



Received: 04 May 2018  
Accepted: 18 July 2018  
First Published: 27 July 2018

\*Corresponding author: Lisa S. Chow,  
MMC 101 420 Delaware St SE  
Minneapolis, MN 55455 612-625-8934  
Fax: 612-626-3133  
E-mail: [Chow0007@umn.edu](mailto:Chow0007@umn.edu)

Reviewing editor:  
Niall MacFarlane, School of Life  
Sciences, University of Glasgow,  
United Kingdom

Additional information is available at  
the end of the article

## SPORTS & EXERCISE | RESEARCH ARTICLE

# The impact of high BMI on acute changes in body composition following 90 min of running

Seth H. Brayton<sup>1</sup>, Tyler A. Bosch<sup>1</sup>, Anne E Bantle<sup>1</sup>, James S. Hodges<sup>2</sup>, Donald R. Dengel<sup>3</sup> and Lisa S. Chow<sup>1\*</sup>

**Abstract:** Objectives: Although physical activity ameliorates the metabolic impact of high body mass index (BMI), runners with BMI  $\geq 25$  kg/m<sup>2</sup> are relatively understudied. This study had two goals: (1) to identify differences in body composition, as measured by dual X-ray absorptiometry (DXA), between overweight (BMI  $\geq 25$  kg/m<sup>2</sup>) runners (OWR) and normal weight (BMI  $< 25$  kg/m<sup>2</sup>) runners (NWR) and (2) to examine whether a 90-min run alters total or regional fat mass, as measured by DXA, in OWR and NWR. We hypothesized that OWR would have higher total body fat than NWR and OWR with greater changes in visceral fat after a prolonged run. Design: Body composition analysis before and after a supervised run. Methods: We recruited NWR ( $n = 16$ , F:  $n = 7$ ,  $28.1 \pm 1.4$  years, BMI  $22.0 \pm 0.4$  kg/m<sup>2</sup>, results as mean  $\pm$  SE) and OWR ( $n = 11$ , F:  $n = 7$ ,  $32.0 \pm 1.6$  years, BMI  $30.5 \pm 1.4$  kg/m<sup>2</sup>) participants. DXA-based body composition was measured before and after a supervised, 90-min run at 60% heart rate reserve. Results: OWR had higher body fat than NWR in all measured regions. Both groups did not significantly reduce fat mass at any measured fat depots after the running exposure. Conclusions: OWR had higher body fat in all measured regions than NWR. DXA could not demonstrate any acute fat mass changes after a prolonged run.

**Subjects:** Biochemistry of Sport and Exercise; Exercise Physiology; Obesity

**Keywords:** Overweight body composition running exercise dual Xray absorptiometry

### 1. Introduction

It is well established that a high level of cardiorespiratory fitness is associated with lower rates of mortality (Blair et al., 1996; Chow et al., 2016) and development of diabetes, regardless of body mass index (BMI) (Carnethon et al., 2009). Although cardiorespiratory fitness has a strong genetic component (Bouchard et al., 2011), cardiorespiratory fitness has an established dose-response relationship to physical activity (Church, Earnest, Skinner, & Blair, 2007). There has been particular interest in aerobic training effects on overweight/obese subjects, as this population is perceived to especially benefit. However, most exercise intervention studies in this population involve training sedentary participants (AbouAssi et al., 2015; Church et al., 2007; Timothy, 2009) while runners with high BMI

### ABOUT THE AUTHORS

Seth Brayton was the lead trainer for TrainMeUp study group, led by Dr. Chow at the University of Minnesota. Dr. Chow's research interest is the effects of exercise on fat metabolism. This article compares differences in whole body fat levels before and after an acute run in high BMI vs. normal BMI runners.

### PUBLIC INTEREST STATEMENT

This study evaluates whether changes in body composition from an acute run might be different in high BMI vs. normal BMI runners.

(BMI  $\geq 25$  kg/m<sup>2</sup>) have been less well studied. This unique population (BMI  $\geq 25$  kg/m<sup>2</sup>) is estimated to comprise roughly 25% of runners under the age of 40 (Williams, 1997).

In individuals with a history of regular endurance training, fat oxidation is the primary fuel source during mild to moderate endurance exercise (Brooks & Mercier, 1994). In the setting of endurance exercise training, body composition is generally compared before and after weeks of training (Schwartz et al., 1991; Wilmore et al., 1999). In contrast, fewer studies have examined acute changes in body composition before and after an exercise bout. In active participants ( $n = 55$ , mean BMI  $\sim 24$  kg/m<sup>2</sup>), acute strength training ( $\sim 60$  min) or cycling ( $\sim 80$ – $110$  min) did not alter fat mass as measured by dual-energy X-ray absorptiometry (DXA); the act of acute exercise generally increased the technical error of measurement by 10% (Nana, Slater, Hopkins, & Burke, 2013). A study in runners [ $n = 6$  finishers, finishing time: 27 (2.3 h) (mean (SD)),  $n = 4$  nonfinishers, finishing time: 16.7 (1.4 h), weight: 73.1 (14.1 kg)] examined body composition as quantified by DXA before and after a 161-km ultramarathon (Hew-Butler, Hoxea, Fogard, Stuempfle, & Hoffman, 2015). Body mass did not significantly change pre-race to post-race whereas % body fat declined [ $-2.3\%$  (2.8)]; the authors felt this was consistent with the race-related energy deficit ( $\sim 5,000$ – $8,000$  kcals) (Hew-Butler et al., 2015). In another study, DXA-based body composition was measured before and after an Ironman triathlon [ $n = 8$ , BMI: 22.8 (2.6 kg/m<sup>2</sup>), race duration: 11.27 (1.24 h)] and reported decline in fat mass by  $-0.4$  (0.3 kg). In contrast, % body fat did not significantly change; this apparent discrepancy was attributed to the decline in lean mass post exercise (Mueller, Anliker, Knechtle, Knechtle, & Toigo, 2013). To date, the literature on DXA measured change in fat mass from an acute exercise bout appears modest. However, these studies enrolled normal weight active participants and did not report changes in visceral fat, which has high metabolic relevance (Giannopoulou et al., 2005; Johnson et al., 2009; Rheume et al., 2011; Wajchenberg, 2000).

Therefore, the current study has two goals: (1) to identify differences in body composition, as measured by DXA, between overweight runners (OWR: BMI  $\geq 25$  kg/m<sup>2</sup>) and normal weight runners (NWR: BMI  $< 25$  kg/m<sup>2</sup>) and (2) to examine whether changes in body composition, as measured by DXA, during a prolonged (90 min) run differ between OWR and NWR. We hypothesized that OWR would have higher total body fat than NWR and OWR would have greater changes in visceral fat during a prolonged run.

## 2. Methods

We recruited runners with NWR and OWR who were otherwise healthy, with the goal of examining body composition, measured by DXA, before and after a prolonged run (90 min) at 60% heart rate reserve (HRR). Each subject had two visits at the University of Minnesota campus. At the first visit, we measured baseline fitness and established HRR during a maximal aerobic capacity (VO<sub>2max</sub>) treadmill test. The second visit involved a prolonged run for 90 min at 60% HRR with body composition measured by DXA before and after the run. The University of Minnesota's Institutional Review Board (IRB) approved the study protocol and methods. All participants provided written informed consent before study participation. The clinicaltrials.gov number for this study is NCT02150889.

### 2.1. Participant recruitment

Participants were recruited from the Twin Cities area between July 2014 and April 2017 using fliers, online advertising, and email distribution through local running groups. We preferentially recruited participants from recent running events, to ensure that they could complete a prolonged (90 min) run. Inclusion criteria included (1) age 18–40 years and (2) regular aerobic exercise, preferably running, at least 3–5 sessions/week. Exclusion criteria included (1) self-reported clinically significant medical issues (for example, diabetes, cardiovascular disease, and uncontrolled pulmonary disease), (2) abnormal electrocardiogram (EKG) indicating cardiac disease (study EKG performed), and (3) current pregnancy (screening pregnancy test performed). We recruited with the goal of similarity in age and sex between the two groups.

This is a clinical study in healthy lean trained and overweight trained humans where a DXA scan was obtained pre and post an exercise bout. Four comparisons were made: (1) NWR vs. OWR pre-exercise, (2) NWR vs. OWR post-exercise, (3) NWR pre- vs. post-exercise, and 4) OWR pre- vs. post-exercise.

## 2.2. Fitness assessment

Fitness was assessed at the Laboratory of Integrative Human Physiology (July 2014 to March 2016) and the Masonic Clinical Research Unit (March 2016 to April 2017) at the University of Minnesota. Height and weight were measured using a portable stadiometer and digital scale. Resting blood pressure and heart rate were obtained using an automatic blood pressure monitor (Colin Press-Mate BP8800C, Colin Medical Instruments Corp., San Antonio, TX, USA), after the subject had been seated in a quiet room for 5 min. A 12-lead EKG was obtained at rest and reviewed by a licensed medical professional (physician or physician's assistant) before exercise testing.

Participants were instructed to refrain from intentional exercise for 72 h before the first visit. Participants were also advised to eat a light snack 2–3 h before testing. Maximum oxygen consumption ( $VO_{2max}$ ) was evaluated by indirect calorimetry using one of two metabolic carts, either at the Human Performance Teaching Laboratory (Ultima Medgraphics CPX-D, Medical Graphics Corporation, St. Paul, MN) or Masonic Clinical Research Unit (ParvoMedics TrueOne 2400—OUSW 4.3.4 (20160202), Sandy, UT, USA). The NWR participants were tested using a modified Åstrand protocol that began at the subject's self-selected race pace, which was maintained for the duration of the test (Åstrand & Ryhming, 1954). Each subject ran 4 min at 0% elevation, and then the treadmill increased by 2.5% in elevation every 2 min. The OWR participants were tested using the Bruce protocol (Bruce, Kusumi, & Hosmer, 1973). Since the NWR participants were anticipated to be more highly trained than the OWR participants, the modified Åstrand protocol was selected to specifically insure achievement of  $VO_{2max}$  and establishment of the maximum heart rate to calculate the 60% HRR for the exercise bout. During the  $VO_{2max}$  test, each subject wore a mask for measuring inspired and expired air and heart rate was measured using a Polar Heart Rate monitor (Polar Electro Inc., Lake Success, NY, USA). Each test was reviewed for maximal output by examining that maximal heart rate (determined by age adjusted estimation) was reached, oxygen uptake plateaued, respiratory exchange ratio (RER) of 1.10 or greater was achieved, and exhaustion was communicated using rating of perceived exertion scale (RPE) (Borg, 1962). To measure the capacity to do exhaustive work, we reported  $VO_{2max}$  as ml/kg/min as well as ml/kg lean mass/min.

## 2.3. Acute exercise exposure

At the second visit, each participant performed a prolonged (90 min) run at an intensity (60% HRR) conducive to fat oxidation (Egan & Zierath, 2013). HRR correlates with  $VO_{2max}$  (Swain, Leutholtz, King, Haas, & Branch, 1998) and several studies have shown maximum fat oxidation during exercise occurring between 41–75% of  $VO_{2max}$  (Bircher & Knechtle, 2004; Romijn, Coyle, Sidossis, Rosenblatt, & Wolfe, 2000; Swain et al., 1998). The second visit was scheduled at least 1 week after the first visit to minimize influence of the strenuous exercise from the  $VO_{2max}$  test. Participants were instructed to avoid intentional exercise for two days before the second visit. Participants arrived in the morning at the Delaware Clinical Research Unit at the University of Minnesota for the second visit after fasting overnight (at least 8 h). Height, weight, blood pressure, and pulse were collected using a wall stadiometer, digital scale and electric Colin Press-Mate 8800 BP Monitor blood pressure cuff (Colin Medical Instruments Corporation, San Antonio, TX). Blood was drawn at this time to measure insulin and glucose levels for calculation of insulin sensitivity, as estimated by HOMA-IR [(fasting serum insulin (uU/ml)\*fasting glucose (mmol/l))/22.5] (Bonora et al., 2000; Matthews et al., 1985).

For the supervised exercise bout, all participants ran for 90 min on a treadmill. The HRR was calculated from the subject's resting heart rate and maximum heart rate from the  $VO_{2max}$  testing. Each subject's run pace was initially selected by adjusting the speed and incline that achieved 60% HRR during the  $VO_{2max}$ , to keep all participants running at 0% grade. Heart rate was monitored during the entire run by study staff to maintain proper running intensity with Polar heart rate

monitor and the Polar Beat Multi-Sport Fitness Tracker smartphone app (Polar Electro Inc., Bethpage, NY, USA). If heart rate fluctuated more than 5% HRR, study staff adjusted the treadmill speed in 0.2 mph increments until the target heart rate was maintained. Participants were offered free access to water during their exercise bout.

#### **2.4. Body composition measurement**

Body composition was measured immediately before and after the exercise bout. Body composition was measured by DXA scanner, the GE Healthcare Lunar iDXA (GE Healthcare Lunar, Madison, WI, USA), with enCORE software version 16.2. Participants were scanned by one of three certified DXA technicians using standard imaging and positioning protocols.

Because the exercise intensity was conducive to fat oxidation (Egan & Zierath, 2013), our DXA measurements focused on changes in fat mass. Fat mass was measured in the following regions: total body, trunk, arm, leg, android, gynoid, abdominal subcutaneous, and abdominal visceral. Trunk fat mass included fat mass from the chest, abdomen, and pelvis region. Arm fat mass was calculated by summing fat content in both arms. Leg fat mass was calculated by summing fat content from both legs. The android region was defined as the trunk area approximately between the ribs and the pelvis. The upper boundary was set at 20% of the distance between the iliac crest and the base of the skull. The lower boundary was the top of the iliac crest. The gynoid region included the hips and upper thighs, overlapping both the leg and trunk regions. Visceral and subcutaneous fat were calculated from the android region. Subcutaneous and visceral fat were determined by examining the X-ray attenuation between the edge of the body and the outer edge of the abdominal cavity, as previously described (Kaul et al., 2012). Visceral fat was calculated by subtracting subcutaneous fat mass from the android region fat mass (Kaul et al., 2012).

Although participants were allowed free access to water before, during, and after the exercise bout, changes in lean body mass were not analyzed because of the potential influence of run-associated dehydration on results.

#### **2.5. Statistical analysis**

Descriptive data are expressed as mean  $\pm$  standard error (SE) for continuous variables and *N* (%) for categorical variables. For pre-to-post run change (absolute or percent) within each group, we used a paired *t* test separately for each group. Comparisons between the OWR and NWR groups were performed using multiple linear regression, with pre-to-post run change (absolute or percent) as the outcome and group, age, and sex as the predictors/covariates. Statistical significance was defined as *p* value  $\leq 0.003$  after using the Bonferroni method to adjust for multiple comparisons. Data analyses used SAS 9.3 (SAS Institute, Cary NC).

### **3. Results**

Table 1 shows subject characteristics for the NWR and OWR. A total of 16 NWR (7 females; age =  $28.1 \pm 1.1$  years; BMI =  $22.0 \pm 0.4$  kg/m<sup>2</sup>) and 11 OWR (7 females; age =  $32.0 \pm 1.6$  years; BMI =  $30.5 \pm 1.4$  kg/m<sup>2</sup>) participants were recruited. Although VO<sub>2max</sub> was higher in the NWR than in the OWR groups relative to total body mass ( $56.1 \pm 2.7$  ml/kg/min vs.  $42.5 \pm 2.4$  ml/kg/min, *p* = 0.0015), the VO<sub>2max</sub> was not significantly different relative to lean mass ( $73.9 \pm 2.4$  ml/kg lean mass/min vs.  $66.5 \pm 1.1$  ml/kg lean mass/min, *p* = 0.01). The maximum heart rate achieved during VO<sub>2max</sub> testing was not different between the two groups.

Table 1 compares the body composition between NWR and OWR participants before the run exposure. As expected, OWR participants had higher percent body fat ( $34.0\% \pm 3.1$  vs.  $19.4\% \pm 1.9$ , *p* = 0.001) and total fat mass ( $30.8 \pm 3.3$  kg vs.  $12.0 \pm 1.1$  kg, *p* = 0.0002). The OWR participants had higher fat mass than the NWR participants in the arms, legs, trunk, abdominal subcutaneous, abdominal visceral, android, and gynoid regions (all *p*  $\leq 0.003$ ). Lean mass was not significantly different between the groups.

**Table 1. Participant characteristics**

Mean (±SE)	Overall (n = 27)	NWR (n = 16)	OWR (n = 11)	p Value NWR vs. OWR*
Number (% female)	14(52)	7(44)	7(64)	0.31
Age (years)	29.7 ± 1.1	28.1 ± 1.4	32.0 ± 1.6	0.08
Weight (kg)	77.2 ± 3.3	66.0 ± 1.8	93.4 ± 4.5	<b>&lt;0.0001</b>
Height (cm)	173.0 ± 1.6	172.3 ± 2.0	174.0 ± 2.7	0.62
Resting Heart Rate (beats/min)	64 ± 2	62 ± 3	66 ± 3	0.44
VO <sub>2max</sub> (ml/kg/min)	50.6 ± 2.3	56.1 ± 2.7	42.5 ± 2.4	<b>0.0015</b>
VO <sub>2max</sub> (ml/kg lean mass/min)	70.9 ± 1.7	73.9 ± 2.4	66.5 ± 1.1	0.01
Maximum HR from VO <sub>2max</sub> testing (beats/min)	183 ± 2	187 ± 3	179 ± 3	0.1
Body Mass Index (kg/m <sup>2</sup> )	25.5 ± 1.0	22.0 ± 0.4	30.5 ± 1.4	<b>0.0002</b>
Glucose (mmol/L)	4.6 ± 0.1	4.4 ± 0.1	4.7 ± 0.2	0.28
Insulin (mU/L)	6.0 ± 0.6	4.0 ± 0.6	7 ± 0.9	0.005
HOMA-IR	1.2 ± 0.1	0.9 ± 0.1	1.6 ± 0.2	0.01
<b>Body composition measures</b>				
Body fat %	25.3 ± 2.2	19.4 ± 1.9	34.0 ± 3.1	<b>0.001</b>
Fat mass (kg)	19.7 ± 2.3	12.0 ± 1.1	30.8 ± 3.3	<b>0.0002</b>
Lean mass (kg)	53.9 ± 2.2	50.1 ± 2.2	59.4 ± 3.84	0.05
Trunk fat mass (kg)	9.2 ± 1.2	5.1 ± 0.5	15.0 ± 1.6	<b>&lt;0.001</b>
Arm fat mass (kg)	2.3 ± 0.3	1.4 ± 0.1	3.6 ± 0.5	<b>0.0008</b>
Leg fat mass (kg)	7.3 ± 0.9	4.7 ± 0.5	11.3 ± 1.5	<b>0.001</b>
Abdominal subcutaneous fat mass (kg)	1.1 ± 0.2	0.5 ± 0.1	2.0 ± 0.3	<b>0.0007</b>
Abdominal visceral fat mass (kg)	0.3 ± 0.1	0.2 ± 0.0	0.6 ± 0.1	<b>0.0001</b>
Android fat mass (kg)	1.4 ± 0.2	0.7 ± 0.1	2.6 ± 0.3	<b>0.0001</b>
Gynoid fat mass (kg)	3.6 ± 0.5	2.1 ± 0.3	5.7 ± 0.7	<b>0.0006</b>

Data are presented as mean ± SE. \*Significant if  $p \leq 0.003$  given multiple comparisons, adjusted for age and sex.

Each participant ran for 90 min at 60% HRR under direct supervision. The mean 60% HRR was  $135 \pm 2$  bpm.

Table 2 shows the percent change in total and regional body fat pre-to post run in the overall group ( $n = 27$ ) and separately in the NWR ( $n = 16$ ) and OWR ( $n = 11$ ) groups. The pre-to-post run change, as measured by percent fat change, did not differ significantly in the overall or specific groups in any compartment, even after adjusting for age and sex (all  $p$  values  $\geq 0.003$ ). Similar findings were noted for absolute change in fat mass pre-to-post run (Supplemental Table 1).

#### 4. Discussion

This study compares the effects of an exercise bout between OWR and NWR. The goal was to compare body composition between NWR and OWR before and after a run (90 min) at an intensity (60% HRR) emphasizing fat oxidation. The primary observation is that OWR have higher body fat in all measured regions (total, trunk, arm, leg, android, gynoid, subcutaneous, and visceral) than

**Table 2. Percent change in body composition pre and post 90-min run at 60% HRR**

Mean ± SE	Overall (27)	p Value*	NWR (n = 16)	p Value*	OWR (n = 11)	p Value*	p Value for NWR vs. OWR**
% change in body fat mass	-0.9 ± 0.6	0.13	-0.9 ± 1.0	0.38	-1.1 ± 0.5	0.08	0.91
% change in trunk fat mass	-2.4 ± 1.0	0.02	-3.3 ± 1.4	0.03	-1.1 ± 1.2	0.45	0.21
% change in arm fat mass	0.8 ± 1.1	0.46	1.5 ± 1.4	0.31	-0.2 ± 1.4	0.88	0.43
% change in leg fat mass	-0.5 ± 0.7	0.46	-0.6 ± 0.9	0.53	-0.3 ± 0.8	0.72	0.66
% change in abdominal subcutaneous fat mass	-2.7 ± 3.3	0.42	-2.1 ± 5.6	0.72	-3.7 ± 1.3	0.04	0.46
% change in abdominal visceral fat mass	3.3 ± 4.7	0.5	1.4 ± 7.8	0.87	5.9 ± 2.5	0.08	0.58
% change in android fat mass	-4.8 ± 3.3	0.15	-2.0 ± 1.8	0.28	-8.9 ± 6.4	0.27	0.58
% change in gynoid fat mass	-1.7 ± 2.7	0.52	0.8 ± 1.6	0.6	-5.5 ± 5.1	0.39	0.44

\*Relative to 0% change, significant if  $p \leq 0.003$  given multiple comparisons.

\*\*Adjusted for age and sex.

NWR. The secondary observation is the lack of statistically significant change in total fat mass or specific fat regions in response to a run at 60% HRR.

The concept of “fat and fit” has generated intense interest. Although fitness has a strong genetic component (Bouchard et al., 2011), exercise training has an established dose–response relationship with fitness (Church et al., 2007). The benefits of high fitness include lower rates of mortality (Blair et al., 1996) and lower incidence of diabetes, even after adjusting for BMI (Carnethon et al., 2009; Chow et al., 2016). This suggests that the benefits of exercise may be disassociated from weight. Indeed, exercise without dietary intervention produced only modest weight loss (<3% of initial body weight; Jakicic, 2009; Wing, 1999) and reduction in waist circumference independent of weight change (Church et al., 2009).

By focusing on runners with BMI  $\geq 25$  kg/m<sup>2</sup>, our study extends the current literature. Although large cohort studies often use treadmill exercise testing results to identify participants in the “high” fitness category, “high” fitness is frequently defined in a rudimentary manner, such as the upper 30–40% of the population (Blair et al., 1996; Carnethon et al., 2003; Chow et al., 2015). Exercise training studies of overweight/obese sedentary people allow direct assessment of the intervention. However, these training studies are generally short term (3–9 months) in duration (AbouAssi et al., 2015; Church et al., 2007; 2009; Dube et al., 2008; Wilmore et al., 1999). These chronic training studies in sedentary participants have found reductions in abdominal visceral fat (Irwin et al., 2003; Wilmore et al., 1999) and waist circumference (Church et al., 2009; Wilmore et al., 1999). Our study adds to the literature by focusing on well-trained overweight/obese persons capable of running for 90 min (mean  $VO_{2max}$ :  $42.5 \pm 8.0$  ml/kg/min), whose fitness is well above post-training measures from overweight/obese sedentary participants (post-training  $VO_{2max}$ : 16–28 ml/kg/min) (AbouAssi et al., 2015; Church et al., 2007). Our NWR had similar body fat ( $19.4 \pm 1.9\%$ ) to reported literature (6–24%) (Malina, 2007). In addition, we made the novel comparison with OWR who are capable of running for 90 min and still observed higher levels of

fat in OWR in all DXA measured regions (total, trunk, arm, leg, android, gynoid, abdominal subcutaneous, and abdominal visceral). Previous literature had also suggested this finding, although body fat was calculated from body anthropometric measures (Garrido-Chamorro, Sirvent-Belando, Gonzalez-Lorenzo, Martin-Carratala, & Roche, 2009) rather than DXA. Lean mass was similar between OWR and NWR.

Acute exercise increases lipolysis (Romijn et al., 1993). Therefore, we examined whether DXA would detect shifts in fat mass at an exercise intensity that stimulates fat oxidation. Our interest was sparked by earlier observations that the lipolytic rate of abdominal fat was higher than gluteal fat (Arner, Kriegholm, Engfeldt, & Bolinder, 1990) and that participants with obesity have lower lipolytic response to acute exercise than their lean counterparts (Mittendorfer, Fields, & Klein, 2004). As previously reported, the effect of acute exercise in altering fat mass, as measured by DXA, is modest (Hew-Butler et al., 2015; Mueller et al., 2013; Nana et al., 2013). Similarly, we observed that body fat, as measured by percent change or absolute change, was not altered by a 90 min run at 60% HRR. We note that DXA may not be sufficiently sensitive to measure fat mass change from the exercise exposure. We estimate ~1,000 kcal was burned from running at ~60%  $VO_{2max}$  for 90 min. Since fat contains 9 kcals/gram, we estimate a potential loss of ~110 g of fat from the energy deficit. This fat loss may not be detectable since repositioning can alter DXA measures by 1–3% and recent acute exercise can alter DXA measures by 10% (Nana et al., 2013). Our findings suggest that future studies will likely need a longer running exposure and a larger sample size to detect body composition differences, as measured by DXA.

Our study has several implications. Runners with higher BMI also have higher body fat. This suggests that high fat states can be associated with fitness, as the  $VO_{2max}$  (ml/kg lean mass/min) was not significantly different between OWR and NWR. Since runners with  $BMI \geq 25$  kg/m<sup>2</sup> are not uncommon and represent approximately 25% of the running population under age 40 (Williams, 1997), the relative dearth of studies in this population presents an opportunity to evaluate the metabolic implications of training. This is relevant as the benefits of metabolic health while accounting for BMI has been reported in several large, observational studies. In the National Health and Nutrition Examination Survey (NHANES) cohort, self-reported physical activity was associated with lower all-cause mortality independent of overweight/obesity status or duration of overweight/obesity (Dankel, Loenneke, & Loprinzi, 2016). In Europe, it has been observed that “metabolically healthy” high BMI individuals had lower risk for cardiovascular events (HR ~ 1.3) than their “metabolically unhealthy” counterparts (HR~ 2.3–2.5) and had higher risk than their “metabolically healthy” normal weight counterparts (HR = 1: referent), suggesting that “metabolically healthy obesity” is not necessarily a benign condition (Lassale et al., 2018). Since high fitness is associated with health benefits even when adjusting for BMI (Blair et al., 1996; Carnethon et al., 2009; Chow et al., 2016), the extent to which high fitness/physical activity can further enhance “metabolically healthy obesity” as characterized by metabolic syndrome components (Kramer, Zinman, & Retnakaran, 2013) remains unknown. Therefore, future studies in high BMI runners may provide insights into the effect of training on body fat deposition and adipose tissue metabolism. This would be relevant given the obesity epidemic and increasing recognition of physical activity in ameliorating many obesity-associated complications.

The primary strength of this study is its unique population, runners with high BMI. This population has higher fitness (AbouAssi et al., 2015; Church et al., 2007) than previously sedentary participants with  $BMI \geq 25$  kg/m<sup>2</sup> who received supervised aerobic training for 6–9 months. The primary limitation is the small size ( $n = 27$ ) which limits sex-specific comparisons. This may be relevant as sex-specific differences in body composition within same-sport athletes have been described (Santos et al., 2014) and sex-specific differences in exercise-associated lipolysis have been observed (Horowitz & Klein, 2000; Mittendorfer et al., 2004). We mitigated this limitation by performing within-subject comparison pre-post run and enrolling participants to minimize the differences in sex distribution between lean and runners with  $BMI \geq 25$  kg/m<sup>2</sup>. Another potential study limitation is the lack of quantification of running distance or calories burned during the

exercise bout. The primary study focus, however, was maintaining the relative intensity of exercise for each individual (60% HRR for 90 min) and between the two groups.

## 5. Conclusion

Runners with BMI  $\geq 25$  kg/m<sup>2</sup> had higher body fat in all measured regions than runners with BMI < 25 kg/m<sup>2</sup>. DXA could not demonstrate any acute changes in fat mass in runners after a prolonged run.

## Summary

- Runners with high BMI  $\geq 25$  kg/m<sup>2</sup> had higher body fat in all measured regions than normal weight runners.
- DXA could not demonstrate any acute changes in overall fat mass in runners after a prolonged run, regardless of BMI status.
- A prolonged run did not demonstrate any region-specific changes in fat mass in runners, regardless of BMI status.

## Abbreviations

BMI	Body mass index
CT	Computed tomography
DXA	Dual X-ray absorptiometry
EKG	Electrocardiogram
HRR	Heart rate reserve
NWR	Normal weight runners
OWR	Overweight runners
VO <sub>2max</sub>	Maximum uptake of oxygen during peak exercise (mL/kg/min)

## Supplementary material

Supplemental material for this article can be accessed here  
<https://doi.org/10.1080/2331205X.2018.1502960>

## Acknowledgments

We acknowledge and appreciate the subjects who participated in our study. We acknowledge the contributions of Qi Wang, MS for her statistical support.

## Funding

This work was supported by NIH/NIDDK under grant [R01DK098203]. Research reported in this publication was supported by the National Center for Advancing Translational Sciences of the National Institutes of Health Award Number [UL1TR000114]. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

## Author details

Seth H. Brayton<sup>1</sup>  
E-mail: [brayt007@umn.edu](mailto:brayt007@umn.edu)  
Tyler A. Bosch<sup>1</sup>  
E-mail: [bosch041@umn.edu](mailto:bosch041@umn.edu)  
Anne E Bantle<sup>1</sup>  
James S. Hodges<sup>2</sup>  
E-mail: [hodge003@umn.edu](mailto:hodge003@umn.edu)  
Donald R. Dengel<sup>3</sup>  
E-mail: [denge001@umn.edu](mailto:denge001@umn.edu)  
Lisa S. Chow<sup>1</sup>  
E-mail: [Chow0007@umn.edu](mailto:Chow0007@umn.edu)  
ORCID ID: <http://orcid.org/0000-0002-6210-2307>  
<sup>1</sup> Division of Diabetes, Endocrinology and Metabolism, Department of Medicine, University of Minnesota, Minneapolis, MN, 55455, USA.

<sup>2</sup> Division of Biostatistics, School of Public Health, University of Minnesota University of Minnesota, Minneapolis, MN, 55414, USA.

<sup>3</sup> School of Kinesiology, College of Education and Human Development, University of Minnesota, Minneapolis, 55414, USA.

## Citation information

Cite this article as: The impact of high BMI on acute changes in body composition following 90 min of running, Seth H. Brayton, Tyler A. Bosch, Anne E Bantle, James S. Hodges, Donald R. Dengel & Lisa S. Chow, *Cogent Medicine* (2018), 5: 1502960.

## References

- AbouAssi, H., Slentz, C. A., Mikus, C. R., Tanner, C. J., Bateman, L. A., Willis, L. H., ... Kraus, W. E. (2015). The effects of aerobic, resistance, and combination training on insulin sensitivity and secretion in overweight adults from STRIDE AT/RT: A randomized trial. *Journal of Applied Physiology*, 118(12), 1474–1482. doi:10.1152/jappphysiol.00509.2014
- Arner, P., Kriegholm, E., Engfeldt, P., & Bolinder, J. (1990). Adrenergic regulation of lipolysis in situ at rest and during exercise. *Journal of Clinical Investigation*, 85(3), 893–898. doi:10.1172/JCI114516
- Astrand, P. O., & Ryhming, I. (1954). A nomogram for calculation of aerobic capacity (physical fitness) from pulse rate during sub-maximal work. *Journal of Applied Physiology*, 7(2), 218–221. doi:10.1152/jappphysiol.1954.7.2.218
- Bircher, S., & Knechtel, B. (2004). Relationship between fat oxidation and lactate threshold in athletes and obese women and men. *Journal of Sports Science & Medicine*, 3(3), 174–181.



- Blair, S. N., Kampert, J. B., Kohl, H. W., Barlow, C. E., Macera, C. A., Paffenbarger, R. S., & Gibbons, L. W. (1996). Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA: the Journal of the American Medical Association*, 276(3), 205–210. doi:10.1001/jama.1996.03540030039029
- Bonora, E., Saggiani, F., Targher, G., Zenere, M. B., Alberiche, M., Monauni, T., ... Muggeo, M. (2000). Homeostasis model assessment closely mirrors the glucose clamp technique in the assessment of insulin sensitivity - Studies in subjects with various degrees of glucose tolerance and insulin sensitivity. *Diabetes Care*, 23(1), 57–63.
- Borg, G. (1962). *Physical performance and perceived exertion*. Studia Psychologica et Paedagogica. Series altera, Investigationes XI. Lund Sweden: Gleerup. pp. 1–64.
- Bouchard, C., Sarzynski, M. A., Rice, T. K., Kraus, W. E., Church, T. S., Sung, Y. J., ... Rankinen, T. (2011). Genomic predictors of the maximal O<sub>2</sub> uptake response to standardized exercise training programs. *Journal of Applied Physiology*, 110(5), 1160–1170. doi:10.1152/jappphysiol.00973.2010
- Brooks, G. A., & Mercier, J. (1994, (1985)). Balance of carbohydrate and lipid utilization during exercise: The “crossover” concept, *Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology*, 76(6), 2253–2261. doi:10.1152/jappphysiol.1994.76.6.2253
- Bruce, R. A., Kusumi, F., & Hosmer, D. (1973). Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. *American Heart Journal*, 85(4), 546–562. doi:10.1016/0002-8703(73)90502-4
- Carnethon, M. R., Gidding, S. S., Nehgme, R., Sidney, S., Jacobs, D. R., & Liu, K. (2003). Cardiorespiratory fitness in young adulthood and the development of cardiovascular disease risk factors. *JAMA: the Journal of the American Medical Association*, 290(23), 3092–3100. doi:10.1001/jama.290.23.3092
- Carnethon, M. R., Sternfeld, B., Schreiner, P. J., Jacobs, D. R., Lewis, C. E., Liu, K., & Sidney, S. (2009). Association of 20-year changes in cardiorespiratory fitness with incident type 2 diabetes: The coronary artery risk development in young adults (CARDIA) fitness study. *Diabetes Care*, 32(7), 1284–1288. doi:10.2337/dc08-1971
- Chow, L., Eberly, L. E., Austin, E., Carnethon, M., Bouchard, C., Sternfeld, B., ... Schreiner, P. (2015). Fitness change effects on midlife metabolic outcomes: The CARDIA study. *Medicine & Science in Sports & Exercise*, 47(5), 967–973. doi:10.1249/MSS.0000000000000481
- Chow, L. S., Odegaard, A. O., Bosch, T. A., Bantle, A. E., Wang, Q., Hughes, J., ... Schreiner, P. J. (2016). Twenty year fitness trends in young adults and incidence of prediabetes and diabetes: The CARDIA study. *Diabetologia*, 59(8), 1659–1665. doi:10.1007/s00125-016-3969-5
- Church, T. S., Earnest, C. P., Skinner, J. S., & Blair, S. N. (2007). Effects of different doses of physical activity on cardiorespiratory fitness among sedentary, overweight or obese postmenopausal women with elevated blood pressure - A randomized controlled trial. *JAMA: the Journal of the American Medical Association*, 297(19), 2081–2091. doi:10.1001/jama.297.19.2081
- Church, T. S., Martin, C. K., Thompson, A. M., Earnest, C. P., Mikus, C. R., & Blair, S. N. (2009). Changes in weight, waist circumference and compensatory responses with different doses of exercise among sedentary, overweight postmenopausal women. *Plos One*, 4(2), e4515. doi:10.1371/journal.pone.0004515
- Dankel, S. J., Loenneke, J. P., & Loprinzi, P. D. (2016). Does the fat-but-fit paradigm hold true for all-cause mortality when considering the duration of overweight/obesity? Analyzing the WATCH (Weight, Activity and Time Contributes to Health) paradigm. *Preventive Medicine*, 83, 37–40. doi:10.1016/j.ypmed.2015.12.002
- Dube, J. J., Amati, F., Stefanovic-Racic, M., Toledo, F. G. S., Sauers, S. E., & Goodpaster, B. H. (2008). Exercise-induced alterations in intramyocellular lipids and insulin resistance: The athlete’s paradox revisited. *American Journal of Physiology-Endocrinology and Metabolism*, 294(5), E882–E888. doi:10.1152/ajpendo.00769.2007
- Egan, B., & Zierath, J. R. (2013). Exercise metabolism and the molecular regulation of skeletal muscle adaptation. *Cell Metabolism*, 17(2), 162–184. doi:10.1016/j.cmet.2012.12.012
- Garrido-Chamorro, R. P., Sirvent-Belando, J. E., Gonzalez-Lorenzo, M., Martin-Carratala, M. L., & Roche, E. (2009). Correlation between body mass index and body composition in elite athletes. *Journal of Sports Medicine and Physical Fitness*, 49(3), 278–284.
- Giannopoulou, I., Ploutz-Snyder, L. L., Carhart, R., Weinstock, R. S., Fernhall, B., Gouloupoulou, S., & Kanaley, J. A. (2005). Exercise is required for visceral fat loss in postmenopausal women with type 2 diabetes. *The Journal of Clinical Endocrinology & Metabolism*, 90(3), 1511–1518. doi:10.1210/jc.2004-1782
- Hew-Butler, T., Hoxley, B. T., Fogard, K., Stuempfle, K. J., & Hoffman, M. D. (2015). Comparison of body composition techniques before and after a 161-Km Ultramarathon using DXA, BIS and BIA. *International Journal of Sports Medicine*, 36(02), 169–174. doi:10.1055/s-0034-1387777
- Horowitz, J. F., & Klein, S. (2000). Oxidation of nonplasma fatty acids during exercise is increased in women with abdominal obesity. *Journal of Applied Physiology*, 89(6), 2276–2282. doi:10.1152/jappphysiol.2000.89.6.2276
- Irwin, M. L., Yasui, Y., Ulrich, C. M., Bowen, D., Rudolph, R. E., Schwartz, R. S., ... McTiernan, A. (2003). Effect of exercise on total and intra-abdominal body fat in postmenopausal women: A randomized controlled trial. *JAMA: the Journal of the American Medical Association*, 289(3), 323–330. doi:10.1001/jama.289.3.323
- Jakicic, J. M. (2009). The effect of physical activity on body weight. *Obesity*, 17((S3)), S34–S38. doi:10.1038/oby.2009.386
- Johnson, N. A., Sachinwalla, T., Walton, D. W., Smith, K., Armstrong, A., Thompson, M. W., & George, J. (2009). Aerobic exercise training reduces hepatic and visceral lipids in obese individuals without weight loss. *Hepatology*, 50(4), 1105–1112. doi:10.1002/hep.23129
- Kaul, S., Rothney, M. P., Peters, D. M., Wacker, W. K., Davis, C. E., Shapiro, M. D., & Ergun, D. L. (2012). Dual-energy X-ray absorptiometry for quantification of visceral fat. *Obesity*, 20(6), 1313–1318. doi:10.1038/oby.2011.393
- Kramer, C. K., Zinman, B., & Retnakaran, R. (2013). Are metabolically healthy overweight and obesity benign conditions? A systematic review and meta-analysis. *Annals of Internal Medicine*, 159(11), 758–. doi:10.7326/0003-4819-159-11-201312030-00008

- Lassale, C., Tzoulaki, I., Moons, K. G. M., Sweeting, M., Boer, J., Johnson, L., ... Butterworth, A. S. (2018). Separate and combined associations of obesity and metabolic health with coronary heart disease: A pan-European case-cohort analysis. *European Heart Journal*, 39(5), 397-+. doi:10.1093/eurheartj/ehx448
- Malina, R. M. (2007). Body composition in athletes: Assessment and estimated fatness. *Clinics in Sports Medicine*, 26(1), 37-68. doi:10.1016/j.csm.2006.11.004
- Matthews, D. R., Hosker, J. P., Rudenski, A. S., Naylor, B. A., Treacher, D. F., & Turner, R. C. (1985). Homeostasis model assessment: Insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia*, 28(7), 412-419.
- Mittendorfer, B., Fields, D. A., & Klein, S. (2004). Excess body fat in men decreases plasma fatty acid availability and oxidation during endurance exercise. *American Journal of Physiology-Endocrinology and Metabolism*, 286(3), E354-362. doi:10.1152/ajpendo.00301.2003
- Mueller, S. M., Anliker, E., Knechtle, P., Knechtle, B., & Toigo, M. (2013). Changes in body composition in triathletes during an Ironman race. *European Journal of Applied Physiology*, 113(9), 2343-2352. doi:10.1007/s00421-013-2670-3
- Nana, A., Slater, G. J., Hopkins, W. G., & Burke, L. M. (2013). Effects of exercise sessions on DXA measurements of body composition in active people. *Medicine and Science in Sports and Exercise*, 45(1), 178-185. doi:10.1249/MSS.0b013e31826c9cfd
- Rheaume, C., Arsenault, B. J., Dumas, M. P., Perusse, L., Tremblay, A., Bouchard, C., ... Despres, J. P. (2011). Contributions of cardiorespiratory fitness and visceral adiposity to six-year changes in cardiometabolic risk markers in apparently healthy men and women. *Journal of Clinical Endocrinology & Metabolism*, 96(5), 1462-1468. doi:10.1210/jc.2010-2432
- Romijn, J. A., Coyle, E. F., Sidossis, L. S., Gastaldelli, A., Horowitz, J. F., Endert, E., & Wolfe, R. R. (1993). Regulation of endogenous fat and carbohydrate metabolism in relation to exercise intensity and duration. *American Journal of Physiology*, 265(3), E380-E391. doi:10.1152/ajpendo.1993.265.3.E380
- Romijn, J. A., Coyle, E. F., Sidossis, L. S., Rosenblatt, J., & Wolfe, R. R. (2000, (1985)). Substrate metabolism during different exercise intensities in endurance-trained women. *Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology*, 88(5), 1707-1714. doi:10.1152/jappl.2000.88.5.1707
- Santos, D. A., Dawson, J. A., Matias, C. N., Rocha, P. M., Minderico, C. S., Allison, D. B., ... Silva, A. M. (2014). Reference values for body composition and anthropometric measurements in athletes. *Plos One*, 9(5), e97846. doi:10.1371/journal.pone.0097846
- Schwartz, R. S., Shuman, W. P., Larson, V., Cain, K. C., Fellingham, G. W., Beard, J. C., ... Abrass, I. B. (1991). The effect of intensive endurance exercise training on body fat distribution in young and older men. *Metabolism*, 40(5), 545-551.
- Swain, D. P., Leutholtz, B. C., King, M. E., Haas, L. A., & Branch, J. D. (1998). Relationship between % heart rate reserve and % VO2 reserve in treadmill exercise. *Medicine and Science in Sports and Exercise*, 30(2), 318-321.
- Wajchenberg, B. L. (2000). Subcutaneous and visceral adipose tissue: Their relation to the metabolic syndrome. *Endocrine Reviews*, 21(6), 697-738. doi:10.1210/er.21.6.697
- Williams, P. T. (1997). Evidence for the incompatibility of age-neutral overweight and age-neutral physical activity standards from runners. *American Journal of Clinical Nutrition*, 65(5), 1391-1396. doi:10.1093/ajcn/65.5.1391
- Wilmore, J. H., Despres, J. P., Stanforth, P. R., Mandel, S., Rice, T., Gagnon, J., ... Bouchard, C. (1999). Alterations in body weight and composition consequent to 20 wk of endurance training: The HERITAGE FAMILY STUDY. *American Journal of Clinical Nutrition*, 70(3), 346-352. doi:10.1093/ajcn/70.3.346
- Wing, R. R. (1999). Physical activity in the treatment of the adulthood overweight and obesity: Current evidence and research issues. *Medicine and Science in Sports and Exercise*, 31(11), S547-S552. doi:10.1097/00005768-199911001-00010



© 2018 The Author(s). This open access article is distributed under a Creative Commons Attribution (CC-BY) 4.0 license.

You are free to:

Share — copy and redistribute the material in any medium or format.

Adapt — remix, transform, and build upon the material for any purpose, even commercially.

The licensor cannot revoke these freedoms as long as you follow the license terms.

Under the following terms:

Attribution — You must give appropriate credit, provide a link to the license, and indicate if changes were made.

You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use.

No additional restrictions

You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits.

**Cogent Medicine (ISSN: 2331-205X) is published by Cogent OA, part of Taylor & Francis Group.**

**Publishing with Cogent OA ensures:**

- Immediate, universal access to your article on publication
- High visibility and discoverability via the Cogent OA website as well as Taylor & Francis Online
- Download and citation statistics for your article
- Rapid online publication
- Input from, and dialog with, expert editors and editorial boards
- Retention of full copyright of your article
- Guaranteed legacy preservation of your article
- Discounts and waivers for authors in developing regions

**Submit your manuscript to a Cogent OA journal at [www.CogentOA.com](http://www.CogentOA.com)**

