

Crossfit-based high intensity power training improves maximal aerobic fitness and body composition

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Abstract

The purpose of this study was to examine the effects of a crossfit-based high intensity power training (HIPT) program on aerobic fitness and body composition. Healthy subjects of both genders (23 males, 20 females) spanning all levels of aerobic fitness and body composition completed 10 weeks of HIPT consisting of lifts such as the squat, deadlift, clean, snatch, and overhead press performed as quickly as possible. Additionally, this crossfit-based HIPT program included skill work for the improvement of traditional Olympic lifts and selected gymnastic exercises. Body fat percentage was estimated using whole body plethysmography and maximal aerobic capacity (VO₂max) was measured by analyzing expired gasses during a Bruce protocol maximal graded treadmill test. These variables were measured again following 10 weeks of training and compared for significant changes using a paired t-test. Results showed significant ($P<0.05$) improvements of VO₂max in males (43.10 ± 1.40 to 48.96 ± 1.42 ml/kg/min) and females (35.98 ± 1.60 to 40.22 ± 1.62 ml/kg/min) as well as decreased body fat percentage in males (22.2 ± 1.3 to 18.0 ± 1.3) and females (26.6 ± 2.0 to 23.2 ± 2.0). These improvements were significant across all levels of initial fitness. Significant correlations between absolute oxygen consumption and oxygen consumption relative to body weight was found in both men ($r=0.83$, $P<0.001$) and women ($r=0.94$, $P<0.001$), indicating HIPT improved VO₂max scaled to body weight independent of changes to body composition. Our data shows that HIPT significantly improves VO₂max and body composition in subjects of both genders across all levels of fitness.

Key words: interval training, aerobic fitness, body composition, crossfit, power training

Introduction

High-intensity interval training (HIIT) has been used as an alternative to traditional endurance training for the improvement of aerobic fitness. HIIT is practical for many individuals due to the minimal time commitment required when compared to traditional continuous endurance training. A relatively new variation of HIIT has recently become popular and incorporates high intensity resistance training using varied, multiple joint movements. This high intensity power training (HIPT) may also offer improvement of aerobic fitness with minimal time commitment compared to traditional aerobic training. HIPT has recently become popular worldwide, however, proponents have made many unsubstantiated claims. HIPT differs from traditional HIIT in that it includes a lack of a prescribed rest period, focus on sustained high power output and use of multiple joint movements.

This crossfit-based, HIPT program utilizes named “workouts of the day” (WOD) in varied time domains. HIPT incorporates functional lifts such as the squat, deadlift, clean, snatch, and overhead press. Additionally, HIPT commonly uses basic gymnastic exercises using rings, handstands, and parallel bars. Some workouts are performed for a best time, and others are performed in the “as many rounds as possible” (AMRAP) style using varying time domains, ranging from 10 to 20 minutes. For example, a popular WOD uses 3 sets of 21, 15, and 9 repetitions of barbell front squats with an overhead press, immediately followed by body weight pull-ups. This WOD is performed with the goal of completing the exercises as quickly as possible. In summary, a HIPT training session will often include a random selection of multiple joint exercises and train participants to complete these movements at high resistance as quickly as possible.

The sustained high power output associated with HIPT might serve as a stimulus for positive adaptations of maximal aerobic capacity (VO_{2max}) and body composition. While HIIT has been shown to improve body composition(13) and VO_{2max} (14) in healthy adults, it is not clear if HIPT could offer these same benefits.

To date, there have been no published investigations documenting changes to VO_{2max} or body composition in response to this style of training. Therefore, our aim was to determine if a HIPT training regimen could yield significant improvements to VO_{2max} and body composition in healthy adults. To achieve our aim, we measured maximal aerobic capacity using a Bruce protocol graded exercise test and body composition with whole body plethysmography in healthy adult volunteers before and after a common HIPT training program. We tested the hypothesis that a 10 week HIPT regimen would improve VO_{2max} and body composition in healthy adult volunteers. Furthermore, we hypothesized that improvements of VO_{2max} and body composition would be found across all levels of initial aerobic fitness and body composition, not only in the cohorts of the lowest initial values of these markers.

Methods

Approach to the Problem

This study investigated the effect of a 10 week, crossfit-based, HIPT program on body composition and VO₂max in healthy adults. Body composition using air displacement plethysmography and maximal aerobic capacity using a Bruce treadmill graded exercise test were assessed in all subjects in the morning (7:30 AM to 11:30 AM) over a five day period preceding the onset of training. Measurements were obtained following an overnight fast, and subjects refrained from exercise, alcohol, and caffeine for the previous 24 hours. A total of 43 subjects completed the training program and returned for assessment of changes in the dependent variables of body composition and VO₂max. All returning subjects were assessed at the same time of day as the pre-training measures over a five day period following the completion of the program.

Subjects

Participants of all levels of aerobic fitness and body composition were recruited from and trained at a Crossfit affiliate (Fit Club, Columbus, OH). Out of the original 54 participants, a total of 43 (23 males, 20 females) fully completed the training program and returned for follow up testing. Of the 11 subjects who dropped out of the training program, two cited time concerns with the remaining nine subjects (16% of total recruited subjects) citing overuse or injury for failing to complete the program and finish follow up testing. Subjects had already been following a “Paleolithic” type diet prior to and following completion of the training protocol. All of the subjects provided written informed consent and all study methods and protocols were approved in advance by the Institutional Review Board at The Ohio State University.

Procedures

Training Program

Subjects participated in a crossfit-based HIPT program using basic gymnastic skills (handstands, ring, and bar exercises) and traditional multiple-joint, functional, resistance exercises (squat, press, deadlift, Olympic lifts) performed as quickly as possible at a high intensity (low repetition, high percentage of 1-RM). All training was performed at a CrossFit affiliate under the supervision of a fellow of the American College of Sports Medicine (ACSM) and an ACSM certified registered clinical exercise physiologist. . The 10-week program was varied so that some exercises were performed for a best time, and others were performed in the “as many rounds as possible” (AMRAP) style in varying time domains ranging from 10 to 20 minutes.

During the strength/skill portion of the exercise session, there was no prescribed recovery time, whereas during the WOD portion of the session, subjects completed all the exercises as quickly as possible with no prescribed rest period. Two representative weeks of the training program are found in Figure 1. Subjects were asked to refrain from all other structured physical activity while participating in this study and they complied with this request, as verified by activity logs. A

complete list of all exercises performed over the 10 weeks is found in Table 6.

Body Composition

Percentage body fat was calculated using the Bod Pod air-displacement plethysmography device (Life Measurements Instruments, Concord, CA), which is shown to be an accurate method for assessing body composition in adults(2). Prior to measurement, the system was calibrated for volume using a cylinder of a known volume (50.1461 L) and for mass using two 10 kg weights. Fasting-state body weight was measured to the nearest 0.1 kg and subjects entered the Bod Pod chamber wearing only a tight fitting swimsuit and swim cap. Body volume measurements were taken in duplicate and repeated if measures were not within 150 mL of each other(7). Body density was calculated as mass/body volume and body fat percentage was calculated by using Siri's formula(12). Body mass index (BMI) was calculated as kg body mass divided by height in meters squared.

Graded Exercise Testing

All subjects performed a maximal treadmill exercise test before and after the training program using the Bruce protocol(4) to determine VO₂max. Subjects wore nose clips and breathed into a one-way mouthpiece, which allowed expired gases to be collected in a mixing chamber. Volume of expired air, oxygen consumption, and carbon dioxide production were determined by gas analyzers and a pneumotachometer attached to a calibrated, computerized metabolic cart (Parvomedics, Sandy, UT), which provides accurate and reliable results compared to the Douglas bag method(6). Oxygen consumption values were calculated every 15 s and the two highest consecutive values were averaged to determine absolute maximal oxygen consumption in L/min. Body weight was divided into absolute oxygen consumption to yield a value relative to body mass and is reported as relative VO₂max in units of ml of O₂/kg of body mass/min. The test was terminated and considered maximal when subjects reached self-determined exhaustion, and was verified by the two of following criteria: (1) plateau in oxygen consumption despite an increase in workload, (2) respiratory exchange ratio greater than 1.1, and (3) rating of perceived exertion of 18-20. Using these parameters have previously shown to be a reliable method of verifying VO₂max has been attained, and provides statistically indistinguishable measurements compared to supramaximal testing(8). Metabolic sensors were recalibrated between each exercise test.

Statistical Analyses

Changes of VO₂max and body composition from pre- to post-training were tested using a twotailed, paired t-test. These values were tested as an entire group, and also in subsets that were stratified by initial values of aerobic fitness and body composition, respectively. These subsets were based on normative data for the age and gender of each participant(3). Percentile rankings correspond to descriptors as follows: well above average (>90), above average (70-90), average (50-70), below average (30-50), and well below average (10-30). Two-tailed, paired t-tests were then used to test differences between pre- and post-training values of VO₂max and body

composition. a forward stepwise multivariate linear regression was performed to identify significant predictors of relative VO₂max. The model considered the following variables for inclusion: change in absolute VO₂max and body fat. Additionally, a linear regression analysis was performed and Pearson correlation coefficients calculated to determine the contribution of changes in total body weight, lean mass, and absolute oxygen consumption to the observed increase in relative VO₂max. Data are reported as mean ± SEM. Statistical analysis was performed using STATA (version 11.1, College Station, TX). Statistical significance was defined a priori as the critical α -level of $P < 0.05$.

Results

Characteristics of subjects who volunteered for the study are presented in Table 1. The mean and SEM of the variables prior to and following training for male subjects are presented in Table 2, and female subjects in Table 3. Following the training program, a significant increase in relative VO₂max and decrease in percent body fat were observed. These changes are presented in Figure 2. The differences in relative oxygen consumption and body composition were significant when broken into quantiles of “well below average”, “below average”, “average”, “above average”, and “well above average”, indicating improvement across all initial levels of fitness (Figure 3 and Figure 4).

Improvement in absolute VO₂max was found in the well below average, below average, and above average groups (Figure 5). A regression analysis revealed that absolute VO₂max and body fat percentage was a significant predictor of the change in relative VO₂max in males ($P=0.001$), but only absolute VO₂max was a predictor of relative VO₂max in females (Table 4). Furthermore, the improvement of maximal relative aerobic capacity could be explained by an increase in absolute oxygen consumption in males ($r=0.83$, $P=0.001$) and females ($r=0.94$, $P=0.001$), and was further informed by the correlation of a decrease in body fat in males only ($r=0.49$, $P=0.05$). This correlation analysis is presented in Table 5.

Discussion

The aim of this research was to examine the effects of a novel, crossfit-based HIPT program on aerobic fitness and body composition in healthy adults. Results presented here confirm our hypothesis that a 10-week crossfit based HIPT program significantly improves maximal aerobic capacity and body composition in individuals of all fitness levels and genders. The improvement of relative VO₂max was strongly mediated by improvement of absolute oxygen consumption in females, and by improvement of absolute oxygen consumption and decreased body fat in males.

While HIIT has previously been shown to improve body composition(13) and VO₂max(14) in healthy adults, this is the first investigation showing that similar benefits can be obtained using a crossfit-based HIPT program. Following the HIPT training, body fat percentage dropped by 3.7%, across all individuals, in absolute terms. This reduction corresponds to a pre- to post-

training change of 15.5%. As presented in Figure 4, there were significant declines in body fat percentage for all fitness cohorts. This finding also holds when comparing men and women. Tables 2 and 3 show the results for men and women respectively. Absolute and percentage changes in body fat were similar for both genders. These results indicate a positive role for HIPT in reducing body fat percentage in both genders across all levels of initial fitness. However, given the body composition changes that have been observed in response to a Paleolithic type diet(10), it is impossible to ascribe the entirety of the improvement in body composition in our subjects to HIPT training alone.

The results for oxygen consumption again reveal that quantiles of all initial levels of fitness were improved in response to a HIPT training regimen. Oxygen consumption, as expressed relative to body weight, significantly increased across all groups (Figure 3). Again, men and women attained similar improvements in relative VO₂max, 13.6% and 11.8% respectively (Table 2 and Table 3). As commonly understood, improvement of relative VO₂max can result from increased absolute oxygen consumption, decreased body weight, or changes in both. Our data indicate that improvement of absolute oxygen consumption is the primary factor in the improvement of relative VO₂max, with a small contribution of the reduction of body fat percentage in males only. To our knowledge, this is the first report of improvement of relative and absolute VO₂max in response to a crossfit-based HIPT training protocol.

Combining the quantiles to represent men and women, Tables 2 and 3 show a significant increase of absolute VO₂max for both genders. These findings show that aerobic benefits can be gained through HIPT, regardless of initial fitness or gender. Past HIIT training has revealed similar improvements in VO₂max. Astorino et. al reported more than 6% increase in absolute VO₂max, and 5.5% increase in relative VO₂max, while Trulic et al reported a 13.4% increase in relative VO₂max in response to HIIT. Our finding that improvement of VO₂max in subjects who are stratified as well above average is at odds with previous work using a HIIT protocol that finds no improvement of VO₂max(5). Even HIIT studies in well trained subjects using hyperoxia have previously failed to find an improvement of oxygen consumption in subjects of comparably high VO₂max(9, 11). Compared to HIIT, our results indicate a possible superior role for HIPT in the improvement of maximal aerobic capacity in well-trained subjects. Future studies are needed in this area.

A unique concern with any high intensity training program such as HIPT or other similar programs is the risk of overuse injury. In spite of a deliberate periodization and supervision of our Crossfit-based training program by certified fitness professionals, a notable percentage of our subjects (16%) did not complete the training program and return for follow-up testing. While peer-reviewed evidence of injury rates pertaining to high intensity training programs is sparse, there are emerging reports of increased rates of musculoskeletal and metabolic injury in these programs(1). This may call into question the risk-benefit ratio for such extreme training

programs, as the relatively small aerobic fitness and body composition improvements observed among individuals who are already considered to be “above average” and “well above average” may not be worth the risk of injury and lost training time. Further work in this area is needed to explore how to best realize improvements to health without increasing risk above background levels associated with participation in any non-high intensity based fitness regimen.

In conclusion, we can infer from our data that a crossfit-based HIPT training program can yield meaningful improvements of maximal aerobic capacity and body composition in men and women of all levels of fitness. The improvement of maximal oxygen consumption expressed as a function of body mass was significantly correlated to increased absolute oxygen consumption, indicating HIPT can improve aerobic fitness independent of any concurrent weight loss. While improvements in aerobic fitness are similar to those previously found in HIIT programs, the current HIPT program has demonstrated an increase of maximal oxygen consumption, even in subjects with well-above average VO₂max. This increase in VO₂max has not previously been documented in response to a HIIT program, indicating HIPT may be a possible strategy for improvement of aerobic fitness in athletes who are considered to be well-above average. Future research is needed to investigate these differences.

Practical Applications

To our knowledge no research on the aerobic benefits of HIPT has been conducted. HIPT focuses on high intensity resistance training using multiple joint exercises, with little to no focus on traditional aerobic activities. In spite of this, our results show that this type of training also provides aerobic and body composition benefits. The increased aerobic capacity of the subjects in our HIPT study were similar to those found in past research(5, 13). Based on the results presented here, individuals of all fitness levels and either gender can realize body composition and aerobic benefits from HIPT. Given that our subjects were following a Paleolithic diet, we cannot relate all of the observed weight loss to HIPT training. However, HIPT and Paleolithic diet in combination could be used to promote positive changes in body composition.

Additionally, these findings could be significant for athletes wishing to improve their aerobic performance. While an aerobic training regimen based is primarily on long slow endurance workouts e.g, (cycling and running for extended periods at moderate intensity < 70% VO₂max), we propose that HIPT training could be used as an adjunct to this strategy in light of our findings. Furthermore, HIPT workouts require much less time spent training than traditional aerobic exercise and could serve as a convenient and practical addition to a training regimen focused on improvement of aerobic fitness or body composition in healthy adults.

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| | Monday | Tuesday | Wednesday | Thursday | Friday |
|----------------|---|--|--|--|--|
| Strength/Skill | Back squat x5 @ 65% x5 @ 75% x5 @ 85% Weighted/assist pull up x5 @ 65% x5 @ 75% x5 @ 85% | Novice - HS Intermediate - HSPU Advanced - HSW | Deadlift x5 @ 65% x5 @ 75% x5 @ 85% Overhead Press x5 @ 65% x5 @ 75% x5 @ 85% | Rings: pull up and dip One-legged squats | Back Squat x5 @ 65% x5 @ 75% x5 @ 85% Weighted/assist pull up x5 @ 65% x5 @ 75% x5 @ 85% |
| WOD | <u>For time:</u> 50 bodyweight squat 1 flight stairs 100 double under 25 burpees 50 double under 25 burpees 100 double under 1 flight stairs 50 bodyweight squat | <u>12 min AMRAP:</u> 7 pull-ups 14 front squat #95 males #65 females 21 push-ups w/ release | <u>For time:</u> 30 clean & jerk #135 male #95 female | <u>For time:</u> x21 KB swing x21 ring dip x15 KB swing x15 ring dip x9 KB swing #70 KB for males #53 KB for females x9 ring dip | <u>3 rounds for time:</u> 1 minute rest between rounds. 5 wide-grip deadlift and high pull 5 squat press #135 for males #95 for females 5 pull-ups |
| Week #1 | | | | | |

| | Monday | Tuesday | Wednesday | Thursday | Friday |
|----------------|---|---|--|---|---|
| Strength/Skill | Back squat 5 sets x5 @ 65% | Deadlift 7 sets x2 @ 60% | Bench press 7 sets x3 @ 75% | 15 min power cleans #135 male #95 female | Front squat x5 @ 65% x3 @ 75% x1 @ 85% |
| WOD | <u>20 min AMRAP:</u> x5 pull-ups x10 body weight squat x20 double-unders | <u>10 min AMRAP:</u> 4 HSPU 8 deadlifts #225 males #135 females 16 KB swing #53 KB for males #35 for females | <u>4 rounds:</u> 30 split jumps 10 squat press #95 males #65 females) 20 push-ups | <u>18 min AMRAP:</u> 15 box jumps 24" males 20" females 12 overhead presses #115 males #75 females 9 toes-to-bar | <u>5 rounds for time:</u> 3 minute rest between rounds. 20 pull-ups 30 push-ups 40 sit-ups 50 air squats |
| Week #7 | | | | | |

Figure 1. Representative sample of HIPT training protocol. AMRAP = as many rounds as possible; double-unders = two jump rope passes per jump; HS = hand stand; HSPU = hand stand push-up; HSW = hand stand walk; KB = kettlebell. Percentages listed as relative to participants' 1-repetition maximum.

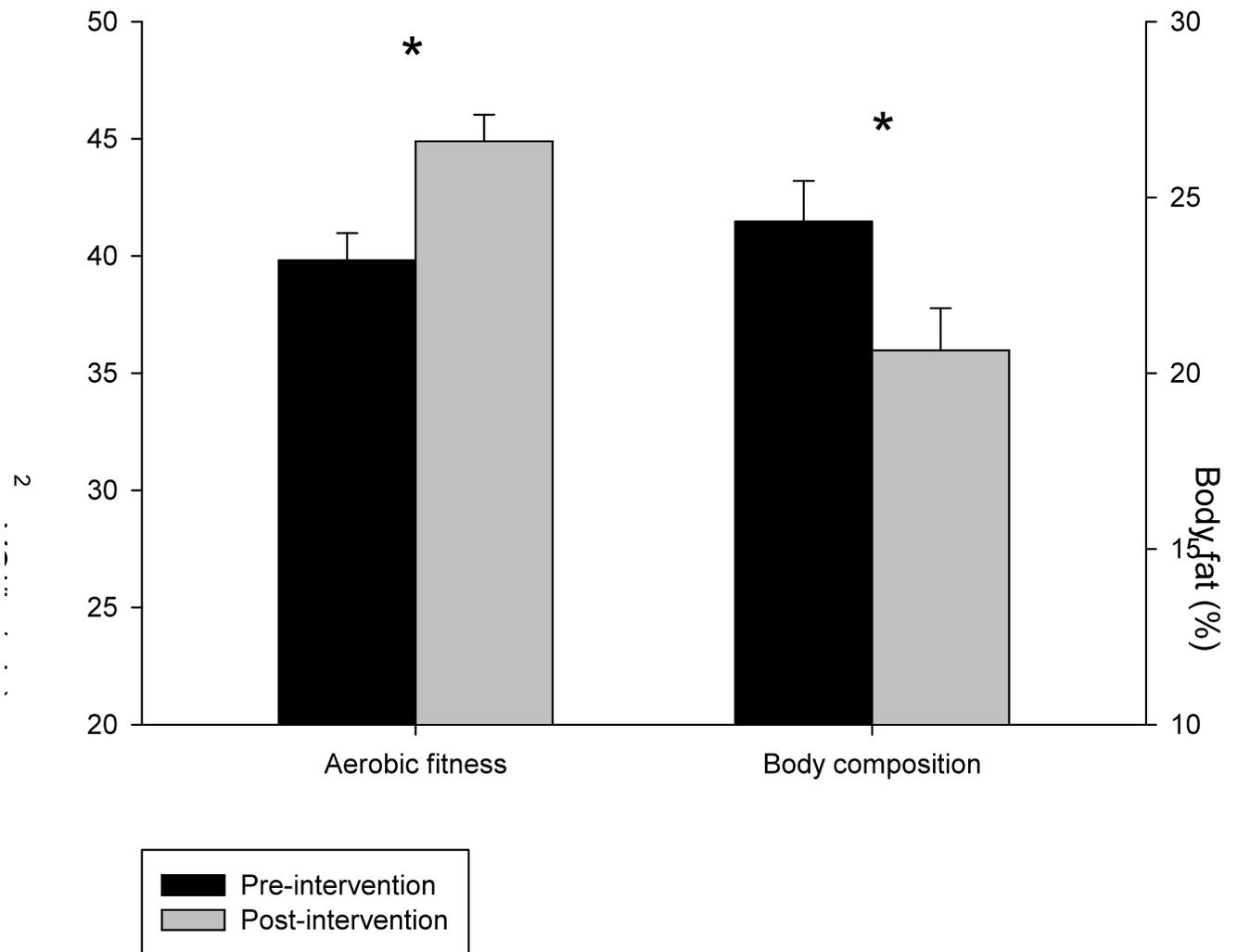


Figure 2. Maximal aerobic fitness and body composition improvements following a 10 week HIPT intervention. Following training, VO2max increased and body fat percentage decreased significantly. * $P < 0.05$.

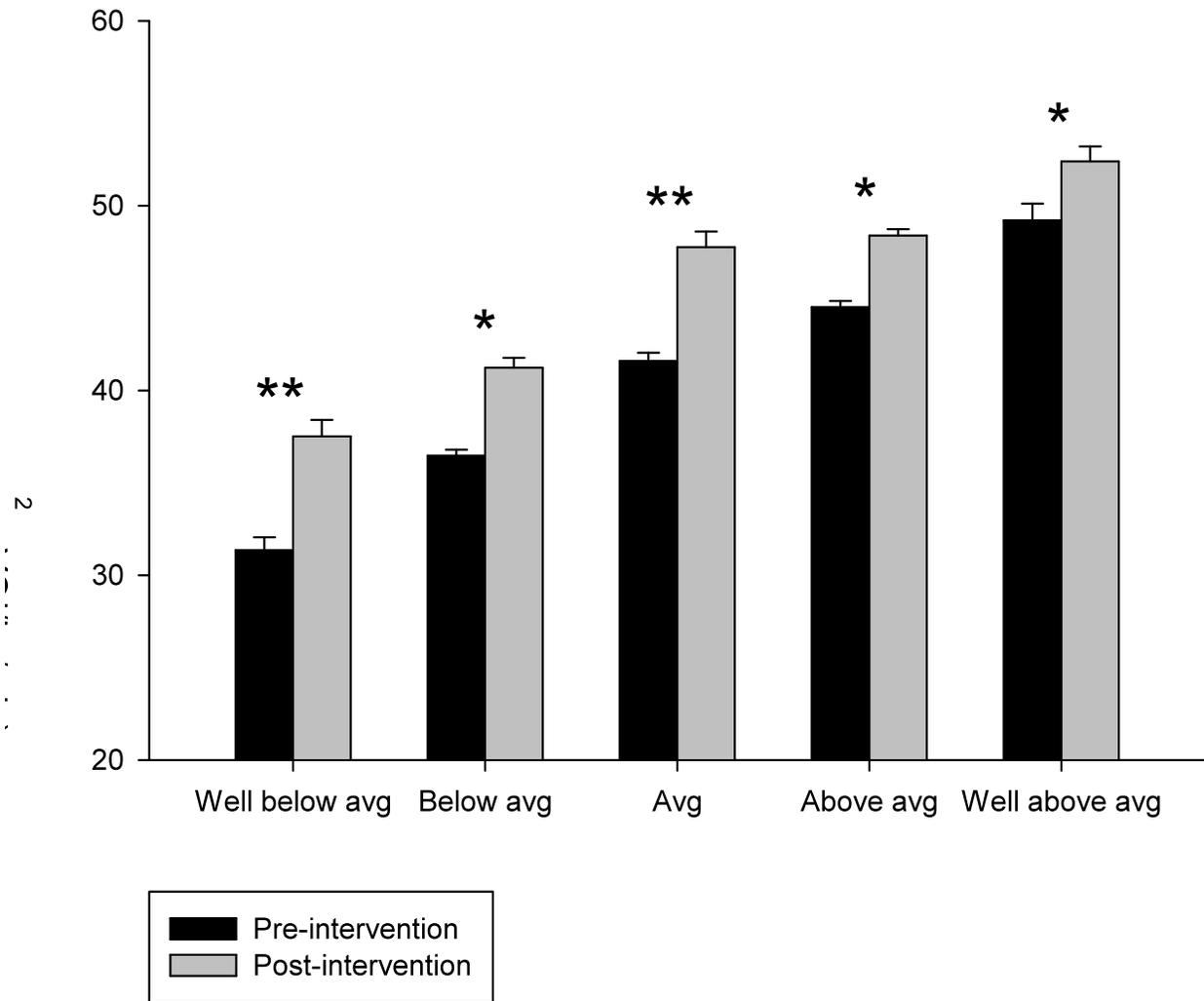


Figure 3. Changes in maximal relative aerobic fitness following a 10 week HIPT intervention. When broken into quantiles of initial aerobic fitness scaled to body weight, a significant increase of VO2max from baseline was observed in all groups. ** $P < 0.01$; * $P < 0.05$.

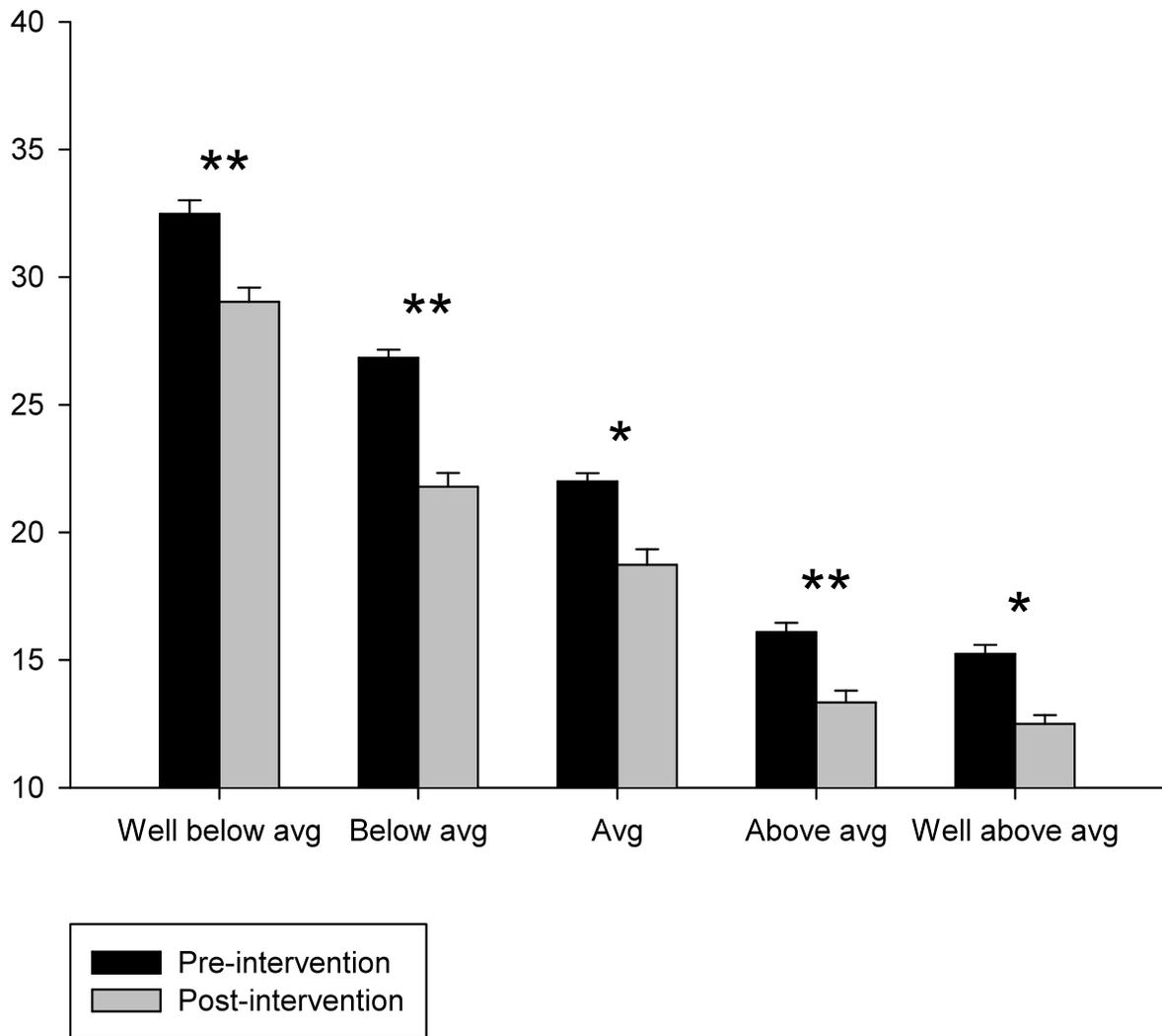


Figure 4. Changes in maximal body composition following a 10 week HIPT intervention. When broken into quantiles of initial body composition, a significant decrease from baseline was observed in all groups. ** $P < 0.01$; * $P < 0.05$.

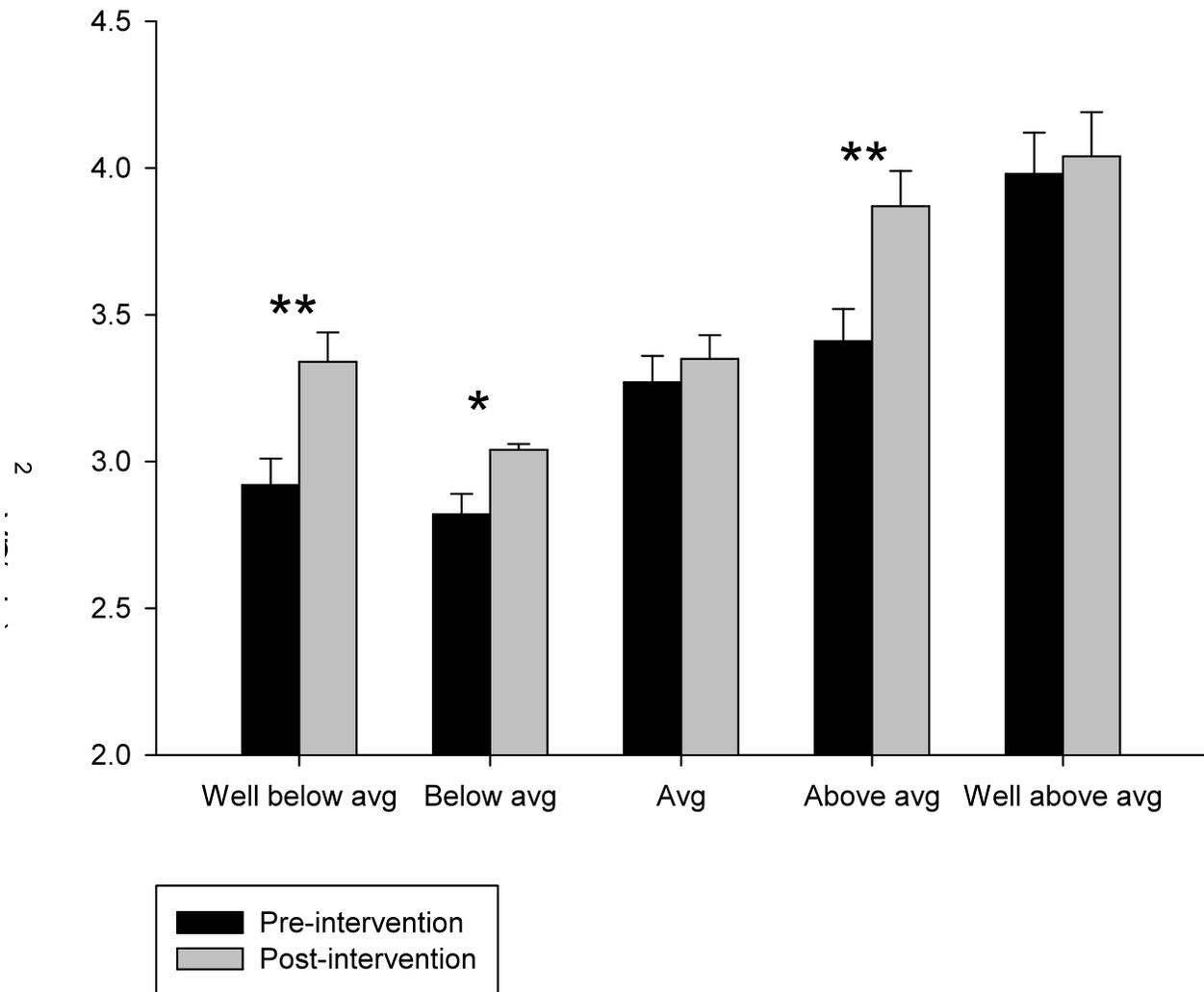


Figure 5. Changes in absolute maximal aerobic fitness following a 10 week HIPT intervention. When broken into quantiles of initial absolute aerobic fitness, a significant increase of VO₂max from baseline was observed the “Well below avg, Below avg, and Above avg” groups. ** $P < 0.01$; * $P < 0.05$.

Table 1. Subject characteristics

| | Males (n=23) | Females (n=20) | Range |
|---------------------------------|---------------------|-----------------------|----------------|
| Age (years) | 33.9 ± 1.6 | 31.2 ± 1.3 | 21.0 – 48.0 |
| Height (in) | 70.6 ± 0.6 | 64.8 ± 0.6 | 60.0 – 77.0 |
| Weight (kg) | 90.71 ± 2.67 | 68.02 ± 3.00 | 44.54 – 118.18 |
| BMI (kg/m ²) | 28.1 ± 0.6 | 25.1 ± 1.1 | 19.1 – 37.4 |
| Body fat (%) | 22.2 ± 1.3 | 26.6 ± 2.0 | 10.7 – 46.1 |
| Lean mass (kg) | 70.25 ± 1.76 | 49.00 ± 1.10 | 36.35 – 82.17 |
| VO ₂ max (L/min) | 3.88 ± 0.13 | 2.39 ± 0.09 | 1.47 – 5.12 |
| VO ₂ max (ml/kg/min) | 43.10 ± 1.40 | 35.98 ± 1.60 | 20.00 – 58.00 |

BMI = body mass index; in = inches; kg = kilograms; VO₂max = maximal oxygen consumption. All data are resting values and is presented as mean ± SEM.

Table 2. Adaptations in male subjects following 10 weeks HIPT

| | Pre-training | Post-training | P value |
|---------------------------------|---------------------|----------------------|----------------|
| Weight (kg) | 90.71 ± 2.67 | 87.25 ± 2.58 | 0.0008 |
| BMI (kg/m ²) | 28.1 ± 0.6 | 27.0 ± 0.6 | 0.0006 |
| Body fat (%) | 22.2 ± 1.3 | 18.0 ± 1.3 | 0.000002 |
| Lean mass (kg) | 70.25 ± 1.76 | 71.23 ± 1.87 | 0.001 |
| VO ₂ max (L/min) | 3.88 ± 0.13 | 4.23 ± 0.13 | 0.001 |
| VO ₂ max (ml/kg/min) | 43.10 ± 1.40 | 48.96 ± 1.42 | 0.000004 |

BMI = body mass index; kg = kilograms; VO₂max = maximal oxygen consumption. All data are resting values and is presented as mean ± SEM.

Table 3. Adaptations in female subjects following 10 weeks HIPT

| | Pre-training | Post-training | P value |
|---------------------------------|---------------------|----------------------|----------------|
| Weight (kg) | 68.02 ± 3.00 | 66.23 ± 2.70 | 0.01 |
| BMI (kg/m ²) | 25.1 ± 1.1 | 24.4 ± 1.0 | 0.01 |
| Body fat (%) | 26.6 ± 2.0 | 23.2 ± 2.0 | 0.00008 |
| Lean mass (kg) | 49.00 ± 1.1 | 50.06 ± 1.2 | 0.01 |
| VO ₂ max (L/min) | 2.39 ± 0.09 | 2.62 ± 0.1 | 0.005 |
| VO ₂ max (ml/kg/min) | 35.98 ± 1.60 | 40.22 ± 1.62 | 0.0006 |

BMI = body mass index; kg = kilograms; VO₂max = maximal oxygen consumption. All data are resting values and is presented as mean ± SEM.

Table 4. Multivariate regression analyses model for $\Delta\text{VO}_2\text{max}$ (ml/kg/min)

| Gender | Variables | $\beta \pm \text{SEM}$ | P | R² |
|---------------|---|--|----------|----------------------|
| Male | Δ Absolute VO_2max (L/min) | 12.50 \pm 1.05 | 0.001 | 0.88 |
| | Δ Body fat (%) | -0.67 \pm 0.12 | 0.001 | |
| Female | Δ Absolute VO_2max (L/min) | 13.62 \pm 1.06 | 0.001 | 0.91 |
| | Δ Body fat (%) | -0.32 \pm 0.19 | 0.100 | |

Model was built using changes of absolute vo2max and body fat against changes in relative VO2max in both genders.

Table 5. Correlation matrix for $\Delta\text{VO}_2\text{max}$ (ml/kg/min)

| Gender | Variables | Δ AbsVO₂max (L/min) | ΔLM (kg) | ΔBF (%) | ΔWeight (kg) |
|---------------|---|---|---------------------------------------|--------------------------------------|---|
| Male | $\Delta\text{VO}_2\text{max}$ (ml/kg/min) | 0.83** | 0.05 | -0.49* | -0.24 |
| Female | $\Delta\text{VO}_2\text{max}$ (ml/kg/min) | 0.94** | 0.05 | -0.07 | 0.01 |

Δ AbsVO₂max = change in absolute VO₂max from pre- to post-training values; $\Delta\text{VO}_2\text{max}$ = change in relative VO₂max from pre- to post-training values; BF = body fat percentage; LM = lean mass; ** $P < 0.001$, * $P < 0.05$