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Original Article

Effect of different intensities of physical activity on cardiometabolic markers and vascular and cardiac function in adult rats fed with a high-fat high-carbohydrate diet

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Abstract

Background: Physical activity (PA) and diet are 2 lifestyle factors that affect cardiometabolic risk. However, data on how a high-fat high-carbohydrate (HFHC) diet influences the effect of different intensities of PA on cardiometabolic health and cardiovascular function in a controlled setting are yet to be fully established. This study investigated the effect of sedentary behavior, light-intensity training, and high-intensity interval training on cardiometabolic markers and vascular and cardiac function in HFHC-fed adult rats.
Methods: Twelve-week-old Wistar rats were randomly allocated to 4 groups (12 rats/group): control (CTL), sedentary (SED), light-intensity training (LIT), and high-intensity interval training (HIIT). Biometric indices, glucose and lipid control, inflammatory and oxidative stress markers, vascular reactivity, and cardiac electrophysiology of the experimental groups were examined after 12 weeks of HFHC-diet feeding and PA interventions.
Results: The SED group had slower cardiac conduction ($p = 0.0426$) and greater thoracic aortic contractile responses ($p < 0.05$) compared with the CTL group. The LIT group showed improved cardiac conduction compared with the SED group ($p = 0.0003$), and the HIIT group showed decreased mesenteric artery contractile responses compared with all other groups and improved endothelium-dependent mesenteric artery relaxation compared with the LIT group ($p < 0.05$). The LIT and HIIT groups had lower visceral ($p = 0.0057$ for LIT, $p = 0.0120$ for HIIT) and epididymal fat ($p < 0.0001$ for LIT, $p = 0.0002$ for HIIT) compared with the CTL group.
Conclusion: LIT induced positive adaptations on fat accumulation and cardiac conduction, and HIIT induced a positive effect on fat accumulation, mesenteric artery contraction, and endothelium-dependent relaxation. No other differences were observed between groups. These findings suggest that few positive health effects can be achieved through LIT and HIIT when consuming a chronic and sustained HFHC diet.

Keywords: High-intensity interval training; Inflammation; Light-intensity training; Metabolic syndrome; Oxidative stress; Sedentary behavior; Western diet

1. Introduction

Globally, an increasing proportion of people are consuming a diet characterized by a high intake of fat and sugar, also known as the Western diet.[1] Diets such as these increase the risk of developing the cardiometabolic syndrome[1-3] by inducing sustained increases in triglycerides, very low-density lipoprotein, and plasma glucose.[4] Cardiometabolic syndrome

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is the clustering of the following risk factors: central obesity, hypertension, insulin resistance, dyslipidemia, microalbuminuria, and hypercoagulability.[5,6] Collectively, these risk factors also increase the risk of developing cardiovascular disease and diabetes.[5]

The key risk factors for the development of cardiometabolic syndrome are low physical activity (PA) and a poor-quality diet predominantly high in saturated fat, protein, and simple sugars.[7-9] The intensity of PA occurs on a continuum from sedentary to light, moderate, and vigorous. Substantial research has documented the positive effects of moderate-to-vigorous PA (MVPA) on traditional cardiometabolic risk factors such as obesity, dyslipidemia, diabetes mellitus, and hypertension.[10,11] Recently, owing to evidence implicating inflammation and oxidative stress in the pathogenesis of cardiometabolic disease,[12] several studies have evaluated the effects of MVPA on novel risk factors and found decreases in plasma biomarkers of endothelial dysfunction (P-selectin) and inflammation (tumor necrosis factor α) following MVPA.[13-16]

Currently, there is growing interest in how time spent in activities at the lower end of the PA intensity continuum affect health relative to MVPA, because a greater proportion of the waking day is spent in these activities.[17] There is mixed evidence regarding the impact of sedentary behavior[18] and light intensity activity[19] on some cardiovascular disease (CVD) risk factors (i.e., obesity, hypertension, and dyslipidemia). However, despite the knowledge that greater total activity is better for health, there has been a trend toward overall declines in total activity[20,21] and increased sedentary behavior.[17,22] To this end, efforts to optimize health by increasing PA have led to numerous studies focused on identifying alternative approaches to MVPA.[23,24] Light-intensity training (LIT)[25,26] and high-intensity interval training (HIIT)[23] have been suggested as an alternate means of promoting PA to improve health. LIT refers to PA prescriptions that call for an expenditure of less than 40% of maximal oxygen uptake; it has been suggested that this is a more attainable target compared with continuous MVPA.[10] In contrast, HIIT involves alternating short bursts of high-intensity exercise with less-intense recovery periods requiring less time to perform than continuous MVPA.[23] Recent published data have demonstrated that both LIT[26-29] and HIIT[30-32] induce positive adaptations that may reduce cardiometabolic risks. Specifically, LIT was found to improve blood pressure in physically inactive populations with a medical condition,[19] whereas HIIT was found to improve glucose control[33] in healthy individuals and to improve insulin sensitivity and lipoproteins[34] in individuals with metabolic syndrome. In rats fed standard chow, LIT and HIIT were found to improve body weight, fat accumulation, glucose control, high-density lipoprotein (HDL) and total cholesterol (TC) levels, and mesenteric vessel contractile response.[35]

Several studies have examined the impact of low-calorie low-fat diet and PA on health and found a significant reduction in the risk of developing CVD and diabetes compared with a placebo or an educational support group.[36-39] However, although healthy diet and increased PA improve health,[40] many people in developed countries and increasingly in developing countries are becoming sedentary and are consuming significant elements of the Western diet.[41,42] Thus, it is valuable to understand how sedentary behavior and alternative activity modes such as LIT and HIIT affect cardiometabolic risk in populations consuming the Western diet. Therefore, this study aims to determine the effects of sedentary behavior, LIT, and HIIT on metabolic markers and cardiac and vascular function in male adult rats fed with a high-fat high-carbohydrate (HFHC) diet.

2. Methods

2.1. Study design and animals

All research procedures were granted prior approval by Central Queensland University (CQU) Animal Ethics Research Committee (A13/08-303) in accordance with the guidelines of the National Health and Medical Research Council of Australia. Male Wistar rats ($n = 96$) were bred and housed at CQU in an environmentally controlled room (temperature 22°C ± 1°C, relative humidity 50% ± 2%) with a 12-h light–dark cycle. Male rats were used to avoid variability caused by hormonal cycles in females as well as because of their more similar homeostatic adaptation (negative energy balance) to exercise in humans compared with female rats.[43,44] Water and standard rat chow (Riverina Stockfeeds, South Brisbane, Australia) were provided *ad libitum* for 12 weeks. After 12 weeks of aging, rats (437.8 ± 3.9 g) were randomly divided into 4 groups, each comprising 12 animals: control (CTL), sedentary (SED), LIT, and HIIT. Rats were subjected to 12 weeks of PA intervention and HFHC diet feeding in all groups. All rats at 24 weeks of age were euthanized at the end of the intervention period.

2.2. Physical activity protocol

During the 12-week intervention period, animals were subjected to each of the following PA protocols. The CTL group was housed 3 or 4 rats per standard cage with 2400 cm^2 floor area (400 cm^2/400-g rat) and was not subjected to any exercise training beyond normal cage activity. The SED group was not subjected to any exercise training and was housed 3 rats per small cage with 1080 cm^2 floor area (240 cm^2/400-g rat) to initiate a significant reduction in PA.[45] The LIT group was housed 3 or 4 rats per standard cage with 2400 cm^2 floor area (400 cm^2/400 g-rat) and ran at a treadmill speed of 8 m/min, 0% incline, for 125 min/day divided into 4 bouts (30-30-30-35 min) separated by a 2-h rest period, 5 days/week for 12 weeks.[46] The HIIT group was housed 3 or 4 rats per standard cage with 2400 cm^2 floor area (400 cm^2/400 g-rat) and was trained starting at a treadmill speed of 10 m/min, 0% incline, for 10-15 min/day, progressively increased at a speed of 50 m/min, 10% incline, divided into 4 2.5-min work bouts separated by a 3-min rest period, 5 days/week for 12 weeks (training protocol followed as described by Matsunaga et al.[47]).

2.3. Diet protocol

Rats received an HFHC diet (with 25% fructose solution incorporated in the drinking water)[48] *ad libitum* during the 12-week intervention period. The composition of this diet is listed in Table 1. Wistar rats (which are more susceptible to

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