Run sprint interval training induces fat loss in women

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ABSTRACT

There are limited data on whether sprint interval training (repeated super-maximal intensity, short duration exercise; SIT) affects body composition and what is available suggests that men respond more favourably than women. Moreover, most SIT data involves cycling exercise and running may differ due to the larger muscle mass involved. Further, running is a more universal exercise type. This study assessed whether running SIT can alter body composition (air displacement plethysmography), waist circumference (WC), VO_{2max}, peak running speed, and/or the blood lipid profile. Fifteen recreationally active women (22.9±3.6 y; 163.9±5.1 cm; 60.8±5.2 kg) completed 6 weeks of running SIT (four to six, 30 sec 'all-out' sprints on a self-propelled treadmill separated by 4 min rest performed 3 times per week). Training decreased body fat mass by 8.0% (15.1±3.6 to 13.9±3.4 kg; P=0.002) and WC by 3.5% (80.1±4.2 to 77.3±4.4 cm; P=0.048) while increasing fat-free mass by 1.3% (45.7±3.5 to 46.3±2.9 kg; P=0.05), VO_{2max} by 8.7% (46±5 to 50±6 $ml \cdot kg^{-1} \cdot min^{-1}$), and peak running speed by 4.8% (16.6±1.7 to 17.4±1.4 kph; P=0.026). There were no differences in food intake (assessed by a 3-day food records; P>0.329) or blood lipids (P>0.595), except for a slight decrease in high-density lipoprotein concentration (1.34±0.28 to 1.24±0.24 $mmol \cdot L^{-1}$; P=0.034). Running SIT is a time-efficient strategy to decrease body fat while increasing aerobic capacity, peak running speed, and fat-free mass in healthy young women.

Key words: body composition; female; high-intensity interval training; body fat; lean mass

Introduction

Currently a high percentage of Canadians are overweight or obese due in part to a lack of physical activity. To achieve health benefits, the Canadian Physical Activity Guidelines for adults (18-64 years of age) recommend 150 minutes per week of moderate to vigorous-intensity aerobic physical activity, in bouts of 10 minutes or more as well as some muscle and bone strengthening activities using major muscle groups, at least 2 days per week (Tremblay et al. 2011). Although most appreciate the health benefits of regular physical activity, few meet this recommendation and lack of time is the often-cited reason (Kimm et al. 2006, Reichert et al. 2007, Stutts 2002, Trost et al. 2002). As a result, many could benefit from a time efficient exercise modality, especially one that will reduce body fat and/or to improve cardiovascular fitness.

Sprint interval training (SIT) involves repeated, 30-second “all-out” exercise efforts, typically on a cycle ergometer, in which the power output rises quickly and then decreases precipitously over the 30 seconds (Gibala et al. 2006, Hazell et al. 2010). This type of exercise can be distinguished from more conventional high-intensity interval exercise (HIT) because the intensity with SIT is much greater, typically ‘all-out’, i.e., super-maximal, and the durations are much shorter (10-30 sec). A recent review suggests a need for consistency of terminology with regards to interval training which will be important in future research (Weston et al. 2013). Importantly, SIT results in similar training and performance adaptations as both HIT and traditional endurance training, including increased VO_{2max}, improved time trial performance, and increased peak power but with a much reduced time commitment (Burgomaster et al. 2006, Burgomaster et al. 2008, Gibala et al. 2006, Helgerud et al. 2007, MacPherson et al. 2011, Nybo et al. 2010, Trapp et al. 2008). Although HIT has been shown to produce a number of positive

health benefits including improved insulin sensitivity (Hood et al. 2011, Metcalfe et al. 2012, Tjonna et al. 2013, Trapp et al. 2008), cardiac function (Sijie et al. 2012), blood lipid profile (Tjonna et al. 2013), and fat oxidation (Astorino et al. 2013), to date any health benefit focus of SIT has been on insulin sensitivity primarily (Babraj et al. 2009, Gillen et al. 2012, Little et al. 2011, Richards et al. 2010, Sandvei et al. 2012, Whyte et al. 2010). Consequently, there has been much less study of the effects of SIT on more general health measures such as body composition and/or cardiovascular disease markers and there is a dearth of information available on exercise modes other than cycling.

Interestingly, some studies have demonstrated HIT can improve body composition in both normal (Trapp et al. 2008, Tremblay et al. 1994) and overweight (Gillen et al. 2013, Heydari et al. 2012, Sijie et al. 2012) participants although others found no improvement in normal weight participants (Nybo et al. 2010, Tjonna et al. 2013). Two SIT studies have demonstrated no changes in body mass (Burgomaster et al. 2008, Hazell et al. 2010) and one reported no change in skinfold fat measures (Astorino et al. 2011), although these studies were only over 2 weeks where changes in body mass or composition would not be expected. Further, skin fold measures may not be sensitive enough to detect changes in body composition (Sillanpaa et al. 2013). In contrast, we have shown that 6 wk of running SIT reduced fat mass by 12.4% (MacPherson et al. 2011). This suggests that body mass (and perhaps skinfold fat) measures are inadequate to assess body composition changes and/or that running SIT is somehow different than cycling. Further, of 10 participants in our SIT group, only the men (n=6) lost body fat (3.3 kg) and did so in the absence of changes in dietary intake (MacPherson et al. 2011). Consequently, sex differences may exist with respect to the effects of SIT on body fat loss but the wide range of body fatness and the small number of women (n=4) in the SIT

group in this study (MacPherson et al. 2011) may have biased these observations. Of course, any beneficial changes in body composition with SIT would enhance its value for many struggling with overweight and obesity.

Therefore, the purpose of this study was to revisit our previous running SIT work but with a larger and more homogeneous sample of women to address the potential benefits of running SIT on body composition, especially relative to any potential sex differences. Further, we also examined whether running SIT might be an effective modality for altering cardiovascular disease (CVD) risk markers favourably through modulation of the blood lipid profile.

Methods

Twenty healthy recreationally active women (not currently participating in a structured exercise training program more than 2x/wk) volunteered for this study (age: 22.9±3.6 y; height: 163.9±5.1 cm; mass: 60.8±5.2 kg; mean±SD). Prior to study initiation, the experimental procedures and potential risks were explained fully and all participants provided written, informed consent, and completed the PAR-Q health questionnaire (Thomas et al. 1992). The University of Western Ontario Ethics Committee approved this study for Research on Human Subjects.

Study Design

Participants completed 6 wk of running sprint interval training ($3x \cdot wk^{-1}$). Pre- and post-treatment, all underwent a densitometric body composition test via air displacement (BodPod®),

waist circumference measurement, VO_{2max} test, a fasted blood lipid profile, and a three-day food record. Post-testing began between 48 and 96 h after the final training session to eliminate any acute exercise effects and was completed over a two-day period.

Familiarization

Prior to baseline testing, participants reported to the laboratory for an introduction to all testing and training procedures to minimize any potential learning effects.

Baseline Tests

Baseline testing was performed over two days, completed at least 48 h before the start of any training. The participants refrained from alcohol, caffeine, and physical exercise during the prior 12 h.

1) Blood Lipid Profile

Venous blood samples were obtained between 0700 and 1100 h after a 12-h overnight fast. Time of day was replicated as closely as possible following treatment. Blood samples were drawn into an 8.5 mL SST plus blood collection tube from a vein in the antecubital region (BD Vacutainer®, Becton, Dickinson and Company, Franklin Lakes, USA). The samples were placed in ice for 20-30 min and then centrifuged for 15 min at 3500 rpm at 4°C (Allegra™ 21R, Beckman Coulter™, Brea, USA). Subsequently the serum was aliquoted into 2mL tubes and frozen at -20°C until analysis for high-density lipoprotein (HDL), triglycerides (TG), and total cholesterol. Low-density lipoprotein (LDL) content was calculated by subtracting HDL from the total-cholesterol (Friedewald et al. 1972). Both the total cholesterol to HDL ratio and the TG to HDL ratio were calculated.

At the start of the study, participants (n=15) were asked to identify which phase of the menstrual cycle they were in (12 follicular; 3 in luteal) and whether or not they were using oral contraceptives (7 were using, 8 were not) as both of these factors are known to affect blood lipid values (Berenson et al. 2009, Woods et al. 1987). This information was used in the analysis to help determine if any changes in the blood lipid profile were due to the treatment, oral contraceptive use or menstrual cycle phase.

2) Body Composition

Body composition (lean mass and fat mass) was determined by whole body densitometry using air displacement (Noreen and Lemon 2006) via the BodPod® (Life Measurements, Concord, USA). Testing was done in accordance with the manufacturer's instructions as detailed in the manual. Briefly, participants wore approved clothing, i.e., tight swimsuit or compression shorts, Lycra® cap, and a sports bra. Thoracic gas volume was estimated for all subjects using the predictive equation integral to the BodPod® software (McCrory et al. 1998, Weyers et al. 2002) and the measured body density was used in the Siri equation to estimate body composition (Siri 1961).

3) Waist Circumference

Waist circumference was measured above the superior border of the iliac crest with a tape measure (Myotape®, Accu-Measure, LLC, Greenwood Village, USA) directly against the skin (Mason and Katzmarzyk 2009, Wang et al. 2003). Participants were instructed to breathe normally and to relax their arms at their sides. Duplicate measurements (to the nearest 0.5 cm) were taken by a single technician at the end of normal expiration, following a 12-h overnight fast and the average was recorded.

4) VO_{2max} Test

Participants performed a 5 min warm up on the treadmill (Woodway, Desmo Pro, Wisconsin, USA) at 8 kph (5 mph). Following the warm up, a Hans Rudolph silicon facemask (8490 Series, Hans Rudolph Inc, Kansas City, USA) was positioned over the nose and mouth using strapping around the head and, after checking for leaks, connected via a flow sensor to a breath-by-breath gas analysis system (Vmax Legacy, Sensor Medics, Yorba Linda, USA). The system was calibrated before testing by using gases of known concentration, and flow using a 3-L syringe. Participants then performed a progressive incremental speed treadmill test (at 0% grade) to determine VO_{2max}. The speed started at 8.8 kph (5.5 mph) and increased 0.8 kph (0.5 mph) every minute until volitional exhaustion. The duration of the test varied between 6-12 min. Oxygen uptake was measured continuously each breath throughout the test. Heart rate was monitored and recorded throughout using a Polar RST200TM heart rate monitor (Polar Electro Inc., Lachine, CAN). VO_{2max} was taken as the greatest value averaged over a 30 s collection period. All of the participants achieved a plateau in VO_2 (<2ml/kg increase VO_2 despite an increase in workload demanding an increase of 2.5 ml/kg) and attained a max HR within 10 beats of age predicted max.

5) Nutritional Intake

Participants completed a three-day food record after receiving detailed verbal instructions as well as written instructions and recording sheets. All food, beverage, and supplement intake was recorded as accurately as possible for two weekdays and one weekend day and these records were analyzed for energy, protein, carbohydrate and fat content using Food Processor SQL, ESHA (10.5, Salem, OR, USA).

Exercise Training

Training commenced 48 h after the last baseline measure and consisted of four repeated, 30 sec running maximal efforts with 4 min of recovery (active recovery between bouts was encouraged, i.e., walking), 3 times/wk. Each sprint was completed on a treadmill (Woodway, Desmo Pro, Waukesha, WI, USA) set in dynamic mode (self-propelled), allowing the subject to become the power source, i.e., the treadmill was propelled as fast the subject ran and slowed as the individual fatigued creating a safe environment vs a motorized treadmill. Training volume increased linearly over the training program (4 bouts in weeks 1 and 2, 5 in weeks 3 and 4 and 6 in weeks 5 and 6). The treadmill was interfaced with a computer to allow peak speed (kph) and heart rate data collection during each bout using MED-PRO software (Woodway USA Personal Trainer, version 4.4). After the completion of each training session subjects were asked to give a Rating of their Perceived Exertion (RPE) on a scale of 1-10 (Borg 1982).

Post-Training Tests

Post-training measures were identical to the baseline testing and completed 2-5 days after the final training session. All measures were made at the same time of day as pre-testing measures.

Statistical Analysis

Statistical analyses were performed using Sigma Stat for Windows (version 3.5). After testing for normality and variance homogeneity, paired t-tests were used to test significance between pre- and post-training. The significance level was set at $p<0.05$. All data are presented as means ± standard deviation (SD).

RESULTS

Initial recruitment consisted of 20 participants. Five of the 20 SIT participants did not complete the training: two withdrew due to unrelated illness, one due to time commitment, and two became injured during the study (one of the participants injured her knee playing volleyball while the other reported severe lower back pain due to scoliosis which may have been aggravated by the sprinting). Consequently, fifteen SIT participants finished the training and completed all testing sessions.

Dietary Intake

There were no differences in total energy intake (1931±485 to 1903±216 kcal/d or 8084±2032 to 7966±905 kJ/d; P=0.791), carbohydrate intake (254±61 to 265±38 g/d; P=0.355), fat intake (62±24 to 58±16 g/d; P=0.623), or protein intake (80±20.8 to 84±21 g/d; P=0.329) from pre-to post-training.

Body Composition

Six weeks of running SIT decreased body mass from 60.8±5.2 to 60.3±4.8 kg (P=0.048; Figure 1a), fat mass from 15.1±3.6 to 13.9±3.4 kg (P=0.002; Figure 1c), body fat percentage from 24.7±4.9 to 23.0±4.6% (P=0.003; Figure 1c), and waist circumference from 80.1±4.2 to 77.3±4.4 cm (P<0.001; Figure 1d) while increasing fat-free mass from 45.7±3.5 to 46.3±2.9 kg (P=0.050; Figure 1c).

VO_{2max}, Peak Running Speed, and RPE

SIT increased VO_{2max} by 8.7% (46±5 to 50±6 $ml \cdot kg^{-1} \cdot min^{-1}$; P=0.004). Peak running speed, achieved during the first 30 sec bout of the last session increased by 3.8% or 0.64 kph

(p=0.026) with training vs the first 30 sec bout of the first session. There was no significant difference (p=0.302) in RPE between the first and last training session or among any of the training sessions and the average RPE over the entire training study was 9.06 ± 0.17 (10-point scale).

Blood Lipid Panel Profile

Training had no effect on the concentration of total cholesterol (P=0.571), triglycerides (P=0.464), low-density lipoprotein (P=0.595), TG:HDL ratio (P=0.086), or the total cholesterol:HDL ratio (P=0.112; Table 1). Run SIT decreased HDL slightly from 1.34±0.28 to 1.24±0.24 $mmol \cdot L^{-1}$ (P=0.034).

DISCUSSION

This study demonstrated that six weeks of running SIT improved body composition, aerobic capacity, and peak running speed in young healthy women without changes in dietary intake. Specifically, running SIT induced an 8.0% fat loss (-1.2 kg), a 3.5% reduction in waist circumference (-2.8 cm), a 1.3% fat-free mass increase (+0.6 kg), an 8.7% increase in VO_{2max} (+4 $ml \cdot kg^{-1} \cdot min^{-1}$), and a 4.3% increase in peak running speed (+0.64 kph), all significant changes. These observations are novel because they indicate running SIT produces similar aerobic/anaerobic benefits to cycle SIT and that these effects are not sex specific. However, our previous 3.3 kg fat loss in men using the same training program (MacPherson et al. 2011) appears to be greater than the 1.2 kg observed here, even considering the obvious differences in body mass so more study regarding potential sex effects is needed. While these results differ from several previous cycling SIT studies, those were either of insufficient duration to cause

changes (Astorino et al. 2011, Hazell et al. 2010) and/or didn't assess body composition (Burgomaster et al. 2008). Future research is warranted to determine if 6 weeks of cycling SIT results in an improvement in body composition similar the running SIT employed here.

Previous studies using less intense forms of HIT but over longer training periods have reported similar fat losses in inactive young women (Trapp et al. 2008), in overweight women (Gillen et al. 2013, Sijie et al. 2012), in overweight men (Heydari et al. 2012), and in a mixed sample of men and women (Tremblay et al. 1994). Apparently, some of the observed reduction in fat mass with running SIT was from the abdominal area as reflected by a decrease in waist circumference (-2.8 cm or 3.5%) and this is particularly important because of the inverse relationship between abdominal fat and health (Canoy 2008). Interestingly, this absolute fat loss was similar to two weeks of SIT (Whyte et al. 2010) or less intense HIT (Leggate et al. 2012) in obese men. Further, other HIT results have demonstrated decreases in trunk fat in inactive women (Trapp et al. 2008), although the mechanism related to the decrease in visceral adiposity remains to be clarified. Possible sex differences in insulin sensitivity with SIT may be involved (Metcalfe et al. 2012). From all these data, we conclude that SIT can induce significant body fat loss in women and that the absence of fat loss observed in the women in our previous study was likely due to the small sample size (n=4).

As with our previous studies in men, the running SIT body fat loss in these women is impressive especially considering the training consisted of only 6-9 min per week (45 min over the entire 6 wk study). As alluded to above, mechanisms for fat loss with SIT are not well understood but HIT increases plasma glycerol concentration both acutely (McCartney et al. 1986) and chronically (Trapp et al. 2008) suggesting that lipids may serve as an important energy source both during and following this type of exercise. Further, HIT improves lipid transport

into skeletal muscle and increases enzyme activity related to aerobic energy production (Burgomaster et al. 2008, Parra et al. 2000, Perry et al. 2008, Rodas et al. 2000, Talanian et al. 2007, Tremblay et al. 1994). Prolonged increased post-exercise metabolism may also contribute (Chan and Burns 2013, Hazell et al. 2012), although controversial, as others have not observed an increase (Kelly et al. 2013, Williams et al. 2013). Our recent 24 h data indicate that while continuous exercise (30 min at 70% VO_{2max}) results in a much greater exercise VO_2 vs SIT, there is a consistent and prolonged increase in VO_2 over the remainder of the day with the latter resulting in similar 24-h total energy expenditures for both exercise types (Hazell et al. 2012). Therefore, the amount of energy utilised during SIT exercise bout is small but the increased energy expenditure over the remainder of the day is sufficient to result in fat loss over 6 weeks of SIT.

Our dietary intake records indicate no change in overall energy, protein, fat and/or carbohydrate intake pre- to post-treatment so it appears that the observed fat losses were not due to obvious decreases in energy or macronutrient intake, although food record data can be inaccurate (Yang et al. 2010). Recent HIT studies suggest appetite suppression may be involved (Boutcher 2011, Sim et al. 2013, Williams et al. 2013) so more detailed assessments of the effects of SIT on food intake (especially on exercising days) are needed before a definite conclusion on its effects on appetite are possible. Regardless, it is reasonable to assume that the combination of a low energy diet and SIT would promote even greater fat loss.

The increase in fat free mass (+0.6 kg) seen in the current study is similar to our previous 6 wk SIT study (MacPherson et al. 2011) indicating that the running sprints on our self-propelled treadmill generate enough external resistance to stimulate an increase in fat-free mass (likely

muscle mass due to the short duration of the training program). Such results may not occur with over the ground running.

Cycling SIT has been shown to increase VO_{2max} in several studies (Astorino et al. 2011, Burgomaster et al. 2007, Burgomaster et al. 2006, Burgomaster et al. 2008, Burgomaster et al. 2005, Gibala et al. 2006, Hazell et al. 2010, Howarth et al. 2007, MacDougall et al. 1998, McKenna et al. 1997, Parra et al. 2000, Rodas et al. 2000) and our results (+8.7%) are consistent with these as well as our previous running SIT study (MacPherson et al. 2011). Apparently, these improvements in aerobic power with SIT are largely the result of increased mitochondrial volume and content as well as oxidative enzyme activity (Burgomaster et al., 2007, Burgomaster et al., 2006, Burgomaster et al., 2008, Burgomaster et al., 2005, Gibala et al., 2006, MacDougall et al., 1998) and not due to increases in maximal cardiac output (MacPherson et al. 2011). However, it has recently been shown that 2 weeks of HIT with more bouts (8-12) of longer duration (60 sec) at a lower intensity (95-100% VO_{2max}) increased submaximal exercise cardiac output via increases in stroke volume and end-diastolic volume in untrained men (Esfandiari et al. 2014). Perhaps an exercise duration longer than 30 seconds is required to stimulate increases in stroke volume. More research varying exercise duration and intensity is needed to determine the underlying mechanisms (central vs peripheral) responsible for the adaptations observed with this type of training. Moreover, running SIT increased peak running speed pre- to post training (+3.8%) consistent with our previous study (MacPherson et al. 2011). Other cycling SIT investigations have observed increases in peak power output ranging from 4.2-10.6% (Astorino et al. 2011, Burgomaster et al. 2006, Hazell et al. 2010).

While running SIT did not affect TG or LDL, it did result in a very small decrease in HDL. Although previous research demonstrates increased HDL in both men and women using

either aerobic or interval exercise (Durstine et al. 1987, Mosher et al. 2005, Musa et al. 2009, Stasiulis et al. 2010, Thompson et al. 1991), small decreases in HDL have been demonstrated in women during weight loss (Dattilo and Kris-Etherton 1992, Grandjean et al. 1998, Kraemer et al. 1997, Thompson et al. 1979). Apparently, the negative energy balance necessary for weight loss produces a decrease in HDL that returns to pre-weight loss concentrations after weight loss ceases and body weight is stabilized. Further, the absence of increase in HDL could be due to the fact that all the participants were young, active, healthy and normo-cholesterolemic, because HDL increases are less likely with greater baseline values (Herd et al. 2000). The observed absence of a change in LDL in healthy normal individuals agrees with prior studies (Durstine et al. 2002, Thompson et al. 1997) that found changes in hyper-cholesterolemic individuals only. Our participants had normal cholesterol concentrations and no reduction in dietary fat intake, thus changes were unlikely. Further, no TG changes were found in the current study, consistent with other SIT work (Whyte et al. 2010), although aerobic training can decrease TG in normo- and hyper-triglyceridemic participants (Durstine and Haskell 1994, Stasiulis et al. 2010). Perhaps blood fat improvements in a young healthy population should not be expected and future work should investigate SIT effects in populations with abnormal blood lipid profiles.

Limitations

We did not utilize a control group in the present study because it is well known that changes in body mass, body fat %, TC, HDL, LDL, TG (LeMura et al. 2000, Mosher et al. 2005, Stasiulis et al. 2010), and/or exercise capacities (Burgomaster et al. 2006, Burgomaster et al. 2008, Burgomaster et al. 2005) do not occur without a treatment. The number of combined control subjects in these studies was 140. Other confounding factors include effects of menstrual cycle and oral contraceptives. As mentioned, time of menstrual cycle was recorded but it was

not controlled and due to the length of the training (6 weeks), the women were in a different phase of their menstrual cycle for the pre- and post training measures and this may have affected our blood fat results. Twelve women started the study in the follicular phase of their menstrual cycle and 3 started in the luteal phase. There were no apparent differences with SIT training for these women. Oral contraceptives use may affect blood fats but again there were no differences in this study between the women taking them (n=7) vs those who did not (n=8).

Conclusion

Six weeks of running SIT (3 times/wk) reduced both body fat and waist circumference in young women while increasing fat-free mass, peak running speed, and aerobic fitness. These adaptations were achieved despite a very low volume of total exercise suggesting that running SIT is an effective and time efficient exercise strategy to improve health and fitness in young women.

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Figure 1 – Body composition changes pre-and post-SIT for 6 weeks. a) Total body mass; b) Fat-free mass; c) Fat mass and body fat %; and d) Waist Circumference.

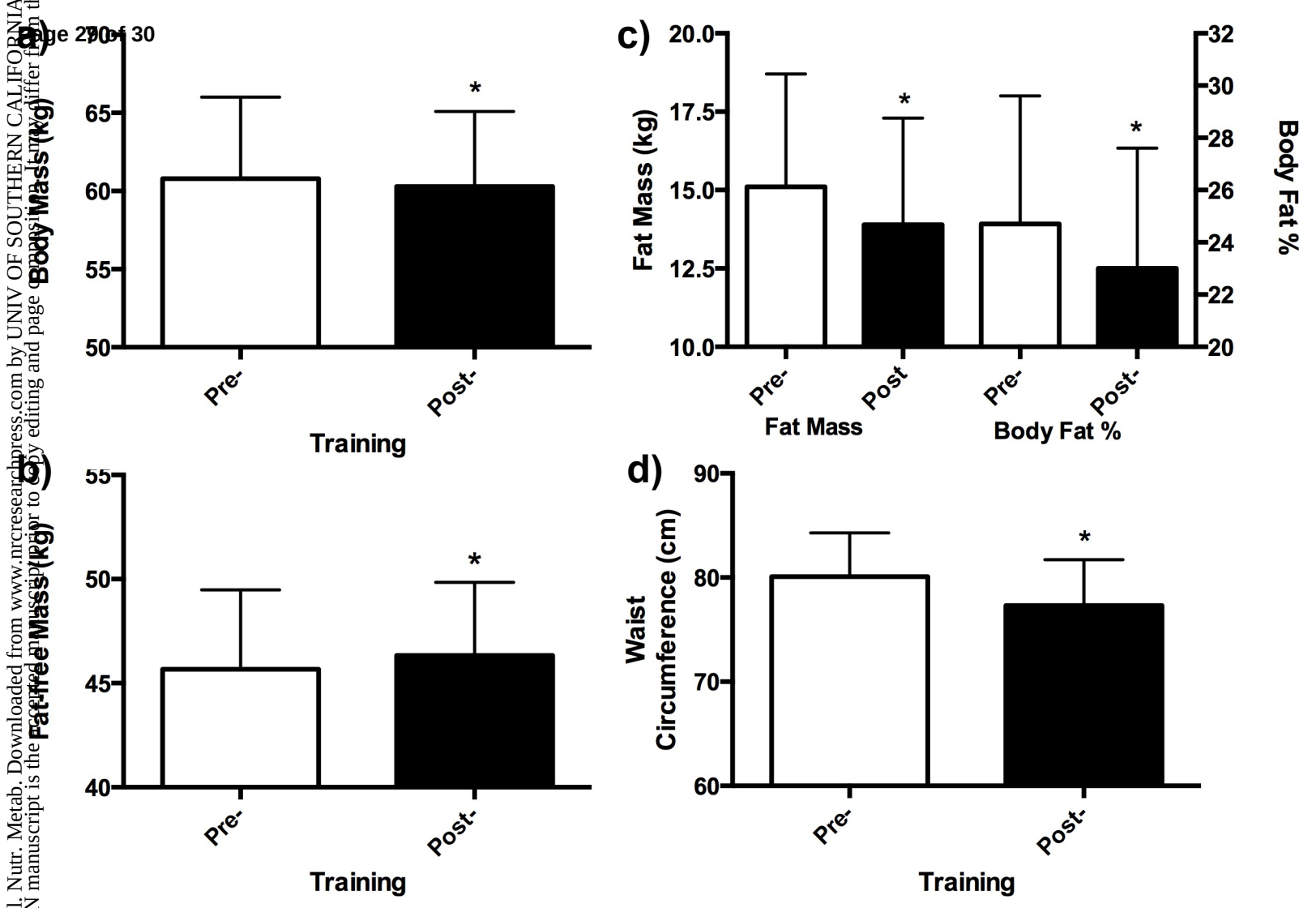

Table 1 – Blood Lipid Profile Pre- and Post-training

	Pre-Training	**Post-Training**	**P-value**
HDL (mmol/L)	1.34±0.44	1.23±0.39	0.034*
LDL (mmol/L)	2.48±0.91	2.55±0.85	0.595
TG (mmol/L)	1.11±0.56	1.07±0.48	0.464
CHOL (mmol/L)	4.33±1.39	4.26±1.25	0.571

* denotes significant difference $P<0.05$

HDL – High-density lipoprotein; LDL – Low-density lipoprotein; TG – Triglycerides; CHOL – total cholesterol.