CrossFit-Based High-Intensity Power Training Improves Maximal Aerobic Fitness and Body Composition

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Abstract

Smith, MM, Sommer, AJ, Starkoff, BE, and Devor, ST. Crossfit-based high-intensity power training improves maximal aerobic fitness and body composition. *J Strength Cond Res* 27(11): 3159–3172, 2013–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 men, 20 women) 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 ($\dot{V}O_2$max) was measured by analyzing expired gasses during a Bruce protocol maximal graded treadmill test. These variables were measured again after 10 weeks of training and compared for significant changes using a paired *t*-test. Results showed significant ($p < 0.05$) improvements of $\dot{V}O_2$max in men (43.10 ± 1.40 to 48.96 ± 1.42 ml·kg^{-1}·min^{-1}) and women (35.98 ± 1.60 to 40.22 ± 1.62 ml·kg^{-1}·min^{-1}) and decreased body fat percentage in men (22.2 ± 1.3 to 18.0 ± 1.3) and women (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 that HIPT improved $\dot{V}O_2$max scaled to body weight independent of changes to body composition. Our data show that HIPT significantly improves $\dot{V}O_2$max and body composition in subjects of both genders across all levels of fitness.

Key Words interval training, aerobic fitness, body composition, crossfit, power training

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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 with 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 uses 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, hand-stands, 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 ($\dot{V}O_2$max) and body composition.

Although HIIT has been shown to improve body composition (13) and $\dot{V}O_2$max (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 $\dot{V}O_2$max or body composition in response to this

	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	*For time:* 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	*12 min AMRAP:* 7 pull-ups 14 front squat #95 men #65 women 21 push-ups w/ release	*For time:* 30 clean & jerk #135 men #95 women	*For time:* x21 KB swing x21 ring dip x15 KB swing x15 ring dip x9 KB swing #70 KB for men #53 KB for women x9 ring dip	*3 rounds for time:* 1 min rest between rounds. 5 wide-grip deadlift and high pull 5 squat press #135 for men #95 for women 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 men #95 women	Front squat x5 @ 65% x3 @ 75% x1 @ 85%
WOD	*20 min AMRAP:* x5 pull-ups x10 body weight squat x20 double-unders	*10 min AMRAP:* 4 HSPU 8 deadlifts #225 men #135 women 16 KB swing #53 KB for men #35 for women	*4 rounds:* 30 split jumps 10 squat press #95 men #65 women 20 push-ups	*18 min AMRAP:* 15 box jumps 24" men 20" women 12 overhead presses #115 men #75 women 9 toes-to-bar	*5 rounds for time:* 3 min rest between rounds. 20 pull-ups 30 push-ups 40 sit-ups 50 air squats
Week #7					

Figure 1. Representative sample of high-intensity power training protocol. AMRAP = as many rounds as possible; double-unders = 2 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.

style of training. Therefore, our aim was to determine if an HIPT training regimen could yield significant improvements to $\dot{V}O_2$max 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 $\dot{V}O_2$max and body composition in healthy adult volunteers. Furthermore, we hypothesized that improvements of $\dot{V}O_2$max and body composition would be found across all levels of initial aerobic fitness and body

Table 1. Complete WOD list for 10 weeks of HIPT training.*

Date	Strength/skill	WOD	Notes
Week 1			
1/9/2012	Back squat, 3 × 5	For best time:	95 lbs For men, 65 lbs for women for thrusters
	5 @ 65% 1RM	50 Air squat	15:00 Time limit
	5 @ 75% 1RM	3 Flight stairs	
	5 @ 85% 1RM	100 Double under jump rope	
		25 Burpees	
	Assist pull-up	50 Double under jump rope	
	5 @ 65% 1RM	25 Burpees	
	5 @ 75% 1RM	100 Double under jump rope	
	5 @ 85% 1RM	3 Flight stairs	
		50 Air squat	
1/10/2012	10-min "double unders"	AMRAP 12 min:	HS; for novices
	10-min HSW/HSPU/HS	7 Pull-ups	HSPU; for intermediates
	1-mile Run for best time	14 Front squat	HSW; for advanced
		21 Push-ups with release	
1/11/2012	Deadlift	For best time:	As many 3RM as possible in 20 min
	5 @ 65% 1RM	30 Clean and jerk	135 lbs For male, 95 lbs female
	5 @ 75% 1RM		
	5 @ 85% 1RM		
1/12/2012	Ring work 10 min	21 Kettle bell swings	70-lb Kettle bell for men, 53-lb kettle bell for women
	Pull-ups and dips	21 Ring dips	
		15 Kettle bell swing	
		15 Ring dips	
		9 Kettle bell swings	
		9 Ring dips	
1/13/2012	Back squat	3 Rounds for time:	
	5 @ 65% 1RM	5 Wide grip deadlift/high pull	135 lbs For men, 95 lbs women
	5 @ 75% 1RM	5 Squat press	
	5 @ 85% 1RM	5 Pull-ups	
	Assist pull-ups		
	5 @ 65% 1RM		
	5 @ 75% 1RM		
	5 @ 85% 1RM		
Week 2			
1/16/2012	Thrusters 5 @ 85% 1RM	"Fran" for best time:	
		21 Thrusters	
		21 Pull-ups	
		15 Thrusters	
		15 Pull-ups	
		9 Thrusters	
1/17/2012	10-min HSW/HSPU/HS	AMRAP 12 min:	HS for novices, HSPU for intermediate, HSW for advanced
		7 Pull-ups	
		14 Front squats	95 lbs For men, 65 lbs for women for squats

		21 Push-ups with release	
1/18/2012	Deadlift, 3 × 5	30 High hang power clean and jerks	135 lbs For men, 95 lbs for women
	5 @ 65% 1RM		
	5 @ 75% 1RM		
	5 @ 85% 1RM		
	Overhead press, 3 × 5		
	5 @ 65% 1RM		
	5 @ 75% 1RM		
	5 @ 85% 1RM		
1/19/2012	10-min Muscle up practice	"Angie" in reverse, for time:	20-min Max time limit
	10-min Pistol squat practice	100 Body weight air squats	
		100 Sit-ups	
		100 Push-ups	
		100 Pull-ups	
1/20/2012	Back squat, 3 × 5	3 Rounds, 1-min rest between rounds:	
	5 @ 65% 1RM	5 Reps Sumo deadlift high pull	135 lbs For male, 95 lbs for female
	5 @ 75% 1RM	5 Reps thruster	135 lbs For male, 95 lbs for female
	5 @ 85% 1RM	5 Pull-ups	
	Weighted pull-up		
	5 @ 65% 1RM		
	5 @ 75% 1RM		
	5 @ 85% 1RM		
Week 3			
	Deadlift, 3 sets × 3 reps	AMRAP, 20 min	
1/23/2012	3 @ 70% 1RM	10 High hang power cleans	60% of 1RM for power cleans
	3 @ 80% 1RM	10 Toe to bar	
	3 @ 90% 1RM	10 Burpees	
	Overhead press, 3 sets × 3 reps		
	3 @ 70% 1RM		
	3 @ 80% 1RM		
	3 @ 90% 1RM		
1/24/2012	Advanced: muscle ups	3 Rounds for time:	
	4 Sets of 1RM	400-m Run	
		15 Pull-ups	
	Beginner: ring push-ups	30 Side lunges w/dowel overhead	
	4 Sets of 1RM		
1/25/2012	Back squat, 3 sets × 3 reps		
	3 @ 70% 1RM		
	3 @ 80% 1RM		
	3 @ 90% 1RM		
	Pull-ups	3 Rounds for time:	
	5 @ 70% 1RM	20 Back squats	135 lbs For men, 95 lbs for women
	3 @ 80% 1RM	6 Flights of stairs	
	3 @ 90% 1RM		
1/26/2012	10-min Practice snatch form	21 Reps high hang power snatch	95 lbs For men, 65 lbs for women
	10-min HSW/HSPU/HS	21 Reps wall ball	10' Distance from wall, 20 lbs for men, 14 lbs for women
		15 Reps high hang power snatch	
		15 Reps wall ball	
		9 Reps high hang power snatch	
		9 Reps wall ball	
1/27/2012	Hang power clean, 3 sets × 3 reps	30 Double unders	

	3 @ 70% 1RM	21 Deadlift	185 lbs For men, 115 lbs for women
	3 @ 80% 1RM	21 Box jumps	24" For men, 20" for women
	3 @ 90% 1RM	30 Double unders	
		15 Deadlifts	
	Push press, 3 sets	15 Box jumps	
	5 @ 70% 1RM	30 Double unders	
	3 @ 80% 1RM	9 Deadlifts	
	3 @ 90% 1RM	9 Box jumps	
Week 4			
1/30/2012	3 Sets back squat	Every 30 s until fatigue:	185 lbs For men, 115 lbs for women
	5 @ 75% 1RM	1 Power clean	
	3 @ 85% 1RM	1 High hang power clean	
	1 @ 95% 1RM	1 Push jerk	
	Pull-ups		
	5 @ 75% 1RM		
	3 @ 85% 1RM		
	1 @ 95% 1RM		
1/31/2012	Rest	For time:	For novice: substitute burpee for double unders
		50 Double unders	
		50 Sit-ups	
		40 Double unders	
		40 Sit-ups	
		30 Double unders	
		30 Sit-ups	
		20 Double unders	
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		20 Sit-ups	
		30 Double unders	
		30 Sit-ups	
		40 Double unders	
		40 Sit-ups	
		50 Double unders	
		50 Sit-ups	
2/1/2012	3 Sets deadlift	5 Rounds for best time:	155 lbs For men, 95 lbs for women
	5 @ 75% 1RM	12 Deadlifts	
	3 @ 85% 1RM	9 High hang power clean	
	1 @ 95% 1RM	6 Push jerk	
	3 Sets overhead press		
	5 @ 75% 1RM		
	3 @ 85% 1RM		
	1 @ 95% 1RM		
2/2/2012	Gymnastics ring work:	1 Round for time:	Ring work done for form and at the skill level of each individual
	Toes to rings	1,000-m Run	
	Lever hang	50 Kettle bell swings	53-lb Kettle bell for women, 35-lb Kettle bell for men

	Lever pull-up Muscle up Dip Lever sit Forward roll Back lever	100 Body weight squats	
2/3/2012	3 Sets front squat 5 @ 75% 1RM 3 @ 85% 1RM 1 @ 95% 1RM 3 Sets pull-up 5 @ 75% 1RM 3 @ 85% 1RM 1 @ 95% 1RM	For best time: 10 Reps front squat 15' Rope climb 9 Reps front squat 15' Rope climb 8 Reps front squat 15' Rope climb 7 Reps front squat 15' Rope climb 6 Reps front squat 15' Rope climb 5 Reps front squat	135 lbs For men, 95 lbs for women
Week 5			
2/6/2012	Snatch technique practice 10 min (no load or rep requirement)	3 Rounds for best time: 15 Reps deadlift @ 60% of 1RM 15 Knees to elbows	
2/7/2012	Turkish getup technique practice 10 min (no load or rep requirement) Pull-up technique practice 10 min (no load or rep requirement)	2 Rounds for best time: 12 Chest to bar pull up 12 Box jumps 9 Chest to bar pull-up 9 Box jumps 6 Chest to bar pull-ups 6 Box jumps	Assist bands used for novice 24" Box for men, 20" box for women
2/8/2012	Jerk technique practice 10 min (no load or rep requirement)	For best time: 21 Squat cleans 21 Push-up with release 15 Squat cleans 15 Push-up with release 9 Squat cleans 9 Push-up with release	95 lbs For men, 65 lbs for women
2/9/2012	Muscle up technique practice 10 min (no load or rep requirement)	For best time: 5 Muscle ups 30 Kettle bell swings 4 Muscle ups 25 Kettle bell swings 3 Muscle ups 20 Kettle bell swings 2 Muscle ups 15 Kettle bell swings 1 Muscle up 10 Kettle bell swings	As little assistance as possible given during muscle ups Novice men: 53-lb kettle bells Advanced men: 70-lb kettle bells Novice women: 35-lb kettle bells Advance women: 53-lb kettle bells
2/10/2012	Overheat squat technique 10 min (no load or rep requirement)	3 Rounds for best time: 30 Double unders	

		10 Overhead squats	95 lbs For men, 65 lbs for women
		10 HSPU	HS/HSW for novice and intermediates
		1 Flight of stairs	
Week 6			
2/13/2012	3 Sets of back squats 5 Reps @ 75% 1RM	8 Rounds for max reps: 20-s Deadlift 1RM 10-s Rest 20-s HSPU 10-s Rest	HS substituted for novice
2/14/2012	Rest	AMRAP in 20 min 3 Burpees 5 Pull-ups	
2/15/2012	3 Sets power clean 5 Reps @ 75% 1RM	Rest	
2/16/2012	Rest	Rest	
2/17/2012	3 Sets overhead squat 5 Reps @ 75% 1RM	Rest	
Week 7			
2/20/2012	5 Sets back squat 5 Reps @ 65% 1RM	AMRAP in 20 min 5 Pull-ups 10 Body weight squat 20 Double unders	
2/21/2012	7 Sets deadlift 2 Reps @ 60% 1RM	AMRAP in 10 min 4 HSPU 8 Deadlifts	225 lbs For men, 135 lbs for women
		16 Kettle bell swings	53 lb Kettle bell for men, 35 lb kettle bell for women
2/22/2012	7 Sets bench press 3 Reps @ 75% 1RM	4 Rounds for best time: 30 Split jumps 10 Squat press 20 Push-ups	95 lbs For men, 65 lbs for women
2/23/2012	Power clean practice, 15 min 135 lbs For male, 95 lbs female	18-min AMRAP: 15 Box jumps	24" Box for men, 20" box for women
		12 Overhead presses	115 lbs For men, 75 lbs for women
		9 Toes to bar	
2/24/2012	3 Sets front squats 5 Reps @ 65% 1RM 3 Reps @ 75% 1RM 1 Rep @ 85% 1RM	5 Rounds for best time: 20 Pull-ups 30 Push-ups 40 Sit-ups 50 Body weight squats 30-min Rest between rounds	
Week 8			
2/27/2012	3 Sets back squats 5 Reps @ 65% 1RM 3 Reps @ 75% 1RM 1 Rep @ 85% 1RM	For best time: 15 Thrusters 15 Pull-ups 12 Thrusters 12 Pull-ups 9 Thrusters 9 Pull-ups 12 Thrusters	

		12 Pull-ups 15 Thrusters 15 Pull-ups	
2/28/2012	Pistol and HSPU drills: HSW	AMRAP 15 min: 9 Deadlifts	155 lbs for men, 100 lbs for women
	Parallettes DB presses	12 Push-ups with release 15 Box jumps	24" Box for men, 20" box for women
	Wall walks Shoulder touches (no load or rep requirement)		
2/29/2012	3 Sets, 5 reps bench press for form	5 Rounds for time: 15' Rope climb 10 Wall ball	10' Distance from wall, 20 lbs for men, 14 lbs for women
		15 Toes to bar 20 Kettle bell swings	53 lbs For men, 35 lbs for women
3/1/2012	10-min Power snatch practice	10-min AMRAP 75/45-lb Snatch, 30 reps 135/75-lb Snatch, 30 reps 165/100-lb Snatch, 30 reps 210/120-lb Snatch, as many as possible	Men/women
3/2/2012	3 Sets front squat 5 Reps @ 65% 1RM 3 Reps @ 75% 1RM 1 Rep @ 85% 1RM	Rest	
Week 9			
3/5/2012	Low bar back squat 5 Sets, 5 reps @ 65% 1RM	AMRAP 20 min: 5 Pull-ups 10 Body weight squats 20 Double unders	
3/6/2012	HSPU practice, 10 min Deadlifts 7 sets, 2 reps @ 55% 1RM (work on form)	AMRAP 10 min 4 HSPU 8 Deadlifts	HS for novice 225 lbs For men, 135 lbs women
		16 Kettle bell swings	53 lbs Men, 35 lbs women
3/7/2012	Bench press 7 Sets, 3 reps @ 65% 1RM	Not for time: 4 Rounds 30 Split jumps 10 Thrusters	95 lbs Men, 65 lbs women
		20 Push-ups	
3/8/2012	Rest	AMRAP 18 min: 15 Box jumps	24" Box for men, 20" box for women
		12 Push presses	115 lbs For men, 75 lbs women
		9 Toes to bar	
3/9/2012	Rest	For best time: 5 Rounds, 3-min rest between rounds 20 Pull-ups 30 Push-ups 40 Sit-ups	

		50 Body weight squats	
Week 10			
3/12/2012	Low bar back squat	AMRAP 15 min:	
	3 Sets, 5 reps @ 50% 1RM	3 Reps hang clean	115 lbs For men, 75 lbs for women
	3 Sets, 5 reps @ 65% 1RM	3 Thrusters	
	3 Sets, 5 reps @ 75% 1RM	3 Rope climbs	
	3 Sets, 5 reps @ 85% 1RM		
3/13/2012	Bench press		
	3 Sets, 5 reps @ 50% 1RM		
	3 Sets, 5 reps @ 65% 1RM	4 Rounds for best time:	
	3 Sets, 5 reps @ 75% 1RM	5 Muscle ups	Assist for novices
	3 Sets, 5 reps @ 85% 1RM	30 Double unders	
		10 Dips	
3/14/2012	15-min Power cleans	7 Rounds for time:	
	Emphasis on form	10 Burpees	
		10 Clean high pulls	95 lbs For men, 65 lbs women
3/15/2012	Rest	AMRAP 12 min:	
		150 Wall ball	10 ft From wall, 20 lbs male, 14 lbs female
		90 Double unders	
		30 Muscle ups	Assist for novices
3/16/2012	Rest	3 Rounds for time:	
		800-m Run	
		50 Romanian deadlifts	45 lbs For men, 45 lbs women
		50 Sit-ups	

*AMRAP = as many rounds as possible; double-unders = 2 jump rope passes per jump; HS = hand stand; HSPU = hand stand push-up; HSW = hand stand walk; HIPT = high-intensity power training; KB = kettle bell; WOD = workouts of the day; RM = repetition maximum.

composition, not only in the cohorts of the lowest initial values of these markers.

Methods

Experimental Approach to the Problem

This study investigated the effect of a 10-week, crossfit-based, HIPT program on body composition and $\dot{V}O_2$max in healthy adults. Body composition using air displacement plethysmography and maximal aerobic capacity using a Bruce treadmill graded exercise test were assessed in all the subjects in the morning (7:30–11:30 AM) over a 5-day period preceding the onset of training. Measurements were obtained after an overnight fast, and the 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 $\dot{V}O_2$max. All returning subjects were assessed at the same time of the day as the pretraining measures over a 5-day period after the completion of the program.

Table 2. Subject characteristics.*†

	Men (n = 23)	Women (n = 20)	Range
Age (y)	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 ($kg \cdot m^{-2}$)	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
$\dot{V}O_2$max ($L \cdot min^{-1}$)	3.88 ± 0.13	2.39 ± 0.09	1.47–5.12
$\dot{V}O_2$max ($ml \cdot kg^{-1} \cdot min^{-1}$)	43.10 ± 1.40	35.98 ± 1.60	20.00–58.00

*BMI = body mass index; in. = inches; kg = kilograms; $\dot{V}O_2$max = maximal oxygen consumption.
†All data are resting values and are presented as mean ± *SEM*.

Subjects

The participants of all levels of aerobic fitness and body composition were recruited from and trained at a Crossfit affiliate (Fit Club, Columbus, OH,

Table 3. Adaptations in male subjects after the 10-week HIPT.*†

	Pretraining	Posttraining	*p*
Weight (kg)	90.71 ± 2.67	87.25 ± 2.58	0.0008
BMI ($kg \cdot m^{-2}$)	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
$\dot{V}O_2max$ ($L \cdot min^{-1}$)	3.88 ± 0.13	4.23 ± 0.13	0.001
$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	43.10 ± 1.40	48.96 ± 1.42	0.000004

*BMI = body mass index; $\dot{V}O_2max$ = maximal oxygen consumption; HIPT = high-intensity power training.
†All data are resting values and are presented as mean ± *SEM*.

Table 4. Adaptations in female subjects after 10-week HIPT.*†

	Pretraining	Posttraining	*p*
Weight (kg)	68.02 ± 3.00	66.23 ± 2.70	0.01
BMI ($kg \cdot m^{-2}$)	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
$\dot{V}O_2max$ ($L \cdot min^{-1}$)	2.39 ± 0.09	2.62 ± 0.1	0.005
$\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	35.98 ± 1.60	40.22 ± 1.62	0.0006

*BMI = body mass index; $\dot{V}O_2max$ = maximal oxygen consumption; HIPT = high-intensity power training.
†All data are resting values and are presented as mean ± *SEM*.

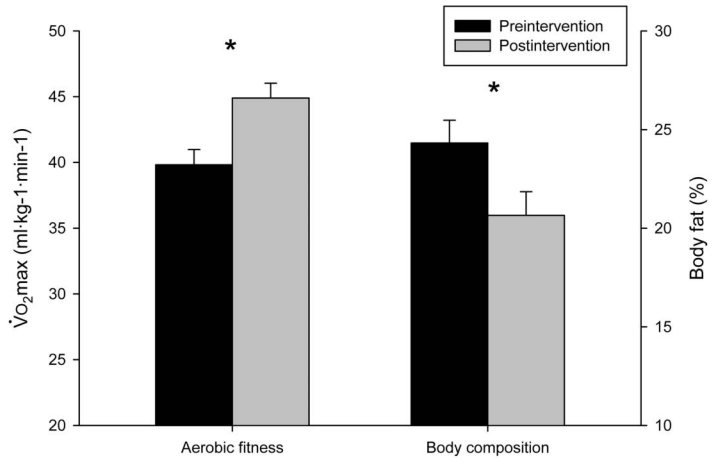

Figure 2. Maximal aerobic fitness and body composition improvements after a 10-week high-intensity power training intervention. After training, the $\dot{V}O_2max$ increased and body fat percentage decreased significantly. *$p < 0.05$.

USA). Out of the original 54 participants, a total of 43 (23 men, 20 women) fully completed the training program and returned for follow-up testing. Of the 11 subjects who dropped out of the training program, 2 cited time concerns with the remaining 9 subjects (16% of total recruited subjects) citing overuse or injury for failing to complete the program and finish follow-up testing. The subjects had already been following a "Paleolithic" type of diet before and after completion of the training protocol. All 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. The subjects participated in a crossfit-based HIPT program using basic gymnastic skills (hand stands, 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-repetition maximum). 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 AMRAP style in varying time domains ranging from 10 to 20 minutes. During the strength and skill portion of the exercise session, there was no prescribed recovery time, whereas during the WOD portion of the session,

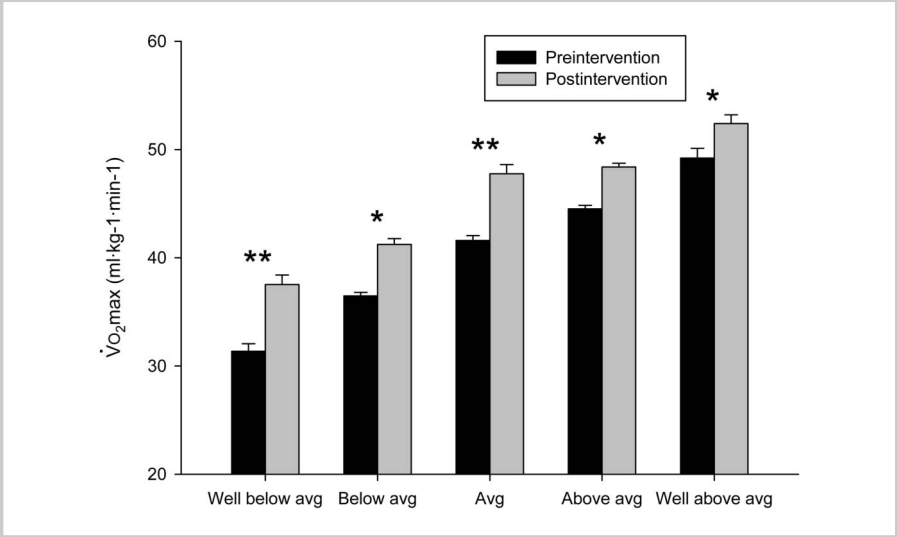

Figure 3. Changes in maximal relative aerobic fitness after a 10-week high-intensity power training intervention. When broken into quantiles of initial aerobic fitness scaled to body weight, a significant increase of the $\dot{V}O_2$max from baseline was observed in all groups. $^{**}p < 0.01$; $^{*}p < 0.05$.

the 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. The 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 1.

Body Composition. Percentage body fat was calculated using the Bod Pod air-displacement plethysmography device (Life Measurements Instruments, Concord, CA, USA), which is shown to be an accurate method for assessing body composition in adults (2). Before 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 the 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 was calculated as kilograms of body mass divided by height in meters squared.

Graded Exercise Testing. All the subjects performed a maximal treadmill exercise test before and after the training program using the Bruce protocol (4) to determine $\dot{V}O_2$max. The subjects wore nose clips and breathed into a 1-way mouthpiece, which allowed expired gases to be collected in a mixing chamber. The 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, USA), which provides accurate and reliable results compared with the Douglas bag method (6). Oxygen consumption values were calculated every 15 seconds, and the 2 highest consecutive values were averaged to determine absolute maximal oxygen consumption in liters per minute. Body weight was divided into absolute oxygen consumption to yield a value relative to body mass and is reported as relative $\dot{V}O_2$max in units of milliliters of O_2·per kilogram of body mass·per minute. The test was terminated and considered maximal when subjects reached self-

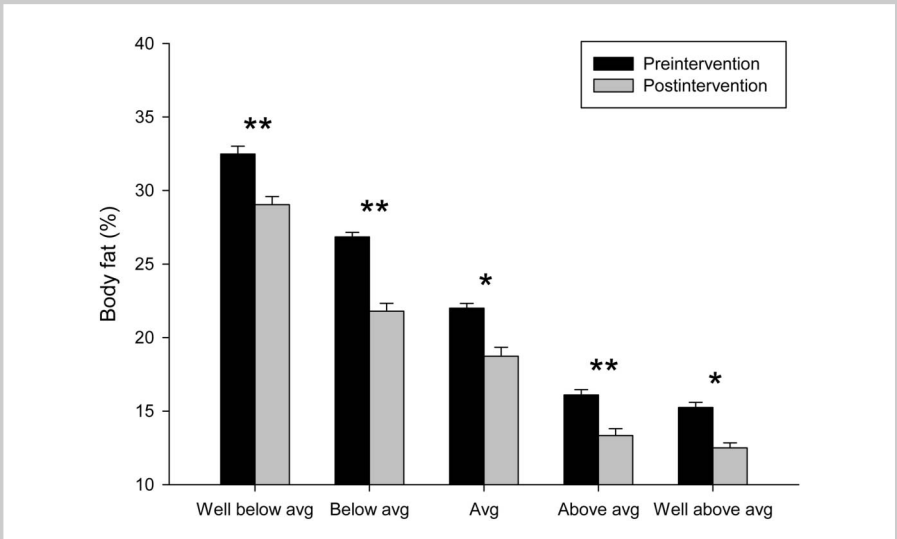

Figure 4. Changes in maximal body composition after a 10-week high-intensity power training intervention. When broken into quantiles of initial body composition, a significant decrease from baseline was observed in all groups. $^{**}p < 0.01$; $^{*}p < 0.05$.

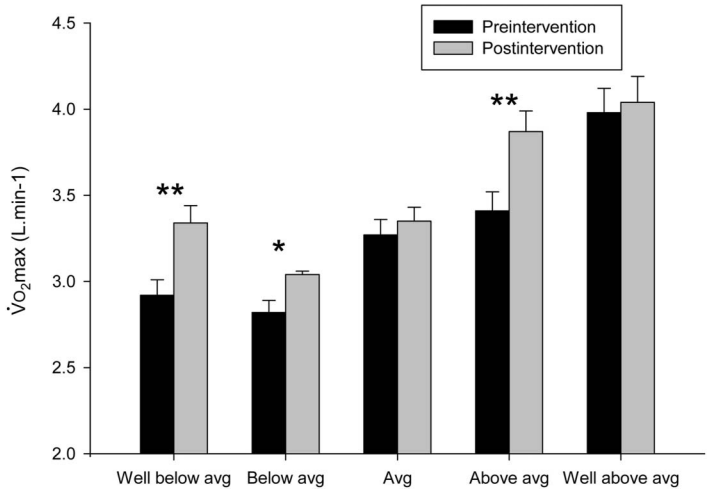

Figure 5. Changes in absolute maximal aerobic fitness after a 10-week high-intensity power training intervention. When broken into quantiles of initial absolute aerobic fitness, a significant increase of the $\dot{V}O_2max$ from baseline was observed in the "Well-below avg, Below avg, and Above avg" groups. $^{**}p < 0.01$; $^{*}p < 0.05$.

Table 5. Multivariate regression analysis model for $\Delta\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$).*

Gender	Variables	β ± *SEM*	*p*	R^2
Male	Δ Absolute $\dot{V}O_2max$ ($L \cdot min^{-1}$)	12.50 ± 1.05	0.001	0.88
	Δ Body fat (%)	−0.67 ± 0.12	0.001	
Female	Δ Absolute $\dot{V}O_2max$ ($L \cdot min^{-1}$)	13.62 ± 1.06	0.001	0.91
	Δ Body fat (%)	−0.32 ± 0.19	0.100	

*Model was built using changes of absolute $\dot{V}O_2max$ and body fat against changes in relative $\dot{V}O_2max$ in both genders.

Table 6. Correlation matrix for $\Delta\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$).*

Gender	Variables	Δ Abs$\dot{V}O_2max$ ($L \cdot min^{-1}$)	ΔLM (kg)	ΔBF (%)	ΔWeight (kg)
Male	$\Delta\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	0.83†	0.05	−0.49‡	−0.24
Female	$\Delta\dot{V}O_2max$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	0.94†	0.05	−0.07	0.01

*Δ Abs$\dot{V}O_2max$ = change in absolute $\dot{V}O_2max$ from pretraining to posttraining values; $\Delta\dot{V}O_2max$ = change in relative $\dot{V}O_2max\dot{V}O_2max$ from pretraining to posttraining values; BF = body fat percentage; LM = lean mass.
†$p < 0.001$.
‡$p < 0.05$.

determined exhaustion, and was verified by the 2 of following criteria: (a) plateau in oxygen consumption despite an increase in workload, (b) respiratory exchange ratio >1.1, and (c) rating of perceived exertion of 18–20. Using these parameters have previously shown to be a reliable method of verifying $\dot{V}O_2max$ has been attained, and provides statistically indistinguishable measurements compared with supramaximal testing (8). Metabolic sensors were recalibrated between each exercise test.

Statistical Analyses

Changes of $\dot{V}O_2max$ and body composition from pretraining to posttraining were tested using a 2-tailed, 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 the differences between pretraining and posttraining values of $\dot{V}O_2max$ and body composition. A forward stepwise multivariate linear regression was performed to identify significant predictors of relative $\dot{V}O_2max$. The model considered the following variables for inclusion: change in absolute $\dot{V}O_2max$ and body fat. Additionally, a linear regression analysis was performed, and Pearson correlation coefficients were calculated to determine the contribution of changes in total body weight,

lean mass, and absolute oxygen consumption to the observed increase in relative $\dot{V}O_2$max. Data are reported as mean ± *SEM*. Statistical analysis was performed using STATA (version 11.1, College Station, TX, USA). Statistical significance was defined a priori as the critical α-level of $p \leq 0.05$.

Results

Characteristics of the subjects who volunteered for the study are presented in Table 2. The mean and *SEM* of the variables before and after training for male subjects are presented in Table 3, and female subjects in Table 4. After the training program, a significant increase in the relative $\dot{V}O_2$max 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 (Figures 3 and 4). Improvement in the absolute $\dot{V}O_2$max was found in the well-below average, below average, and above average groups (Figure 5). A regression analysis revealed that the absolute $\dot{V}O_2$max and body fat percentage were significant predictors of the change in the relative $\dot{V}O_2$max in men ($p = 0.001$), but only absolute $\dot{V}O_2$max was a predictor of relative $\dot{V}O_2$max in women (Table 5). Furthermore, the improvement of maximal relative aerobic capacity could be explained by an increase in absolute oxygen consumption in men ($r = 0.83$, $p = 0.001$) and women ($r = 0.94$, $p = 0.001$), and was further informed by the correlation of a decrease in body fat in men only ($r = 0.49$, $p = 0.05$). This correlation analysis is presented in Table 6.

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. The results presented here confirm our hypothesis that a 10-week crossfit-based HIPT program significantly improves the maximal aerobic capacity and body composition in individuals of all fitness levels and genders. The improvement of the relative $\dot{V}O_2$max was strongly mediated by improvement of absolute oxygen consumption in women, and by improvement of absolute oxygen consumption and decreased body fat in men. Although the HIIT has previously been shown to improve body composition (13) and $\dot{V}O_2$max (14) in healthy adults, this is the first investigation showing that similar benefits can be obtained using a crossfit-based HIPT program.

After the HIPT training, body fat percentage dropped by 3.7%, across all individuals, in absolute terms. This reduction corresponds to a pretraining to posttraining 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 3 and 4 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 an 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 $\dot{V}O_2$max, 13.6 and 11.8%, respectively (Tables 3 and 4). As commonly understood, improvement of relative $\dot{V}O_2$max 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 $\dot{V}O_2$max, with a small contribution of the reduction of body fat percentage in men only. To our knowledge, this is the first report of improvement of relative and absolute $\dot{V}O_2$max in response to a crossfit-based HIPT training protocol.

Combining the quantiles to represent men and women, Tables 3 and 4 show a significant increase of absolute $\dot{V}O_2$max 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 $\dot{V}O_2$max. Astorino et al. reported >6% increase in absolute $\dot{V}O_2$max and 5.5% increase in relative $\dot{V}O_2$max, whereas Trulik et al. reported a 13.4% increase in relative $\dot{V}O_2$max in response to HIIT. Our finding that improvement of $\dot{V}O_2$max in subjects who are stratified as well above average is at odds with previous work using an HIIT protocol that finds no improvement of $\dot{V}O_2$max (5). Even HIIT studies in well-trained subjects using hyperoxia have previously failed to find an improvement of oxygen consumption in the subjects of comparably high $\dot{V}O_2$max (9,11). Compared with 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. Despite 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. Although 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 that HIPT can improve aerobic fitness independent of any concurrent weight loss. Although 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 $\dot{V}O_2$max. This increase in $\dot{V}O_2$max has not previously been documented in response to an HIIT program, indicating that HIPT may be a possible strategy for the 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. Despite 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. Although an aerobic training regimen based is primarily on long slow endurance workouts, for example (cycling and running for extended periods at moderate intensity $<$70% $\dot{V}O_2$max), 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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