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Novel all-extremity high-intensity interval training improves aerobic fitness, cardiac function and insulin resistance in healthy older adults

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ABSTRACT

Aging is associated with decreased aerobic fitness and cardiac remodeling leading to increased risk for cardiovascular disease. High-intensity interval training (HIIT) on the treadmill has been reported to be more effective in ameliorating these risk factors compared with moderate-intensity continuous training (MICT) in patients with cardiometabolic disease. In older adults, however, weight-bearing activities are frequently limited due to musculoskeletal and balance problems. The purpose of this study was to examine the feasibility and safety of non-weight-bearing all-extremity HIIT in older adults. In addition, we tested the hypothesis that all-extremity HIIT will be more effective in improving aerobic fitness, cardiac function, and metabolic risk factors compared with all-extremity MICT. Fifty-one healthy sedentary older adults (age: 65 ± 1 years) were randomized to HIIT (n = 17), MICT (n = 18) or non-exercise control (CONT; n = 16). HIIT (4 × 4 min 90% of peak heart rate; HRpeak) and isocaloric MICT (70% of HRpeak) were performed on a non-weight-bearing all-extremity ergometer, 4×/week for 8 weeks under supervision. All-extremity HIIT was feasible in older adults and resulted in no adverse events. Aerobic fitness (peak oxygen consumption; VO_{2peak}) and ejection fraction (echocardiography) improved by 11% ($P < 0.0001$) and 4% ($P = 0.001$), respectively in HIIT, while no changes were observed in MICT and CONT ($P \geq 0.1$). Greater improvements in ejection fraction were associated with greater improvements in VO_{2peak} ($r = 0.57$; $P < 0.0001$). Insulin resistance (homeostatic model assessment) decreased only in HIIT by 26% ($P = 0.016$). Diastolic function, body composition, glucose and lipids were unaffected ($P \geq 0.1$). In conclusion, all-extremity HIIT is feasible and safe in older adults. HIIT, but not MICT, improved aerobic fitness, ejection fraction, and insulin resistance.

1. Introduction

Aging induces cardiac remodeling and changes in cardiac function that lead to increased risk of cardiovascular disease (CVD) (Fleg and Strait, 2012). Improving aerobic fitness lowers the risk of CVD mortality (Lee et al., 2011), however, the optimal training regimen for improving aerobic fitness in older adults remains undefined. High-intensity interval training (HIIT) has been reported to have superior effects on aerobic fitness, cardiac function, lipids and glucose control compared with moderate-intensity continuous training (MICT) in patients with cardiometabolic disease (Molmen-Hansen et al., 2012; Rognmo et al., 2004; Tjonna et al., 2008; Wisloff et al., 2007). The HIIT protocol in these studies consists of 4-min intervals of high-intensity treadmill walking (usually "uphill") interspersed with periods of moderate-intensity walking. However, older adults frequently experience balance and musculoskeletal problems (Gheno et al., 2012) which limit the feasibility of weight-bearing exercise and in particular high-intensity treadmill walking. Development of an alternative exercise modality for HIIT that avoids the age-related limitations of treadmill walking is necessary for older adults. The use of a stationary cycle eliminates balance and weight-bearing concerns, and is likely to be more suitable as a long-term exercise routine for older adults. More importantly, use of an all-extremity ergometer increases the active amount of muscle mass during exercise compared to lower extremity exercise, allows compensation for unilateral or bilateral lower extremity weakness or fatigue, and ultimately affords a larger proportion of older individuals to undergo HIIT.

Therefore, we sought to evaluate the feasibility and safety of performing HIIT on a non-weight-bearing all-extremity ergometer in previously sedentary older adults. In addition, we tested the hypothesis that 8 weeks of all-extremity HIIT will be more effective in improving aerobic fitness, cardiac function, and metabolic risk factors compared with all-extremity MICT in healthy sedentary older adults.

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2. Methods

2.1. Subjects

Subjects were 55–79 years old, sedentary, non-smokers who were free of cardiovascular and other major clinical disease (e.g., diabetes, liver and renal disease) as assessed by medical history, physical examination, resting blood pressure, ECG and blood analysis (i.e., comprehensive metabolic panel, lipid panel, insulin, and complete blood count with differential). In addition, all subjects demonstrated normal ECG and blood pressure responses to a clinically-supervised diagnostic graded exercise treadmill test. Prior to study enrollment, subjects were weight stable (<5% change in body weight) for at least 6 months, were not on hormone replacement therapy (e.g., estrogen, progesterone or testosterone) for at least 2 years, and female subjects were postmenopausal for at least 2 years. Subjects who were on a stable drug regimen for lipid and blood pressure control were enrolled in the intervention, but were required not to change their use of medication during study participation.

The study was approved by the Institutional Review Board of the University of Florida and was carried out in accordance with the ethical standards of the Declaration of Helsinki. The purpose, nature and risks of the study procedures were explained to the subjects and questions were answered prior to obtaining written informed consent.

2.2. Study design

The study used a randomized controlled parallel group design which included two exercise groups (HIIT and MICT) and a non-exercise control group (CONT). Subjects were recruited and screened according to the study inclusion/exclusion criteria. Subject enrollment to the study was performed by E.M.H. who provided on site clinical support in consultation with J.W.P. Subjects who met the enrollment criteria for the intervention (n = 51) completed the baseline assessment and were then randomized to HIIT (n = 17), MICT (n = 18) or CONT (n = 16) (Fig. 1). Randomization was based on a computer random-number generator and was stratified by baseline peak oxygen consumption (VO_{2peak}, l/min). Subjects were instructed not to alter their diet during study participation. Subjects were also asked not to change their normal physical activity habits with the exception of the scheduled exercise sessions. Outcome assessments were performed at baseline and after the 8-week intervention by the same researchers while strictly adhering to established standard operating procedures. Individual subject data were coded to ensure blinding during data analysis. Study procedures and exercise training were performed at the Integrative Cardiovascular Physiology Laboratory, in the Center for Exercise Science, at the University of Florida.

2.3. Exercise intervention

Subjects assigned to HIIT and MICT performed synchronous arm and leg exercise on a non-weight-bearing all-extremity air-braked ergometer (Airdyne model AD4, Schwinn), 4 days/week for 8 weeks, under the direct supervision of an exercise physiologist. HIIT consisted of 4 × 4 minminute intervals at 90% of peak heart rate (HR_{peak}) interspersed by 3 × 3 minute active recovery periods at 70% of HR_{peak} for a total of 25 min, while MICT consisted of 32 min at 70% of HR_{peak} (Fig. 2). These specific HIIT and MICT protocols were designed by Tjonna et al. to provide equal caloric expenditure (Tjonna et al., 2008). A 10-minute warm-up and a 5-min cool-down at 70% of HR_{peak} was included prior to and at the end of each exercise session, respectively, for both HIIT and MICT as previously described (Tjonna et al., 2008). HR_{peak} was determined during the baseline maximal graded exercise test.

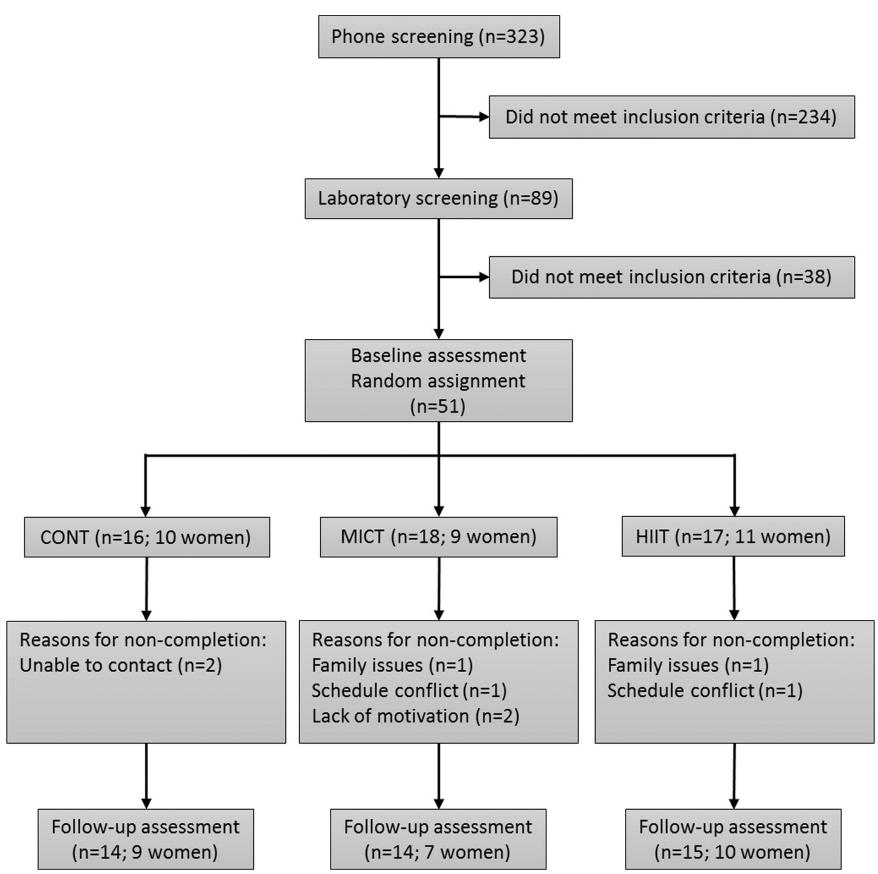

Fig. 1. Study flow chart.