a 9 month exercise trial with fMRI scans completed at baseline and after 9 months of exercise. We will study a sample of ($n = 180$) healthy, HW (BMI = 18.5 to 26.0 kg/m^2) and obese (BMI = 29.0 to 41.0 kg/m^2), sedentary, adult men and women (age 18-50 years). Exercise will consist of a progressive exercise prescription program that will increase in intensity and duration with a target of moderate intensity walking or jogging (75% maximal heart rate), 50 min/session, 5 days/wk. Participants will be encouraged to attend a 2–3 exercise sessions/wk in one of three private exercise rooms at different locations (on campus and off campus) with the remaining 2–3 unsupervised exercise sessions verified through downloadable heart rate monitors. Participants will be encouraged to maintain an ad libitum diet. The following variables will be assessed: height, weight, body composition (dual energy X-ray absorptiometry [DEXA], waist circumference), fitness (sub-maximal treadmill test), and dietary intake (3-day food record). Reward prediction and delay discounting will be assessed using fMRI paradigms described below. The goal of our project is to identify brain function predictors of successful exercise adherence, identify differences between normal weight and obese adults, and monitor changes in brain function as a result of exercise training (Fig. 1).

2.2. Design justification

All participants will be asked to follow a progressive exercise prescription of moderate intensity walking or jogging (75% maximal heart rate) for 50 min/session on 5 days/wk for 9 months. An exercise prescription of 250 min/wk of moderate intensity exercise was selected based on the 2009 American College of Sports Medicine (ACSM) recommendation for

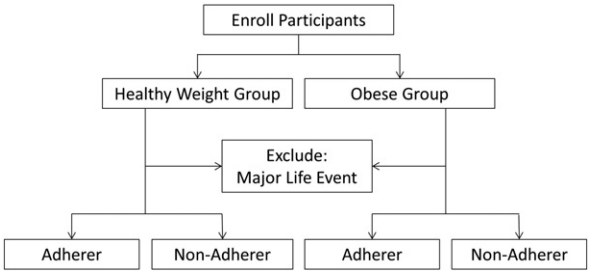

Fig. 1. Proposed participant enrollment and flow diagram.