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Original research

The effects of high intensity interval training on muscle size and quality in overweight and obese adults

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ABSTRACT

Objectives: Despite growing popularity of high intensity interval training (HIIT) for improving health and fitness, limited data exist identifying the effects of HIIT on muscle characteristics. The purpose of the current study was to investigate the effects of a 3-week HIIT intervention on muscle size and quality in overweight and obese men and women.
Design: Randomized controlled trial.
Methods: Forty-four overweight and obese men and women (mean ± SD; age: 35.4 ± 12.3 years; height: 174.9 ± 9.7 cm; weight: 94.6 ± 17.0 kg; %fat: 32.7 ± 6.5%) completed the current study. During baseline and post testing, muscle cross sectional area (mCSA) and echo intensity (EI) were determined from a panoramic scan of the vastus lateralis obtained by B-mode ultrasonography. Body composition variables were measured using dual energy X-ray absorptiometry. Participants were randomized into either a 1:1 work-to-rest ratio HIIT group (SIT; n = 16), a 2:1 work-to-rest ratio HIIT group (LIT; n = 19), or control (CON; n = 9). HIIT participants performed five, 2-min bouts (LIT) or 10, 1-min bouts (SIT) at 85–100% VO_{2peak} for 9 sessions over three weeks.
Results: Analysis of covariance demonstrated a significant increase in mCSA for SIT (p = 0.038; change (Δ) = 3.17 ± 3.36 cm^2) compared to CON (Δ = –0.34 ± 2.36 cm^2). There was no significant difference in EI across groups (p = 0.672).
Conclusions: HIIT may be an effective exercise modality to influence muscle size in overweight and obese individuals. Future studies should investigate muscle characteristics and remodeling in an overweight population following interventions of longer duration and varying work-to-rest protocols.

1. Introduction

The high prevalence of overweight and obesity continues to be a public health concern in the United States.[1] Overweight and obesity has been shown to increase the likelihood of developing metabolic syndrome, which is associated with cardiovascular disease, diabetes, and cancer.[2] High intensity interval training (HIIT) has gained popularity as a safe and efficient exercise method with the potential to influence several health parameters.[3] In various populations, HIIT has been shown to increase maximal oxygen consumption,[4] decrease fat mass, and increase insulin sensitivity.[5,6] Intracellularly, investigations have observed increases in skeletal muscle oxidative and buffering capacity,[7] muscle protein synthesis, and mitochondrial biogenesis[8] as a result of HIIT. Despite the aforementioned data suggesting a potential impact of HIIT on muscle remodeling and growth, there is limited data available, and none, to our knowledge, in an overweight and obese population.

Muscle characteristics, specifically muscle size and quality, have been shown to be related to muscle strength,[9,10] muscle power, and cardiovascular performance.[11] Ultrasonography is becoming a popular tool to determine muscle cross sectional area (mCSA)[12] and muscle quality as measured by echo intensity (EI).[9,10] Echo intensity, determined by the grayscale analysis of a B-mode ultrasound (US) image, estimates the amount of contractile versus non-contractile tissue, such as adipose and connective tissue, within a muscle.[13,14] Increased intramuscular fat content may lead to changes in lipid metabolism and has been shown to be related to insulin resistance and the development of type II diabetes.[15] B-mode US has reliably measured mCSA and EI in young, normal weight[16] and overweight and obese adults.[17] Previous studies have investigated the influence of resistance training interventions on muscle size[12,18] and quality,[9,18] but to our knowledge no studies

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Table 1
Descriptive characteristics for long interval training (LIT), short interval training (SIT), and control (CON) groups at baseline.

	N	Age (years)	Ht (cm)	Wt (kg)	BMI (kg/m^2)	%Fat
LIT	19	38.0 ± 12.2	176.5 ± 9.3	89.7 ± 12.3	28.8 ± 2.8	32.5 ± 6.9
SIT	16	31.4 ± 12.0	174.9 ± 9.2	97.4 ± 14.1	31.8 ± 3.9	32.6 ± 6.5
CON	9	37.0 ± 12.4	171.6 ± 11.4	99.7 ± 27.2	33.6 ± 7.2	33.4 ± 6.4
	44	35.4 ± 12.3	174.9 ± 9.7	94.6 ± 17.0	30.9 ± 4.7	32.7 ± 6.5

Mean ± SD. No significant baseline differences.

have evaluated the effects of HIIT on US mCSA and EI of the VL in an overweight population. Traditional body composition variables such as body fat percentage, lean mass and fat mass are commonly used to observe effects of an intervention, however, many of the devices used to assess the aforementioned measures such as dual-energy X-ray absorptiometry are expensive and immobile. In comparison, the US is an accessible and portable device, therefore determining the relationship of US measures and various body composition variables may increase the application of the US in clinical settings.

Previous studies have utilized HIIT interventions of varying duration (2–24 weeks), interval lengths (8 s–4 min), and work-to-rest ratios (1:1–2:1); many of which have been shown to be effective in overweight and obese populations.[5,19] During the initial stages of training, it is expected that muscular adaptations are predominantly oxidative[4]; therefore previous studies investigating the influence of HIIT interventions have primarily focused on fat mass loss, %fat, and weight loss as opposed to lean mass changes.[3,4,20] However, the increase in muscle protein synthesis reported by Scalzo et al.[8] following nine cycling HIIT sessions, warrants further investigation of muscular remodeling as a result of HIIT. The purpose of the current study was to investigate the effects of a 3-week HIIT intervention on muscle size and quality in overweight and obese men and women. Exploratory analyses evaluated the relationship between leg fat mass and EI and leg lean mass and mCSA.

2. Methods

Fifty-six overweight men and women volunteered to participate in this study. Physiological outcomes (maximal oxygen consumption, body composition, blood work) have been previously published[19,21] for this sample of participants of 'low' fitness level (10–20th percentile as defined by the American College of Sports Medicine[22]).

Of the 56 participants, 54 individuals were scanned pre and post intervention (n = 2 did not return for post testing for reasons unknown). Additionally, n = 10 scans did not show the entire fascial border due to insufficient depth of images, therefore, 44 participants were used for analysis in the current study. Descriptive characteristics are presented in Table 1. Inclusion criteria for participation included: BMI between 25–45 kg m^{-2}, 18–50 years of age, a normal resting 12-lead ECG, willing to maintain their current level of physical activity and physician clearance. Participants were excluded if they were currently participating in HIIT, had untreated hypertension, hyperlipidemia, or a history of cardiopulmonary diseases. Prior to testing, all participants signed an informed consent approved by the University's Institutional Review Board for the protection of human subjects. The content of this study is solely the responsibility of the authors; funding sources had no involvement in data collection, analysis or writing of this report.

The current study evaluated body composition and US assessments before and after a nine-session HIIT intervention. For baseline and post testing, participants arrived to the laboratory at least eight hours fasted. Upon arrival, height was measured using a portable stadiometer (Perspective Enterprises, Portage, MI, USA) and weight was measured using a mechanical scale (Detecto, Webb City, MO, USA). A panoramic ultrasound (US) scan of the vastus lateralis (VL) was performed and then assessed using ImageJ software to quantify echo intensity (EI), muscle cross sectional area (mCSA) and thigh fat thickness (THfat). Additionally, dual-energy X-ray absorptiometry (DXA) was used to determine the combined lean mass of the right and left legs (LegLM) and the combined fat mass of the right and left legs (LegFM). After baseline testing, participants performed a continuous graded exercise test (GXT) on a cycle ergometer to determine peak power output (PPO) for training intensity. Participants were then randomly assigned to one of three groups: control, short interval training (SIT) or long interval training (LIT). Baseline body composition and US testing procedures were repeated following the nine-session intervention.

A panoramic scan of the right vastus lateralis (VL) was performed using a B-mode US (Logiq-e, GE Healthcare, Wisconsin, USA). The ultrasound settings (frequency: 13 Hz, gain: 56) were kept constant to standardize mCSA and EI measures. The depth was set between 4 cm and 5 cm; in the instance an individual had greater subcutaneous fat and the entire VL was not visible at a depth of 5 cm, subject scans were removed from analysis. The depth setting remained consistent within each subject's pre and post testing scans. Prior to each scan, participants were instructed to lay supine with the right leg extended and relaxed on the examination table with a high-density foam pad strapped to the thigh at the midpoint between the femur greater trochanter and femur lateral epicondyle. A wide-band linear array ultrasound transducer probe (GE: 12L-RS) was held perpendicular to the tissue and swept across the skin at equal pressure from the lateral VL border to medial fascia separation. The same technician performed all scans, and then reviewed the initial quality of images on the US monitor.

Muscle cross sectional area and EI were determined from the panoramic scan of the VL using Image-J software (National Institute of Health, USA, Version 1.37). When analyzing images, scans with evident overlay of successive images that resulted in either detectable shadows on the image or the inability to visualize the full muscle border were removed from mCSA analyses (n = 1) and EI analyses (n = 7). Echo intensity was determined in the standard histogram function, which uses grayscale analysis of pixels ranging from 0 to 255. Prior to measuring mCSA and EI, each image was calibrated by measuring the number of pixels within a known distance of 1 cm. To measure mCSA and EI, the same technician traced the outline of the VL for each participants' scan along the fascia border as close as possible to capture only the muscle. Test–retest reliability for EI and mCSA measurements taken from a previous study in this laboratory for individuals of similar stature demonstrated an intraclass correlation coefficient (ICC) of 0.74 and 0.87, standard error of the mean (SEM) of 4.58 a.u and 2.12 cm^2, and minimal difference (MD) of 12.69 a.u. and 5.89 cm^2, respectively. Subcutaneous THfat was determined by a linear measure from the epidermal layer to the fascial border of the VL. A correction factor for subcutaneous thigh fat thickness, previously described by Young et al.,[23] was used to account for the influence THfat has on EI measures. Therefore, the following equation was used to determine EI: $y_2 = y_1 + (t \times cf)$, where y_1 = raw EI, t = THfat, cf = 40.5278, and y_2 = corrected EI.