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Increased Lean Body Mass After Bodyweight-Based High Intensity Interval Training in Overweight and Obese Men

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ABSTRACT

Purpose: The effects of 8 weeks of bodyweight exercise-based, high-intensity interval training (BWHIIT) on body composition and blood-based markers of metabolic health were investigated in overweight and obese, sedentary young men. **Methods:** In a parallel group, PRE-POST design, n = 30 men (age, 25.7 ± 4.3 y; body mass index, 27.7 ± 2.1 kg m^{-2}; 26.1 ± 5.2% body fat) were randomized to BWHIIT (n = 20) or a control group (CON; n = 10). BWHIIT consisted of supervised, group-based training sessions (~30 minutes) performed 3 times weekly. Each session consisted of 6 high-intensity bodyweight-based exercises, with each exercise being performed for 4 minutes in the manner of 8 sets of 20 seconds of exercise, 10 seconds of rest. Prior to commencing training (PRE), and 36 h after the final training session (POST), an overnight fasted blood sample was drawn, and body composition was assessed by dual-energy X-ray absorptiometry. Eighteen participants completed the intervention (CON, n = 9; BWHIIT, n = 9). **Results:** Lean body mass (LBM) was increased at POST in BWHIIT compared to CON (P = .011, η^2_p = .359), with the mean (95% confidence limits) increase in LBM from PRE to POST within BWHIIT being 1.23 (0.55, 1.92) kg. Body mass and fat mass were unchanged in both groups from PRE to POST. BWHIIT had no effect on serum concentrations of total cholesterol, HDL-C, LDL-C, triglycerides, NEFA, hsCRP, or glucose. **Conclusion:** Eight weeks of bodyweight exercise-based high intensity interval training by overweight and obese sedentary young men increased LBM by ~2%, but fat mass and blood-based markers of metabolic health were unchanged.

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Regular physical activity and structured exercise training augment health status as well as lowering the risk of developing many lifestyle-related chronic diseases (Booth et al., 2012; Pedersen & Saltin, 2015), yet sedentary lifestyles and physical inactivity levels are increasing across Westernized societies (Guthold et al., 2018). Time constraints are often cited as an important barrier to physical activity and exercise in adults (Aaltonen et al., 2012; Reichert et al., 2007; Trost et al., 2002). High-intensity interval training (HIIT) has emerged a time-efficient approach to exercise (Coyle, 2005; Gibala, 2018), and has become increasingly popular in the past decade as both an alternative and a compliment to traditional aerobic and resistance exercise training (Gibala, 2018; MacInnis & Gibala, 2017). HIIT typically describes short but intense sessions of exercise wherein the high-intensity intervals (defined as "near maximal" efforts performed at an intensity that elicits ≥80% of maximum heart rate) are repeated several times, but are separated by brief periods of active recovery of low-to-moderate intensity (Gibala et al., 2014; MacInnis & Gibala, 2017). The benefits of HIIT for reducing lifestyle-related chronic disease risk are numerous and well-established, and include increased insulin sensitivity, increased high-density lipoprotein cholesterol (HDL-C), decreased blood pressure, and increased aerobic fitness (Gibala, 2018; Kessler et al., 2012).

A seminal HIIT study described an intervention compromising of 4 minutes training sessions consisting of 7 to 8 repetitions of 20 second "work" intervals on a cycle ergometer at an approximate intensity of 170% peak oxygen uptake (VO_{2peak}) separated by 10 second "rest" intervals (Tabata et al., 1996). This protocol later became popularly known as the "Tabata protocol" (Viana et al., 2019). In that study of young physically-active men, after 6 weeks of training in this manner 5 times per week, an ~13% improvement in aerobic fitness measured by VO_{2peak} was observed, which was similar to that achieved by 30 minutes of steady-state aerobic exercise training per session in the comparator group (Tabata et al., 1996). Although HIIT is typically performed on a treadmill or exercise ergometer (e.g., cycling, rowing), a modified Tabata protocol using bodyweight-based exercises has been the subject of several studies in recreationally-active young adults (Islam et al., 2020; McRae et al., 2012; Schaun et al., 2018, 2019). For example, four weeks of training 4 times per week for 4 minutes each session produced improvements in aerobic fitness and muscular endurance of the lower body, upper body and core musculature (Islam et al., 2020; McRae et al., 2012), whereas sixteen weeks of training 3 times per week for 4 minutes each session produced improvements in aerobic fitness, ventilatory threshold, and leg power (Schaun et al., 2018, 2019).

Bodyweight training involves the use of one's own body mass as a resistive force in various exercises, and can be performed in the absence of specialized exercise equipment, and in non-traditional exercise environments such as at home (Machado et al., 2019; Souza et al., 2020). These points are salient given the call for development of HIIT protocols that require little or no equipment, and/or can be performed in

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a location of an individual's choosing (Gray et al., 2016). There is also increasing interest in "uncomplicated" and "pragmatic" approaches to resistance-type exercise training given the positive outcomes around muscle strength and lean body mass (LBM) that often result (Phillips & Winett, 2010; Tavoian et al., 2020). Bodyweight-based exercise, and/or similarly calisthenics, can be considered examples of such approaches (Gist et al., 2015; Islam et al., 2020; Kikuchi & Nakazato, 2017; Logan et al., 2016; Machado et al., 2019; McRae et al., 2012; Schaun et al., 2018, 2019; Takahashi et al., 2015), and both bodyweight training and HIIT are consistently among the most popular fitness trends of the last decade (Thompson, 2019). Bodyweight exercise-based HIIT is also notable for not requiring complex testing nor equipment to define the intensity of exercise (Souza et al., 2020).

Reducing the barriers to exercise by way of location-flexible, time-efficient, equipment-free workouts using bodyweight exercise-based HIIT may provide greater opportunity for exercise in certain populations (Machado et al., 2019), but the efficacy of this style of exercise training requires further investigation, especially in the context of improving body composition. Generally, HIIT interventions have limited effects on fat mass compared to non-exercise control groups (Sultana et al., 2019), but a recent review of the Tabata protocol noted a lack of investigations of whether this protocol can improve body composition in overweight or obese individuals (Viana et al., 2019). Therefore, the aim of this study was to investigate the effects of an 8 week bodyweight exercise-based HIIT intervention on body composition (LBM and fat mass), and blood-based markers of metabolic health in overweight and obese, sedentary young adult men.

Methods

Study design and participants

Thirty (n = 10 control, n = 20 intervention) overweight and obese, sedentary young adult men (age, 25.7 ± 4.3 y; body mass index, 27.7 ± 2.1 kg m^{-2}; 26.1 ± 5.2% body fat) were recruited for this study through advertisement posters posted on the University College Dublin campus. Sedentary lifestyle was defined as self-reporting not being engaged in more than 1 h of structured physical activity per week. Ethical approval was granted by the Human Research Ethics Committee of University College Dublin (permit number: LS-12-182-Beatty-Egan) in accordance with the *Declaration of Helsinki*. Written informed consent was obtained from all participants before enrolling in the study, including confirmation that no medication was currently being taken, and an answer of "no" to all questions on the PAR-Q health screening questionnaire.

This study employed a randomized, parallel group, PRE-POST experimental design to compare the effects of 8 weeks of bodyweight exercise-based HIIT (BWHIIT) or habitual physical activity (control group, CON) on body composition, and markers of metabolic health. The sample size was determined *a priori* based on the primary outcome of change, if any, in LBM measured by dual-energy X-ray absorptiometry (DXA). In the absence of prior research examining change in LBM in response to BWHIIT, we utilized data from our own lab that described a change in LBM (mean ± SD: control, −0.11 ± 0.70 kg; intervention, +0.93 ± 0.83 kg) in response to 12 weeks of bodyweight exercise-based traditional resistance exercise training (Krause et al., 2019). Using these data, a type I error rate (α) of 0.05, power (1-β) at 0.8, and an allocation ratio of 1:2 CON:BWHIIT, a total sample size of 22 was required (CON n = 7; BWHIIT, n = 15). The unequal allocation ratio was chosen due to the documented drop-out rate being described as high as 25% in HIIT intervention studies (Reljic et al., 2019), and therefore, we recruited a starting sample size of n = 10 for CON, and n = 20 for BWHIIT.

The principal investigator, blind to the assessments, conducted the random allocation procedure using sealed envelopes drawn from an opaque container, which contained the 1:2 distribution of CON and BWHIIT. Once an envelope had been drawn, it was not returned prior to the subsequent randomization. Participants in CON were instructed to maintain their current levels of recreational physical activity and habitual diet throughout the study, and were tested at the same time points as the intervention group. Participants in BWHIIT undertook an 8 week supervised exercise training program (~30 minute sessions, 3 days per week), and were instructed to maintain their habitual diet throughout the study. Two participants from BWHIIT withdrew prior to commencement, and 9 participants did not complete the training program for various reasons including illness, injury and scheduling conflicts (Figure 1). Additionally, one participant from CON did not return for re-testing with no reason given (Figure 1), leaving a final sample size of n = 9 for CON, and n = 9 for BWHIIT (Table 1).

Assessments

Participants reported to the Human Performance Laboratory at University College Dublin 36 h prior to commencing training (baseline; PRE), and 36 h after the final training session (POST) in order to have an overnight fasted blood sample drawn, and to have body composition assessed by DXA (Lunar iDXA, GE Healthcare, USA). Percentage body fat, LBM, and fat mass were derived from the DXA analysis. Body mass was measured to the nearest 0.1 kg using a calibrated digital scales (SECA, Germany), and height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (Holtain, UK).

Assessments took place between 0800 h and 0930 h in an overnight fasted (~10–12 h) state. Participants refrained from exercise training on the morning of these assessments, and were advised to consume 500 mL of water 2 h prior to their scheduled arrival at the laboratory. Compliance with these conditions was confirmed verbally by each participant upon arrival, and assessments took place after voiding of the bladder.

Fasted venous blood samples were taken by a qualified phlebotomist. Blood was collected in silicone-coated plastic tubes (4 mL; Plus Blood Collection Tubes; Becton Dickinson, USA). All collection tubes were pre-chilled, and blood samples were stored on ice before centrifugation at 3000 g for 15 minutes at 4°C, after which aliquots of serum were separated for storage at −80°C until later analysis. Serum

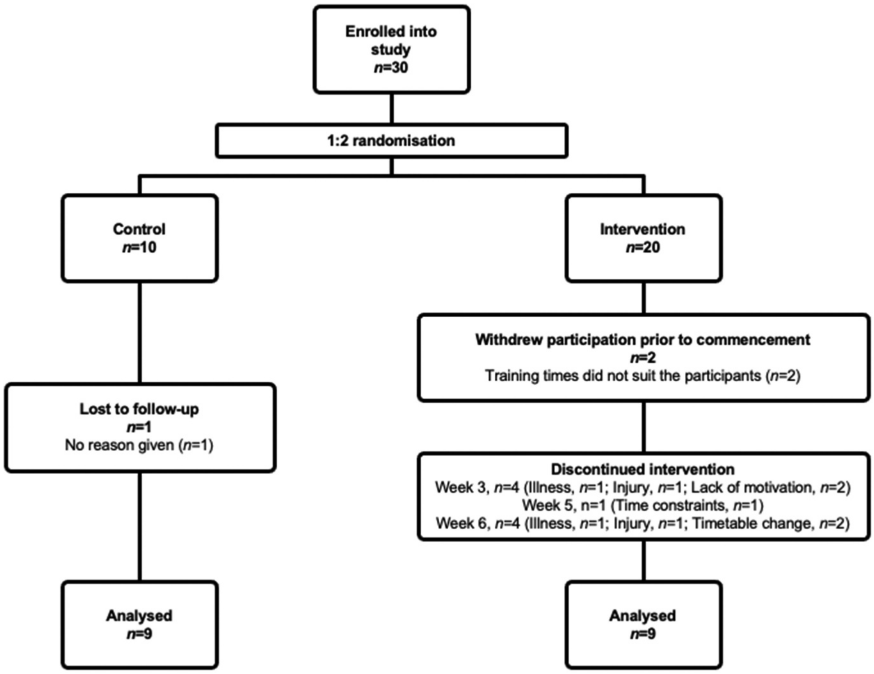

Figure 1. Flow chart of study participation.

Table 1. Participant characteristics at baseline (PRE).

	CON(n = 9) mean ± SD	BWHIIT(n = 9) mean ± SD
Age (y)	26.0 ± 3.6	25.4 ± 5.2
Height (m)	1.81 ± 0.04	1.81 ± 0.06
Body mass (kg)	92.9 ± 6.7	89.3 ± 9.2
BMI (kg m^{-2})	28.2 ± 1.9	27.2 ± 2.3
Body fat (%)	26.4 ± 4.2	25.8 ± 6.3
Fat mass (kg)	23.7 ± 4.8	22.1 ± 7.0
LBM (kg)	65.6 ± 4.8	62.7 ± 6.1

Note: BMI, body mass index; LBM, lean body mass.

concentrations of total cholesterol, HDL-C, low density lipoprotein cholesterol (LDL-C), triglycerides, non-esterified fatty acids (NEFA), high sensitivity C-reactive protein (hsCRP), and glucose were measured using the RX Daytona™ chemical autoanalyzer and appropriate reagents as per the manufacturer's instructions (Randox Laboratories, UK).

BWHIIT intervention

The training program took place in a group setting in gym facilities in the School of Public Health, Physiotherapy and Sports Science at University College Dublin. All training sessions were supervised by the researchers, and an attendance log was completed after each session. Each training session consisted of six bodyweight-based exercises with each exercise performed at high intensity for 4 minutes in the manner of 8 sets of 20 seconds of exercise, 10 seconds of rest ("20 on:10 off") (Figure 2), which is popularly known as a "Tabata protocol" based on the eponymous first author of the study that first described this work-to-rest ratio (Tabata et al., 1996). Exercise intensity was self-determined with the goal of completing as many repetitions as possible with good form within the allotted 20 second time period. Verbal encouragement was provided by the researchers during each set of each exercise including counting of repetitions and providing reminders and/or targets of numbers of repetitions completed in previous sets and sessions.

Thus, one set of a specific exercise took 4 minutes to complete (Figure 2). One minute of rest was taken before proceeding to the next exercise. The exercises performed were as follows: Mountain Climbers, Bodyweight Squats, Push-ups, Garhammer Raises, Overhead Tripod Extensions, and Bodyweight Lunges. The exercise order therefore consisted of exercises that were whole-body anterior chain, lower limb-dominant, upper limb-dominant, core musculature, whole-body posterior chain, and lower limb-dominant, respectively. Given the population being studied, the selection of exercises factored in a minimal skill requirement for the execution of each movement, in addition to being low impact in contrast to exercises such as Burpees and Jumping Jacks that have been used in previous BWHIIT studies in recreationally-active non-obese populations (Islam et al., 2020; McRae et al., 2012; Schaun et al., 2018, 2019). Each exercise training session (23 in total) therefore totaled ~30 minutes with 5 additional minutes allocated each for a low-to-moderate intensity warm-up and cool-down.

Due to the intense nature of the exercise protocol, and the participants' sedentary lifestyle, a gradual progression was built into the training intervention. None of the participants were familiar with performing HIIT or BWHIIT prior to commencing the study. Therefore, all participants completed a familiarization session to learn the appropriate technique for each exercise. In the first training session, participants performed four sets (i.e., 2 minutes) of each of the six exercises, with the number of sets being increased by one set per exercise every second session until the desired eight sets per session were achieved, i.e., by the ninth training session participants were completing the full complement

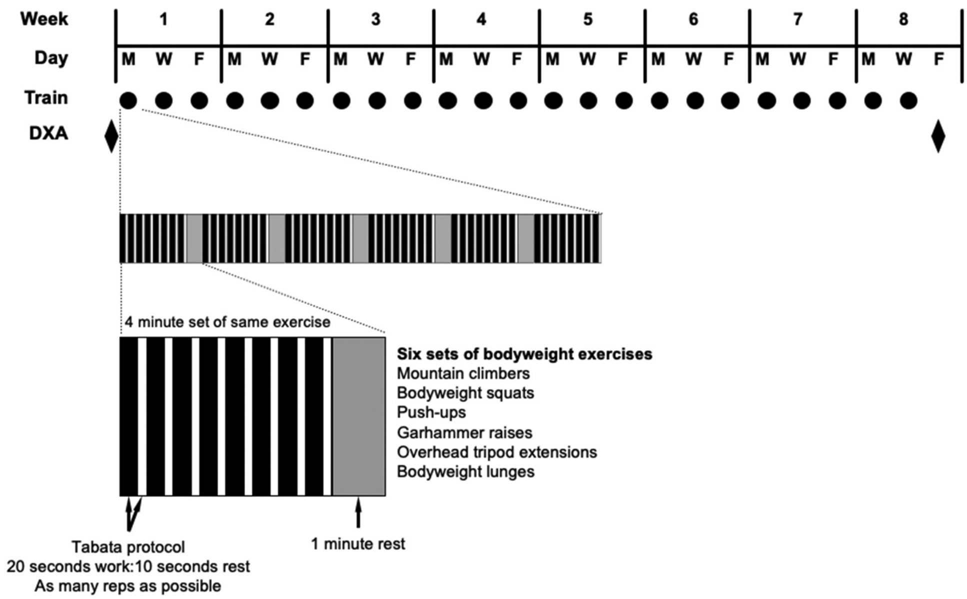

Figure 2. Study design schematic. DXA, dual-energy X-ray absorptiometry; F, Friday; M, Monday; W, Wednesday.

of eight sets of each exercise in each session. Participants maintained this number of sets until the end of the exercise training intervention.

Statistical analysis

Data were analyzed using Jamovi v1.2 (The Jamovi Project, Australia), and illustrated using GraphPad Prism v8.4 (GraphPad Software, Inc., USA). Descriptive statistics are reported as mean ± standard deviation (SD), with data for the difference from PRE to POST presented as mean difference (lower, higher 95% confidence limits of the mean). Normality of data was assessed with the Shapiro–Wilk normality test for which all data passed. Changes, if any, in response to the intervention were assessed using a one-way analysis of covariance (ANCOVA) with the pre-intervention value for a parameter of interest as a covariate, and estimated marginal means at POST reported as mean ± standard error (SE). Estimates of effect size from the ANCOVA analysis were determined using partial eta squared (η^2_p) with thresholds of ≥0.0099, ≥0.0588, and ≥0.1379 interpreted as *small, moderate* and *large* effects, as recommended by Cohen (Cohen, 1969), and discussed elsewhere (Richardson, 2011). Between-group differences in percentage change from PRE to POST were assessed using an independent samples t-test. Standardized differences in the mean were used to assess magnitudes of effects within and between groups, with effect sizes calculated as Cohen's d and interpreted as *trivial* for <0.2, *small* for ≥0.2 to <0.5, *moderate* for ≥0.5 to <0.8, and *large* for ≥0.8 (Cohen, 1969). For null hypothesis statistical testing, the significance level was set at $P \leq 0.05$ for all tests.

Results

Compliance with the training intervention as assessed by training attendance was 20.9 ± 1.6 of the organized 23 sessions (90.8 ± 7.0%), with a range of 18 to 23 sessions completed.

After adjustment for values in the respective parameters at PRE, body mass (mean difference ± SE, 0.59 ± 0.77 kg; $P = .45$, $\eta^2_p = .038$) (Figure 3a,b), fat mass (mean difference ± SE, −0.12 ± 0.51 kg; $P = .82$, $\eta^2_p = .004$) (Figure 3c,d), and percentage body fat (mean difference ± SE, −0.61 ± 0.39%; $P = .13$, $\eta^2_p = .143$) were not different at POST in BWHIIT compared to CON.

However, LBM was significantly increased at POST in BWHIIT compared to CON (mean difference ± SE, 1.32 ± 0.46 kg; $P = .011$, $\eta^2_p = .359$) (Figure 3e). The mean (95% CL) increase in LBM from PRE to POST within BWHIIT was 1.23 (0.55, 1.92) kg, which was equivalent to percentage change from PRE of 2.0 (0.9, 3.1)% ($P = .005$, $d = 1.51$) (Figure 3f).

The BWHIIT intervention had no effect on any of the parameters measured in serum, namely total cholesterol, HDL-C, LDL-C, triglycerides, NEFA, hsCRP, and glucose (Table 2).

Discussion

This 8-week intervention comprising of bodyweight exercise-based, high-intensity interval training (BWHIIT) by overweight and obese, sedentary young adult men resulted in an ~2% increase in LBM, but did not result in changes in fat mass or blood-based markers of metabolic health.

Despite the popular interest in both bodyweight-based exercise training and HIIT (Thompson, 2019), and recommendations for the application of BWHIIT as a training modality (Machado et al., 2019; Souza et al., 2020), only a handful of studies have investigated fitness outcomes in response to this style of training (Gist et al., 2015; Islam et al., 2020; McRae et al., 2012; Schaun et al., 2018, 2019). In recreationally active women, 4 weeks of training 4 times per week for 4 minutes each session of BWHIIT utilizing the Tabata protocol (4 minutes of alternating 20 seconds work, 10 seconds rest) improved muscular endurance of the lower body, upper body and core musculature, and improved aerobic fitness measured as VO_{2peak} by ~8% (McRae et al., 2012). Similar responses for muscular

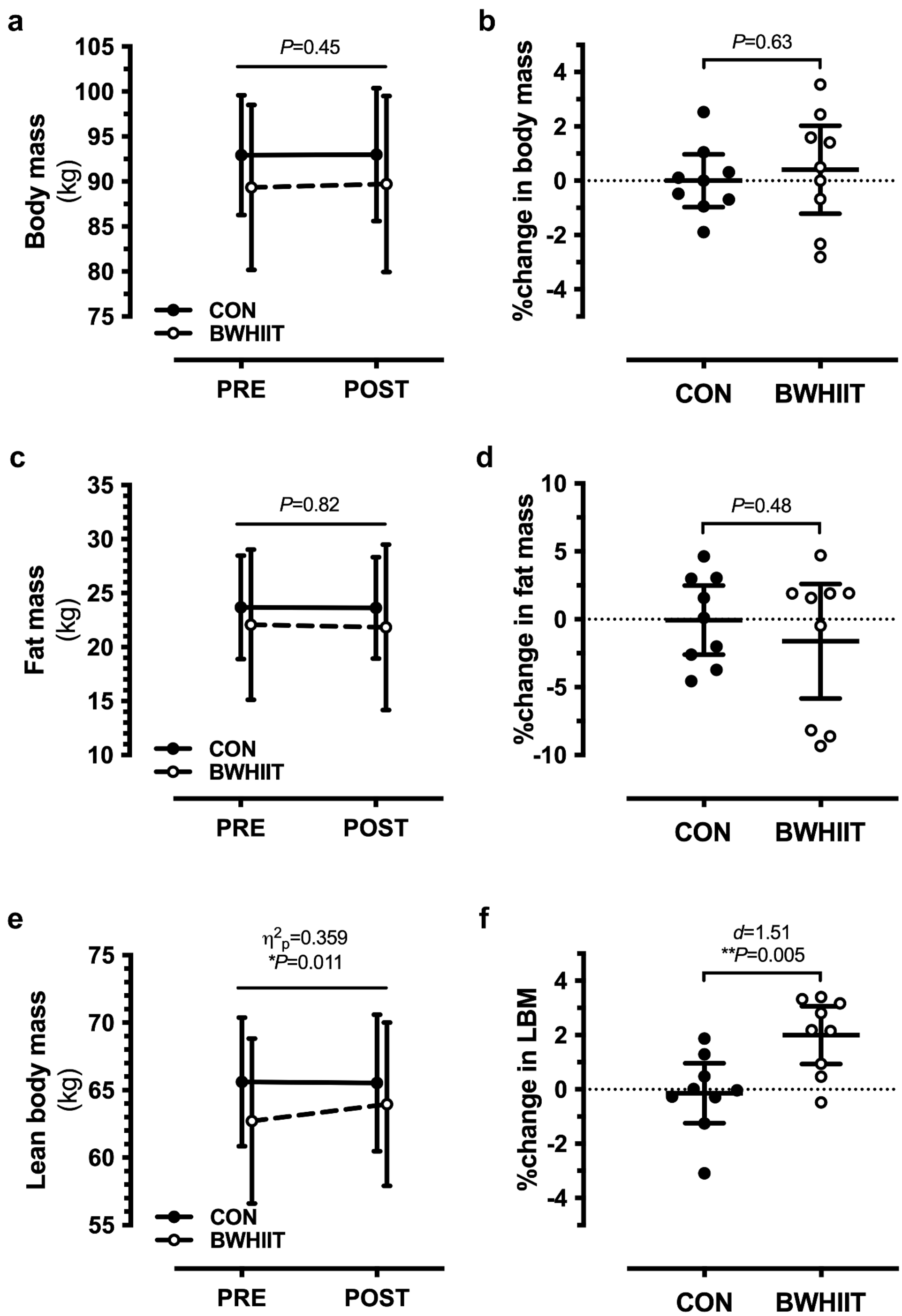

Figure 3. Changes in body mass and body composition after 8 weeks of bodyweight exercise-based high intensity interval training (BWHIIT) or habitual activity (CON). Body mass at PRE and POST (a), and percentage change in body mass between PRE and POST (b) for each group. Fat mass at PRE and POST (c), and percentage change in fat mass between PRE and POST (d) for each group. Lean body mass (LBM) at PRE and POST (e), and percentage change in LBM between PRE and POST (f) for each group. Data are presented as mean values with error bars representing standard deviations (a, c, and e) or 95% confidence intervals (b, d, and f). Circles represent individual data points from the respective groups.

endurance were observed when the same protocol was applied in a larger cohort of recreationally-active men and women, with the additional observation of an improvement in 5 km running time-trial performance (Islam et al., 2020). Improvements in aerobic fitness, ventilatory threshold, and leg power in recreationally-active men were reported by an independent group, again using the same BWHIIT Tabata protocol performed once per session 3 times per week for 16 weeks (Schaun et al., 2018, 2019). However, in male and female members of a university Army Reserves' Officers Training Corps, 4 weeks of training 3 times per week with each session involving 4 to 7 sets of 30 seconds "all out" burpees and each set separated by 4 minutes of recovery did not alter VO_{2peak} or performance in the Army Physical Fitness Test (Gist et al., 2015).

In contrast, rather than investigating fitness and performance outcomes, the present study investigated the effect of BWHIIT on changes in body composition and blood-based markers of

Table 2. Blood-based markers of metabolic health measured in fasting serum collected before (PRE) and after (POST) 8 weeks of bodyweight exercise-based high-intensity interval training (BWHIIT) or habitual activity (CON).

	CONPRE mean ± SD	CON POST mean ± SD	BWHIITPRE mean ± SD	BWHIITPOST mean ± SD	Adjusted CON POST mean ± SE	Adjusted BWHIIT POST mean ± SE	ANCOVA *P* value
Total cholesterol	4.47 ± 0.80	4.57 ± 0.77	4.73 ± 1.18	4.41 ± 0.85	4.66 ± 0.20	4.35 ± 0.18	0.27
HDL-C	1.27 ± 0.15	1.20 ± 0.08	1.28 ± 0.16	1.02 ± 0.39	1.21 ± 0.10	1.01 ± 0.09	0.17
LDL-C	1.34 ± 0.32	1.58 ± 0.35	1.56 ± 0.66	1.65 ± 0.49	1.66 ± 0.10	1.59 ± 0.09	0.62
Triglycerides	0.84 ± 0.29	1.03 ± 0.38	1.76 ± 1.49	1.27 ± 1.04	1.33 ± 0.20	1.03 ± 0.18	0.30
NEFA	0.54 ± 0.47	0.76 ± 0.62	0.51 ± 0.20	0.70 ± 0.46	0.76 ± 0.21	0.70 ± 0.18	0.84
hsCRP	2.64 ± 3.81	1.70 ± 1.56	1.67 ± 1.51	3.55 ± 5.45	1.81 ± 1.86	3.64 ± 1.52	0.46
Glucose	5.11 ± 0.35	5.28 ± 0.80	5.40 ± 0.15	5.13 ± 0.25	5.29 ± 0.24	5.11 ± 0.21	0.60

Note: HDL-C, high density lipoprotein cholesterol; hsCRP, high sensitivity C-reactive protein; LDL-C, low density lipoprotein cholesterol; NEFA, non-esterified fatty acids; SD, standard deviation; SE, standard error. Mean ± SE refers to adjusted means from the ANCOVA analysis, which represent estimated marginal means controlling for the value at PRE for a given parameter as a covariate.

metabolic health in overweight and obese, sedentary young adult men. Notably, we also employed a larger training stimulus by utilizing the Tabata protocol for 6 exercise bouts per session rather than 1 exercise bout as done in previous studies (Islam et al., 2020; McRae et al., 2012; Schaun et al., 2018, 2019; Tabata et al., 1996). Although we did not objectively monitor exercise intensity in the present study, the high-intensity nature of this type of training was previously demonstrated when one 4 minute bout of a Tabata protocol using bodyweight exercises produced an average heart rate (HR) of 131 ± 10 bpm, and peak HR of 170 ± 9 bpm, and thereby resulting in an average intensity of 87 ± 6%HR_{peak} (Schaun & Del Vecchio, 2018).

We observed that our model of BWHIIT resulted in an increase in LBM of 1.23 (0.55, 1.92) kg, with the magnitude of this effect being "large" (d = 1.51), but BWHIIT did not result in a change in fat mass. Previous studies of HIIT that have examined changes in body composition have predominantly used cycling and running modalities for HIIT, and considerable variability in the response of LBM and fat mass has been observed (Sultana et al., 2019). For instance, in a similar demographic cohort to the present study 12 weeks of 3 × 20 minutes per week of cycling HIIT in overweight men resulted in an increase of ~1.2 kg in fat-free mass (Heydari et al., 2012), but a recent meta-analysis found there to be no overall effect of HIIT interventions on LBM compared to non-exercise control groups (Sultana et al., 2019). The present study protocol, by being whole-body resistance-type exercises, is a different stimulus compared to these exercise ergometer-based modalities for HIIT described in that meta-analysis (Sultana et al., 2019). Our data suggest that ~30 minutes of BWHIIT is a training approach that can result in an increase in LBM when performing HIIT. A mechanistic basis to explain the increase in LBM is that BWHIIT is a training protocol that includes a number of features proposed to influence the hypertrophic response to exercise (Schoenfeld, 2010), namely moderate-to-fast concentric contractions, moderate mechanical tension, high metabolic stress, a high volume of repetitions, and some sets being performed to concentric failure.

The beneficial implications of increasing LBM by such training are underscored by the importance of the development and maintenance of skeletal muscle across the life course (Wolfe, 2006). Specifically for overweight and obese individuals like the present cohort, benefits may be accrued by the mitigation of loss of LBM during a weight loss period (Cava et al., 2017). In older adults, an increase or maintenance of LBM is important in relation to offsetting age-related declines in skeletal muscle mass and function, and their associated increased risk of falls and fractures, impaired functional ability and loss of independence (Cruz-Jentoft et al., 2019). Whether this type of training is suitable for such populations, and whether similar outcomes for LBM would be observed, may be the subject of future research, but our previous work has already established that bodyweight-based traditional resistance exercise training can increase LBM in middle-aged and older adults (Krause et al., 2019).

The present study did not, however, observe any change in fat mass in response to BWHIIT. A recent review specifically examining studies of the Tabata protocol concluded that the use of this approach to promote weight loss is not substantiated (Viana et al., 2019). Moreover, a meta-analysis of studies that have measured fat mass found there to be no overall effect of HIIT interventions on fat mass compared to non-exercise control groups (Sultana et al., 2019). The majority of these studies, and the present study, have not included a dietary co-intervention to support HIIT. This is notable because it is generally accepted that dietary co-interventions are needed in order for exercise to result in meaningful changes in fat mass in overweight and obese adults (Donnelly & Smith, 2005; Garrow & Summerbell, 1995; Miller et al., 1997). Additionally, analysis of fasted serum samples in the present study demonstrated the absence of an effect of BWHIIT on blood-based markers of metabolic health. A reduction in body mass in the form of fat mass may be necessary for improvements blood-based markers such as lipid profile (Leon & Sanchez, 2001), and therefore, the lack of change in fat mass herein may, in part, explain this outcome.

This study used an *ad libitum* approach to dietary control whereby participants were encouraged to continue their habitual diet as the aim was to evaluate the effect of BWHIIT, rather than a co-intervention with dietary change. However, the lack of dietary monitoring can be considered a limitation of the present study, and dietary monitoring or intervention should be included in future research that focuses on body composition and/or blood-based markers of metabolic health. Exercise results in greater total daily energy expenditure, and can in turn result in compensatory behaviors that modulate the progression of change in body mass (Dorling et al., 2018; King et al., 2012). Therefore, future work should also investigate whether the observed increase in LBM, or lack of change in fat mass, are due to compensatory behavioral changes affecting energy intake or expenditure, or intrinsic adaptations to the stimulus provided by BWHIIT.

A limitation of this study is that the sample size of participants completing the intervention (n = 9) is underpowered relative to the *a priori* sample size required (n = 15 for BWHIIT), despite the finding of a statistically significant increase in the primary outcome of LBM. Low statistical power due to the small sample size may have resulted in this analysis being underpowered for null hypothesis statistical testing of other changes in body composition and blood-based markers of metabolic health, but it is also possible that this training intervention is simply not efficacious for reducing body fat or improving metabolic health. Moreover, because there are between-sex differences in aspects of physiology relevant to adaptation to exercise training (Ansdell et al., 2020; Smith & Mittendorfer, 2016), the lack of inclusion of female participants is a limitation, and results herein should not be extrapolated to females without caution.

The reason for the small sample size in BWHIIT was due to 11/20 not completing the intervention. Not all cases of non-completion of the intervention can be attributed to drop-out due the exercise training protocol itself, as university timetabling issues accounted for five of eleven drop-outs. This is unsurprising given that university students often cite time constraints as an important barrier to physical activity and exercise (Ebben & Brudzynski, 2008; Gómez-López et al., 2010). However, a drop-out rate of 6/20 attributable to the BWHIIT intervention itself (i.e., illness, injury, lack of motivation) is notable in that it is consistent with the rate of drop-out from other HIIT interventions reported as being as high as 25% (Reljic et al., 2019). Indeed, the real-world effectiveness (e.g., unsupervised) of this BWHIIT protocol, and indeed other HIIT protocols, remain to be explored (Gray et al., 2016). For example, when HIIT was undertaken in an unsupervised manner by overweight and obese men and women, adherence declined rapidly from 0 to 6 months such that over the course of 12 months, only 23% of participants adhered to 3 sessions of HIIT per week (Roy et al., 2018). Relatedly, the fact that the present study was fully supervised and sessions were performed in a group setting should be acknowledged as an important dynamic. Group-based exercise training typically leads to greater adherence than individual exercise training programs (Dishman & Buckworth, 1996), and within training sessions, the group dynamic can often lead to increased motivation and performance of exercises (Hill, 2019). Verbal encouragement is also known to increase performance in demanding exercise tasks (Engel et al., 2019), but would be absent in an unsupervised setting.

In conclusion, an 8 week bodyweight exercise-based, high intensity interval training intervention performed for ~30 minutes per session on 3 days of the week produced a positive effect by way of an ~2% increase in LBM, but did not result in changes in fat mass or blood-based markers of metabolic health. The increase in LBM in this cohort of overweight and obese men compliments previous observations of the effect of BWHIIT to improve aerobic fitness (albeit those observations were made in recreationally-active non-obese men and women). BWHIIT protocols may aid in overcoming the commonly cited barriers to exercise including time constraints, and cost of or lack of facilities and equipment, and thereby facilitate a home-based application of exercise training to produce associated health benefits. The absence of effect on fat mass suggests that future work could explore the effects of dietary co-intervention to target a reduction in fat mass, as well as the efficacy of this BWHIIT protocol, or appropriate modifications of this protocol, in populations ranging from children to older adults.

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Author contributions

JFT, AB, and BE conceived the study; AB, CS, AI, and CC collected the data; JFT, AB, CS, AI, CC, and BE analyzed the data and interpreted the results; JFT and BE wrote the first draft of the manuscript; All authors reviewed and contributed to the final manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

Disclosure statement

No potential conflict of interest was reported by the authors.

Ethical review approval

Ethical approval was granted by the Human Research Ethics Committee of University College Dublin (permit number: LS-12-182-Beatty-Egan) in accordance with the *Declaration of Helsinki*. Written informed consent was obtained from all participants before enrolling in the study, including an answer of "no" to all questions on the PAR-Q health screening questionnaire.

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