High Intensity Interval Training: A Time Efficient Exercise Strategy for Promoting Health

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Exercise & Sport Science
Allied Health Science

Overview – High Intensity Interval Training

- What is it?
- What literature says
- Clinical Connections
- Real world application
- Recommendations


USA TODAY
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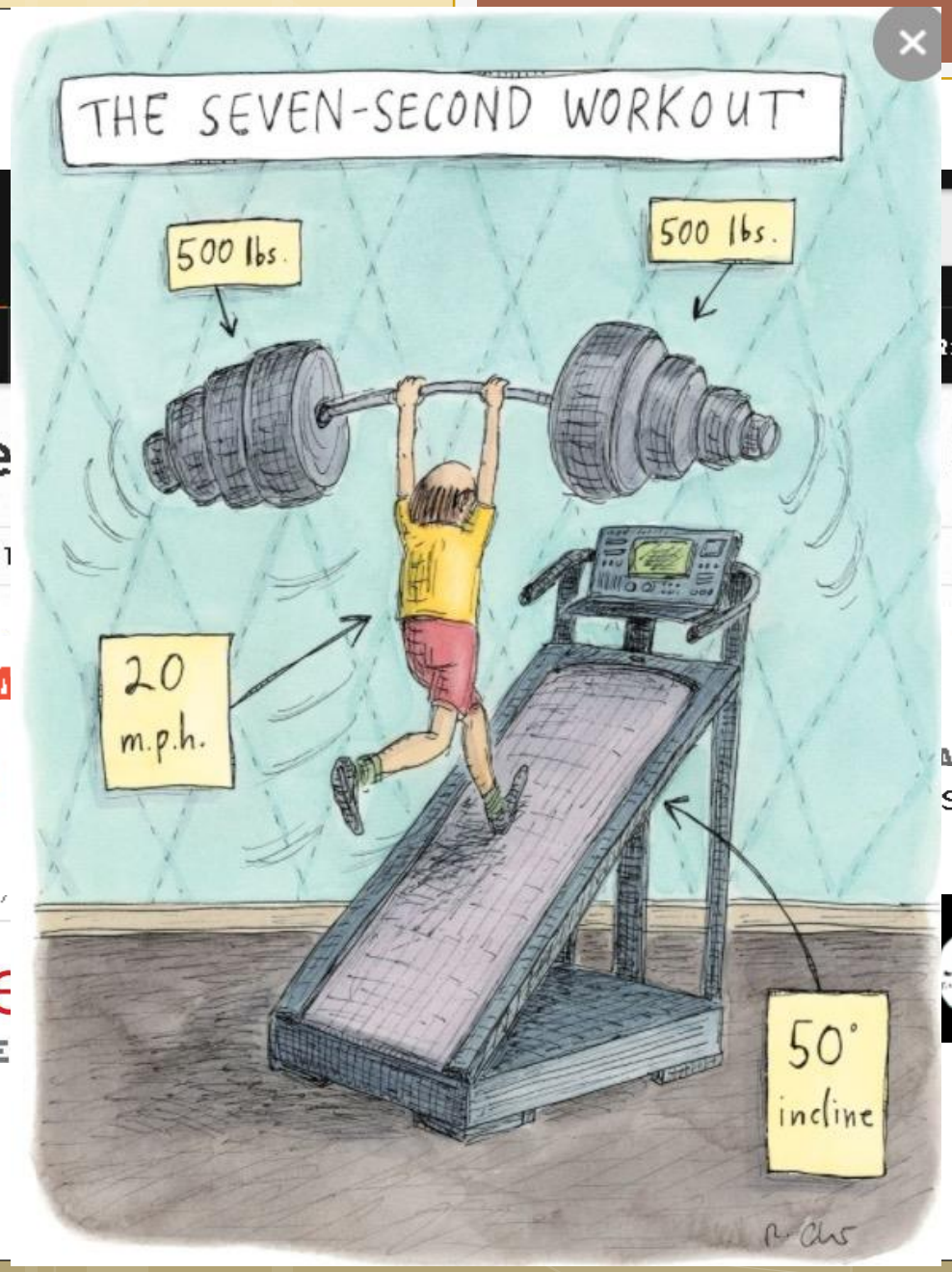
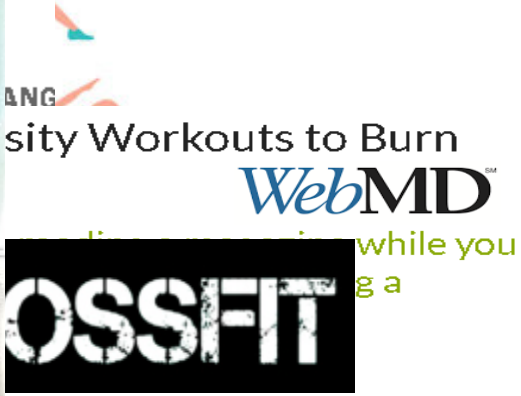

THE SEVEN-SECOND WORKOUT
500 lbs.
500 lbs.
20 m.p.h.
50° incline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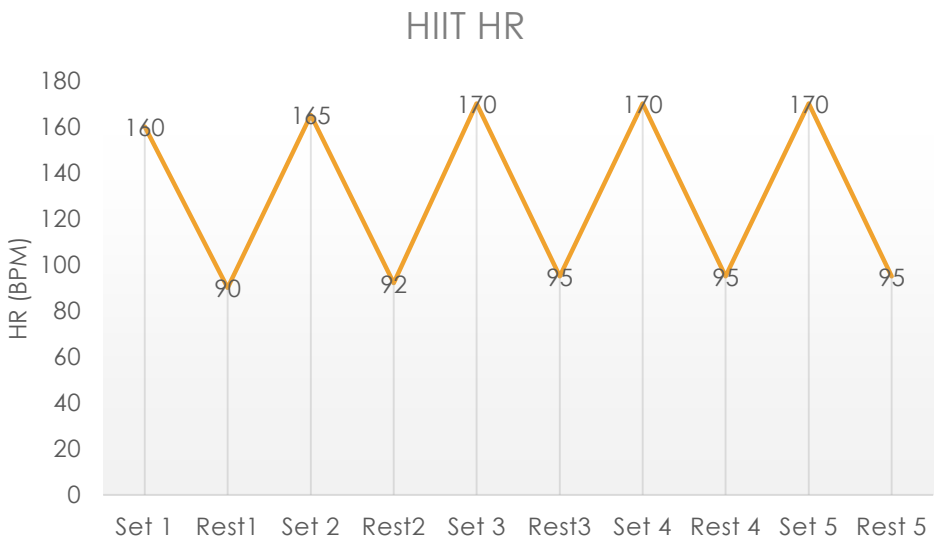
What is it?

- HIIT = short bursts of vigorous activity, interspersed by periods of rest/low-intensity
- Infinitely variable
- Physiological adaptations result from:
  - Intensity
  - Duration
  - #of intervals performed



High intensity interval trai

- Sprint Interval Training:
  - Wingate Repeated Sprint Style Training
    - 30 seconds all-out cycling against a high resi repetitions interspersed by 4 min.
    - Most commonly used protocol

- High intensity interval training:
  - 10 repetitions of 1 min work: 1 min rest
  - 5 repetitions of 2 min work: 1 min rest
  - 3-4 repetitions 4 min work: 3 min rest

Gillen & Gibala. Is high-intensity interval training a time-efficient exercise strategy to improve health and fitness? Appl Phys Nutr Metab. 2014.

What we know

- Most prevalent predictive factor for developing cardiovascular disease:
  - Low cardiorespiratory fitness (CRF)
- Lack of time is the most commonly cited reason for not exercising
- High intensity interval training (HIIT) is a time-efficient and effective method for rapid improvements in CRF and body composition.

Blair et al. Physical fitness and all-cause mortality. A prospective study of healthy men and women. JAMA 1989.

Weston et al. High intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis. BJSM 2014.

Booth et al. Waging war on modern chronic diseases: a primary prevention through exercise biology. JAP 2000.

Recommendations

Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise

AMERICAN COLLEGE of SPORTS MEDICINE

POSITION STAND

This pronouncement was written for the American College of Sports Medicine by Carol Ewing Garber, Ph.D., FACSM, (Chair); Bryan Blissmer, Ph.D.; Michael R. Deschenes, Ph.D., FACSM; Barry A. Franklin, Ph.D., FACSM; Michael J. Lamonte, Ph.D., FACSM; I-Min Lee, M.D., Sc.D., FACSM; David C. Nieman, Ph.D., FACSM; and David P. Swain, Ph.D., FACSM.

- Current Physical Activity Guidelines:
  - 150 minutes of moderate intensity aerobic activity/ week
  - Muscle Strengthening activities on 2+ days per week
  - OR 75 minutes of vigorous intensity activity/ week
  - *Greater health benefits: 300+ minutes (5 hours) per week

Centers for Disease Control and Prevention. Chronic Disease Prevention and Health Promotion.

Application

- Traditional endurance training = best way to improve CRF & lose weight?
  - General 12-week time frame
  - Metabolism actually decreased – mitochondrial efficiency
  - Maintenance or loss in lean body mass

  - Overuse injuries
  - Start slow

Garber et al. American College of Sports Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintain cardiorespiratory and muscular fitness. MSSE. 2011

Aerobic High-Intensity Intervals Improve $\dot{V}O_{2max}$ More Than Moderate Training

Med. Sci. Sports Exerc., Vol. 39, No. 4, pp. 665–671, 2007.

JAN HELGERUD[1,2], KJETILL HØYDAL[1], EIVIND WANG[1], TRINE KARLSEN[1], PÅLR BERG[1], MARIUS BJERKAAS[1],

- 40 young healthy active males
- Baseline VO_2max – CRF
  - Maximal HR for training
- Stroke Volume
- Treadmill Training – Matched for Work
  - Varying protocols: 15/15; 4 min
  - 3 days/ week for 8 weeks

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Med. Sci. Sports Exerc., Vol. 39, No. 4, pp. 665–671, 2007.

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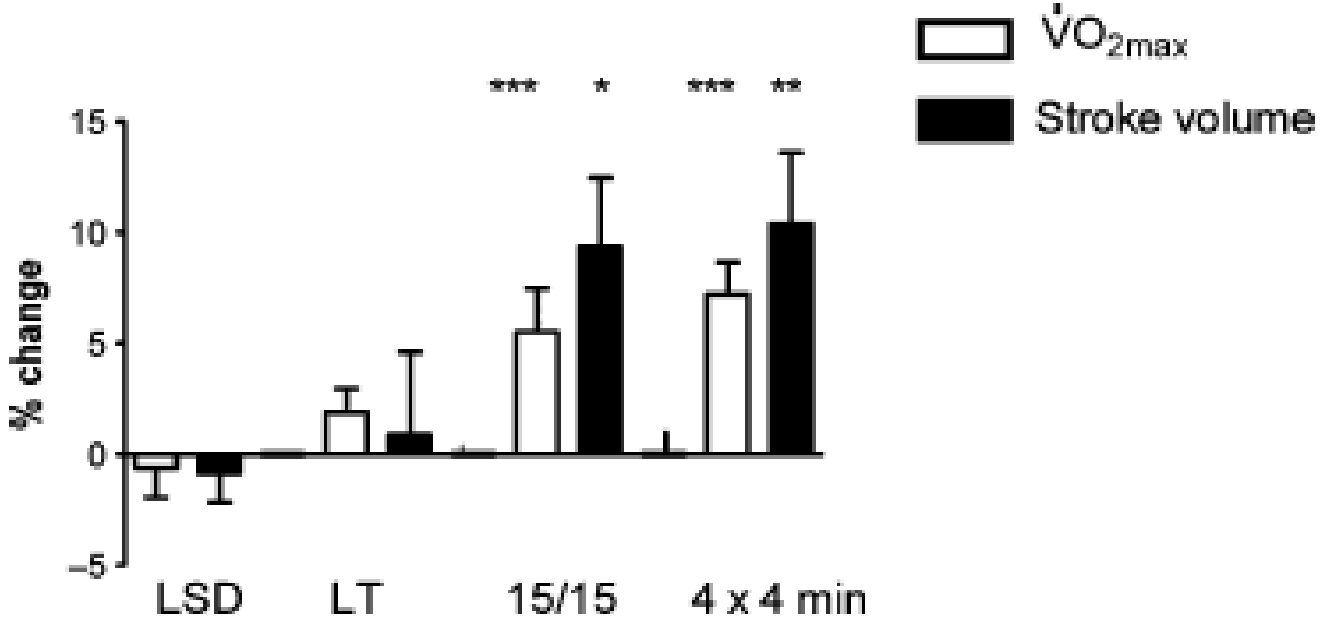


FIGURE 2—Percent change in absolute $\dot{V}O_{2max}$ ($L \cdot min^{-1}$) and absolute stroke volume of the heart ($mL \cdot beat^{-1}$) from pre- to posttraining for each of the groups, presented as mean and SE. Significantly different from pre- to posttraining: * $P < 0.05$, ** $P < 0.01$, *** = $P < 0.001$.

Higher intensity training: 15/15 and 4 × 4 (90-95% HR) significantly increased CRF & SV.

High-intensity interval exercise induces 24-h energy expenditure similar to traditional endurance exercise despite reduced time commitment

Appl. Physiol. Nutr. Metab. 39: 1–4 (2014)

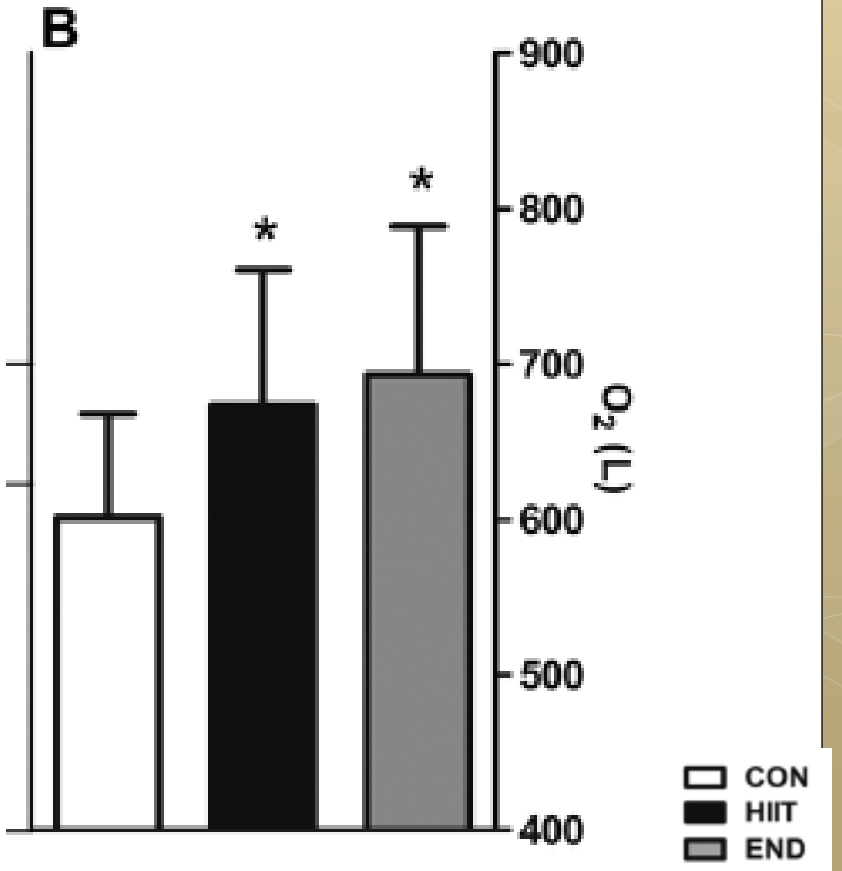
Lauren E. Skelly, Patricia C. Andrews, Jenna B. Gillen, Brian J. Martin, Michael E. Percival,

24-Hr Oxygen Consumption

- 24h Energy Expenditure & Exercise Fuel Utilization

- HIIT: 10 × 60-s @ 90%HR; 60-s rest
- END: cycling @ 70%HR for 50 min
- CON – no exercise

HIIT elicited similar EE over 24 h with ½ as much work



The Acute Effect of Exercise and Nutrition on Energy Expenditure in Women

Hailee L. Wingfield, Abbie E. Smith-Ryan, Malia N. Melvin, Erica J. Roelofs, Eric T. Trexler, Anthony C. Hackney
Applied Physiology Laboratory, Department of Exercise and Sport Science, The University of North Carolina at Chapel Hill

- 20 Eumenorheic women

- Cross-over Design
  - AEE: 30 min run @ 45-55% HRR
  - HIIT: 10 x 1 min @ 85-95% HRR; 1 min rest
  - HIRT: 3 sets x 6-8 RM; 25 sec rest between ex; 2.5 min btwn sets

- Resting Energy Expenditure
- Respiratory Exchange Ratio

- Estrogen/Cortisol

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REE

	Base	IP	30min	60min
AEE	1725 ± 231	2088 ± 235	1728 ± 183	1668 ± 183
HIIT	1614 ± 307	2817 ± 534*♯	1795 ± 272*	1739 ± 274*
HIRT	1663 ± 293	2131 ± 316	1789 ± 255	1705 ± 241

* Indicates significant difference between AEE and HIIT ($p<0.001$-$p=0.002$).
♯ Indicates significant difference between HIIT and HIRT ($p<0.001$).

RER

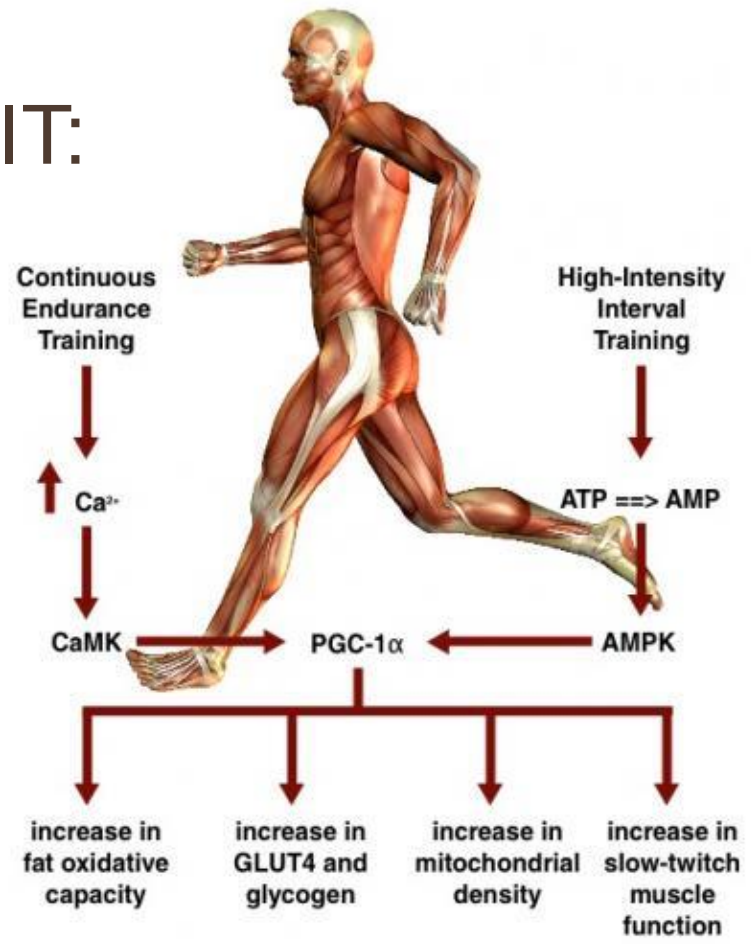
	Base	IP	30min	60min
AEE	0.84 ± 0.07	0.88 ± 0.06	0.82 ± 0.05	0.82 ± 0.05
HIIT	0.84 ± 0.05	0.97 ± 0.09*♯	0.74 ± 0.05*♯	0.78 ± 0.04*
HIRT	0.85 ± 0.06	0.87 ± 0.06	0.77 ± 0.06§	0.79 ± 0.05§

* Indicates significant difference between AEE and HIIT ($p<0.0001$-$p=0.0020$)
♯ Indicates significant difference between HIIT and HIRT ($p<0.0001$-$p=0.0169$)
§ Indicates significant difference between AEE and HIRT ($p=0.0004$-0.0265)

Population Specific Interventions

Application

- As few as 2 weeks (3 x week) of HIIT:
  - ↑ CRF
  - ↑ Mitochondrial Oxidation
  - ↑ Fat oxidation
  - ↑ Insulin sensitivity
  - ↓ visceral fat



Weston et al. Effects of low-volume high-intensity interval training (HIT) on fitness in adults: A meta-analysis of controlled and non-controlled trials. Sports Med. 2014

Low-Volume Interval Training Improves Muscle Oxidative Capacity in Sedentary Adults

Med. Sci. Sports Exerc., Vol. 43, No. 10, pp. 1849–1856, 2011.

MELANIE S. HOOD[1], JONATHAN P. LITTLE[1], MARK A. TARNOPOLSKY[2], FRANK MYSLIK[1], and MARTIN J. GIBALA[1]

- Seven men & women
- Age: 45 ± 5 yrs
- BMI: 27 ± 5 $kg \cdot m^2$
- VO_2: 30 ± 3 $ml/kg/min^{-1}$

- 2 weeks (6 sessions)
  - 10 x 1 min cycling @ 80-85% HRR (60% VO_2 peak power)

- Muscle biopsy before; 72 hr post training

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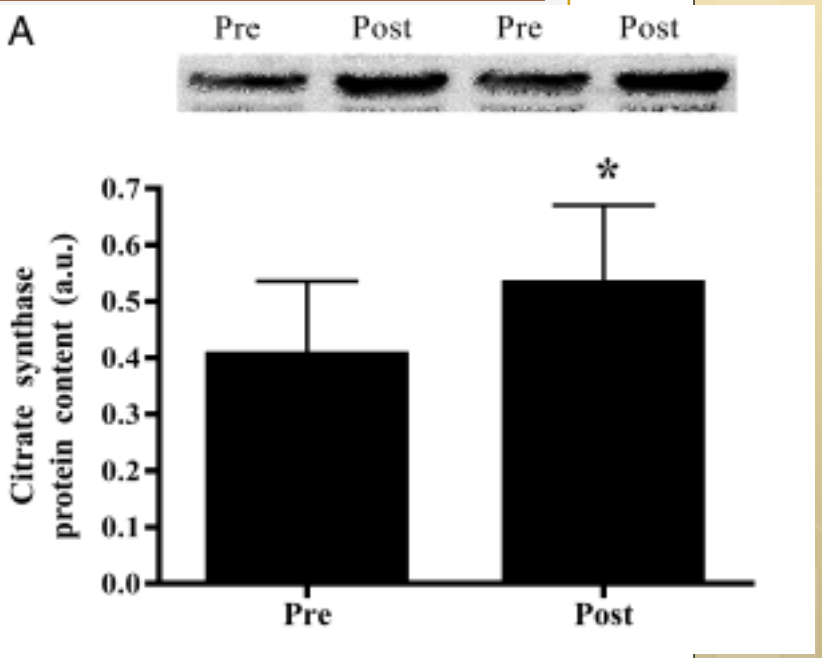
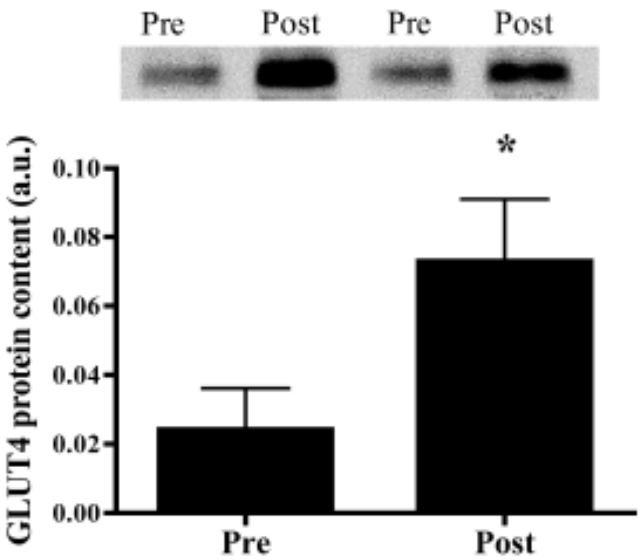
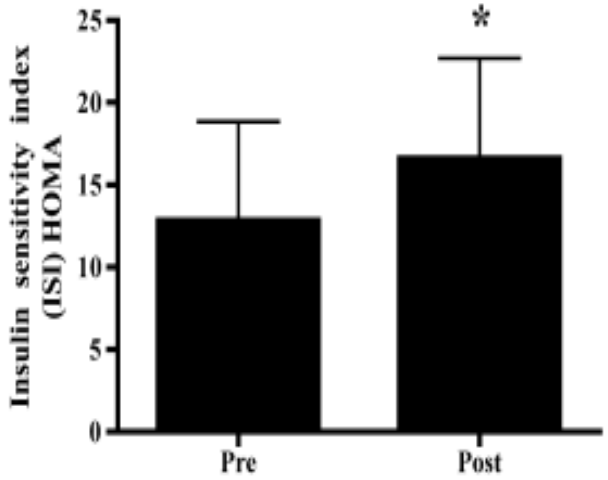
Significant improvement in:

- Muscle oxidative capacity
- GLUT4
- Insulin sensitivity







Effect of 2 weeks of sprint interval training on health-related outcomes in sedentary overweight/obese men

Laura J. Whyte, Jason M.R. Gill*, Andrew J. Cathcart
Metabolism Clinical and Experimental 59 (2010) 1421 – 1428

- 10 OW/OB Men
  - BMI: 31.0 ± 3.7 kg·m^2
  - RER
  - Insulin Sensitivity
  - VO_2max

  - 2 weeks – 6 sessions of SIT
    - 30 seconds all out (0.065 kg FFM Force); 4.5 min rest
      - Ex. 250 lbs @30% BF = 175 lbs (79.5 kg) FFM = 5.2 kg Force

Whyte et al. Effect of 2 weeks of sprint interval training on health-related outcomes in sedentary overweight/obese men. Met Clin Exp. 2010.

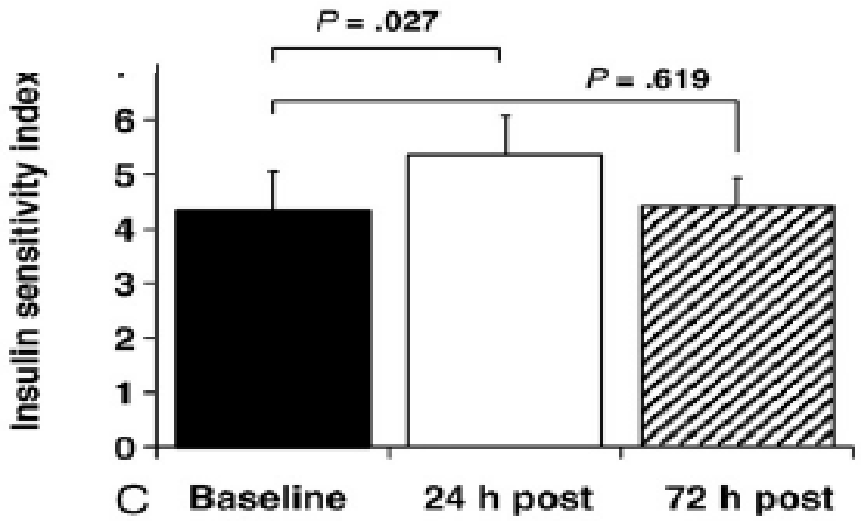
Effect of 2 weeks of sprint interval training on health-related outcomes in sedentary overweight/obese men

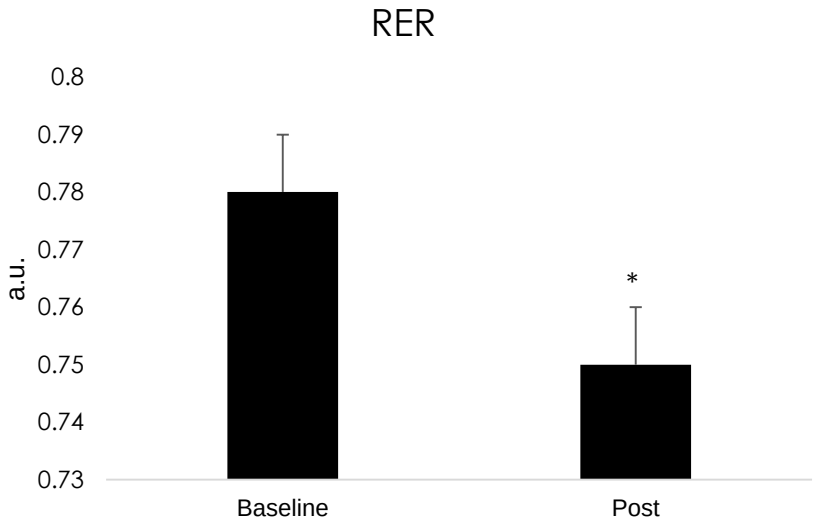
Laura J. Whyte, Jason M.R. Gill*, Andrew J. Cathcart

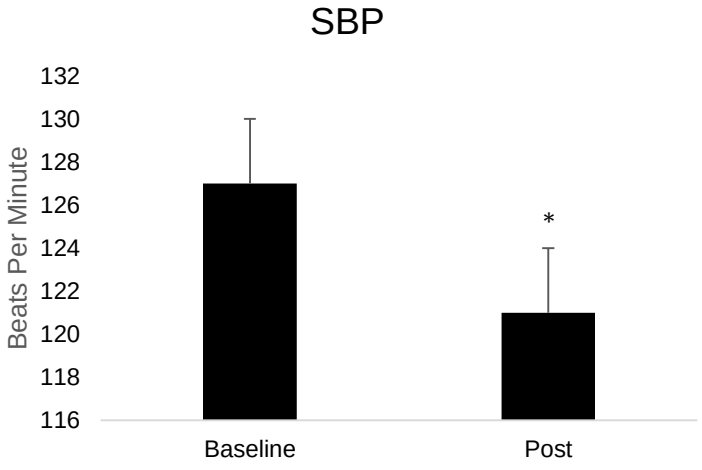
Metabolism Clinical and Experimental 59 (2010) 1421 – 1428

Significant improvement in:

- insulin sensitivity
- RER – fat oxidation
- SBP
- VO_2max







Whyte et al. Effect of 2 weeks of sprint interval training on health-related outcomes in sedentary overweight/obese men. Met Clin Exp. 2010.

Overweight/Obese

- Fifty Five men & women
- 3 weeks of HIIT
  - Cardiorespiratory fitness
  - Metabolic Health
  - Body Composition (4C)
  - Tolerability/Enjoyment

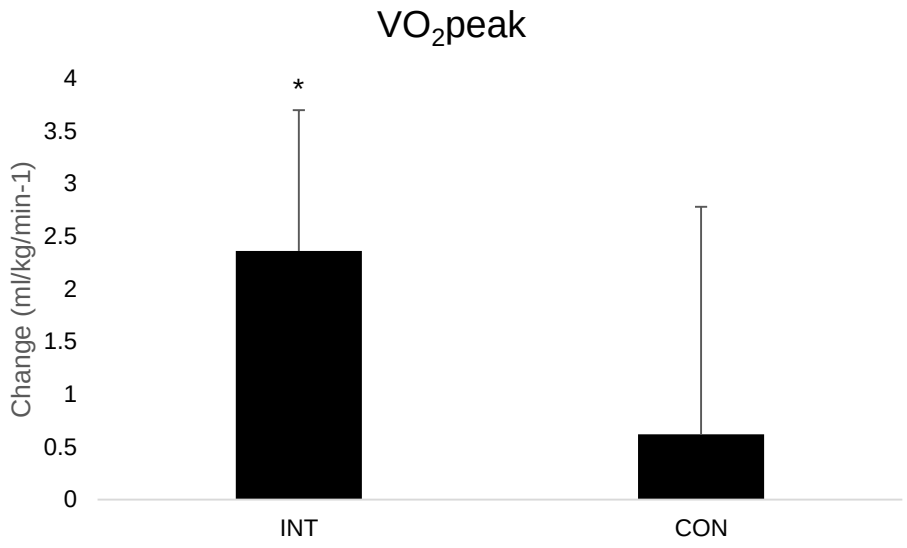
- Compliance High – No AEs

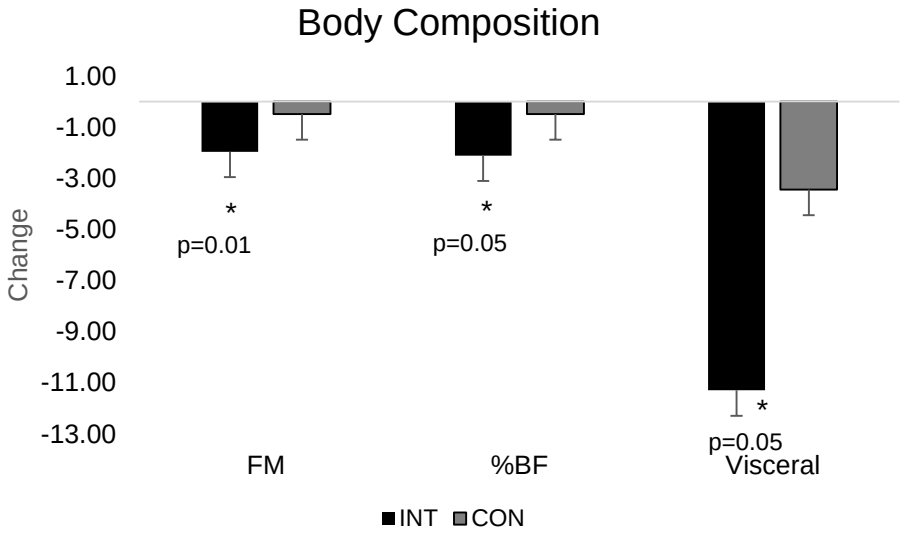
Blood Draw	VO_2peak	Randomization	CON	------	------	------	------	------	------	------	------	------	Blood Draw	VO_2peak
			SIT	90%	90%	90%	90%	90%	90%	90%	90%	90%		
			1 min on: 1 min off (x 10)											
Body Composition			HIT	80%	85%	80%	90%	80%	95%	80%	100%	80%	Body Composition	
			2 min on: 1 min off (x 5)											
Day 1	**Day 2**			Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	**Day 1**	**Day 2**
WEEK 0			WEEK 1				WEEK 2			WEEK 3			WEEK 4	

Smith-Ryan, AE, Melvin, M, Wingfield, H. High-intensity interval training the effects of 1 min and 2 min bouts on cardiorespiratory fitness, body composition, and metabolic health in overweight/obese men. In Review
Smith-Ryan, AE, Melvin, M, Wingfield, H. Interval exercise: effects on cardiometabolic risk factors in overweight/obese women, a randomized trial. In Review

Overweight/Obese

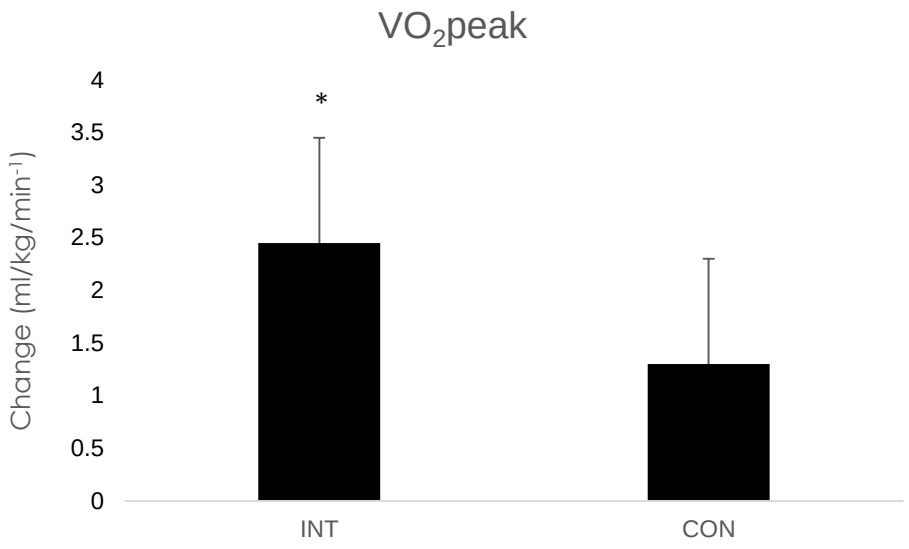
- Thirty Women
  - BMI: 32.0 ± 6.0 kg·m^2
  - %Body Fat: 38.0 ± 5.3 %
  - VO_2peak: 24.3 ± 6.8 ml/kg/min^{-1}

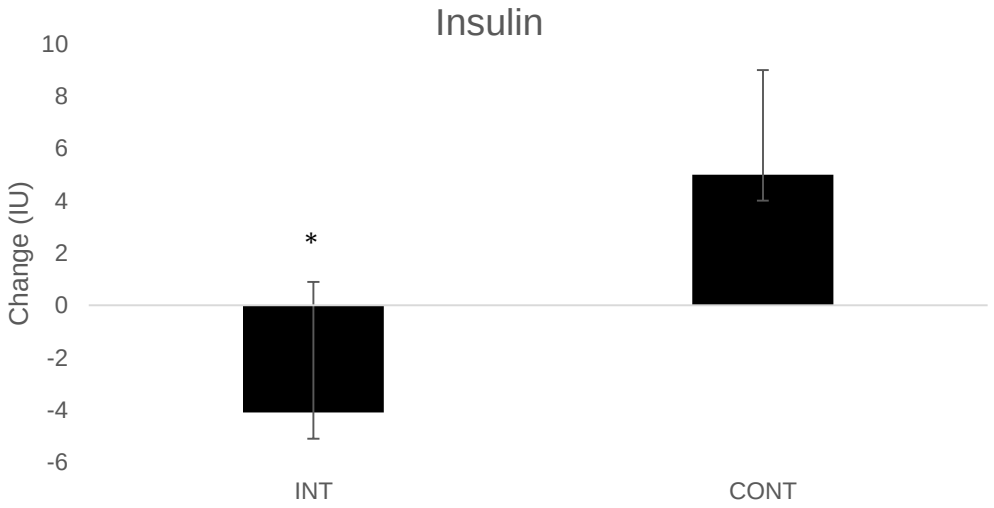




Overweight/Obese

- Twenty five Men
- BMI: 32.0 $kg \cdot m^2$; %BF: 28.3%
- VO_2peak: 31.2 $ml/kg/min^{-1}$





Aerobic interval training vs. continuous moderate exercise as a treatment for the metabolic syndrome - "A Pilot Study"

Circulation. 2008 July 22; 118(4): 346–354.

Arnt Erik Tjønna, MSc[1], Sang Jun Lee, PhD[2], Øivind Rognmo, MSc[1], Tomas Stølen, MSc[1],

- Thirty-two metabolic syndrome patients
- Age: 52.3 ± 3.7 yrs

- Moderate Continuous Training:70% HRmax
- Interval Training: 90% HRmax
- CON
  - 3 x per week; 16 weeks

- Endothelial Function
- CRF
- Insulin Signaling

Tjonna et al Aerobic interval training vs. continuous moderate exercise as a treatment for metabolic syndrome. Circ.. 2008.

Aerobic interval training vs. continuous moderate exercise as a treatment for the metabolic syndrome - "A Pilot Study"

Circulation. 2008 July 22; 118(4): 346–354.

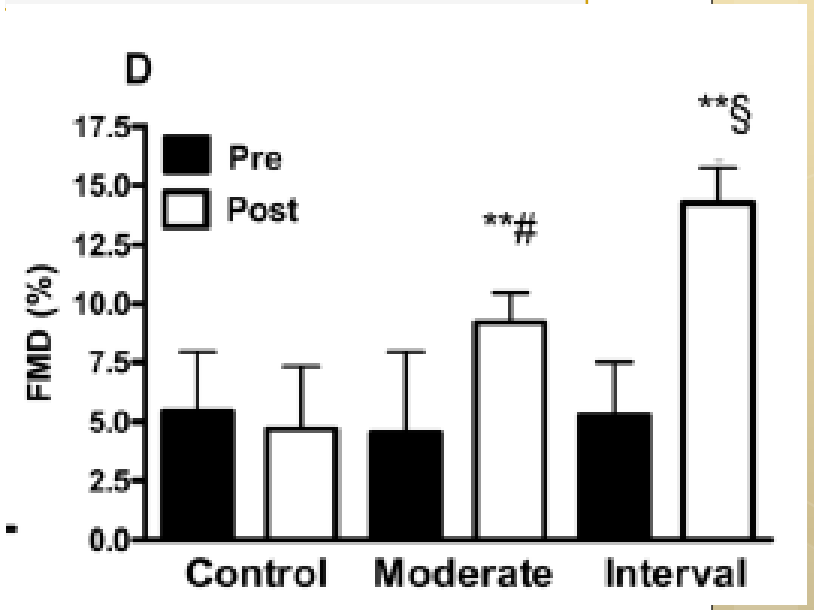
Arnt Erik Tjønna, MSc[1], Sang Jun Lee, PhD[2], Øivind Rognmo, MSc[1], Tomas Stølen, MSc[1],

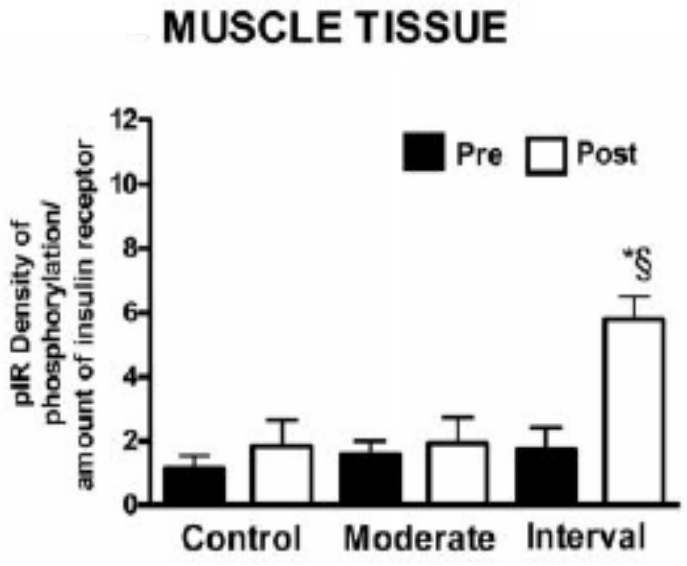
Significant improvement in:

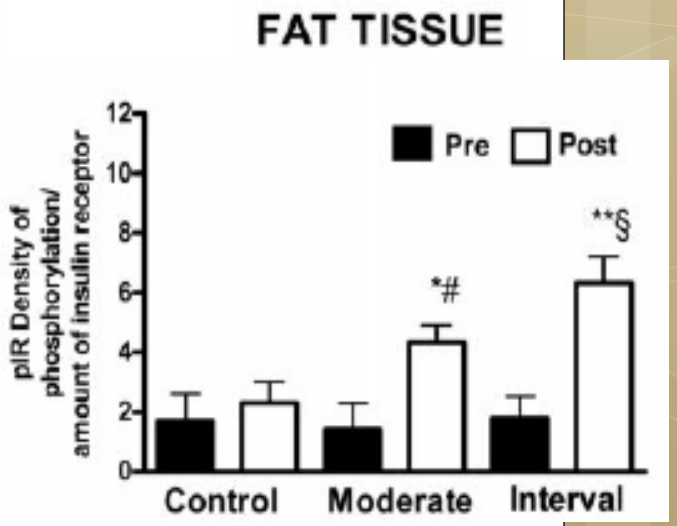
- VO_2max

<u>Removal of more risk factors:</u>

- FMD (endothelial function)
- Insulin Signaling in fat, muscle
- ↓ glucose; lipogenesis







Tjonna et al Aerobic interval training vs. continuous moderate exercise as a treatment for metabolic syndrome. Circ.. 2008.

The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women

International Journal of Obesity (2008) 32, 684–691

EG Trapp[1], DJ Chisholm[2], J Freund[1] and SH Boutcher[1]

- Forty-Five women
- Age: 20 ± 2 yrs
- BMI: 23 ± 2 kg·m^2

- 15-week intervention
  - HIIE: 8 sec sprint; 12 sec rest x 60
  - Steady State: 40 min @ 60% VO_2
  - CON

- Body Composition (DXA)
- Insulin, glucose, leptin

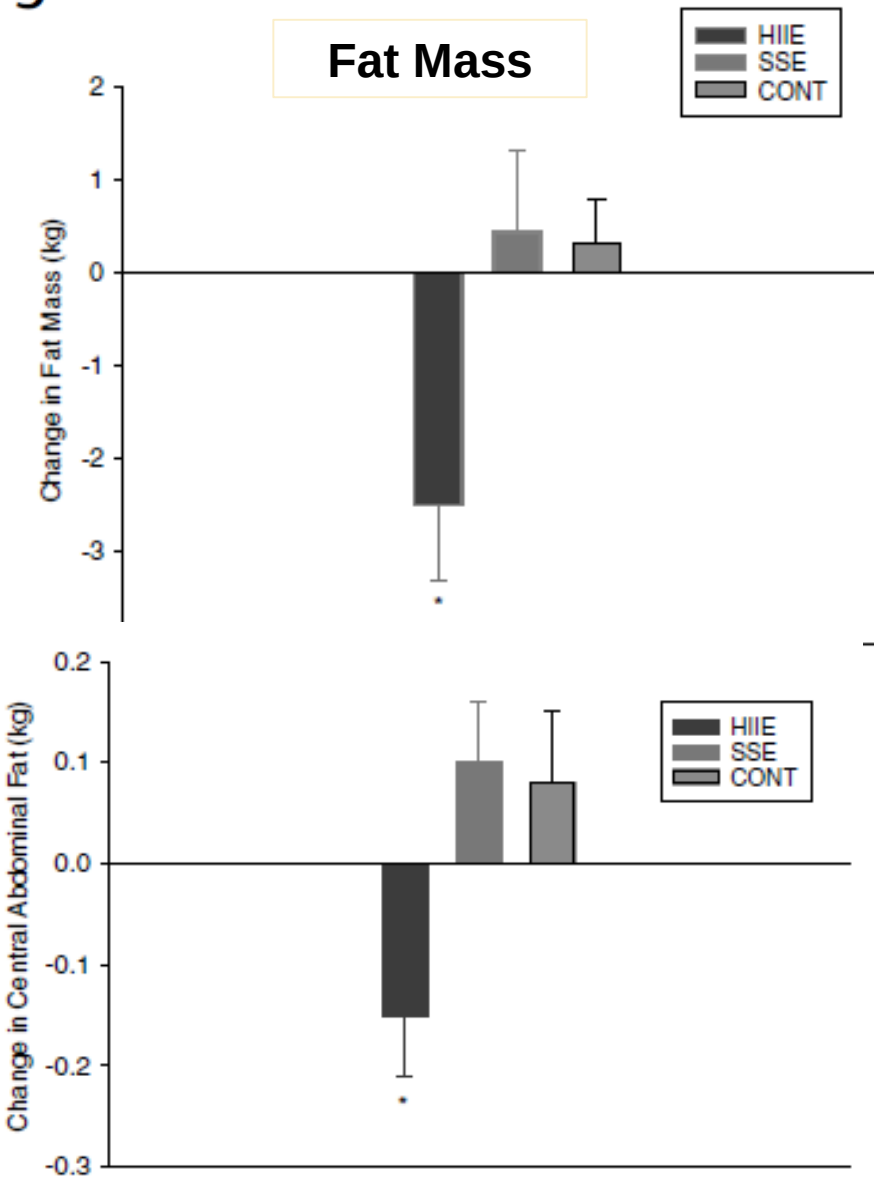
The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women

International Journal of Obesity (2008) 32, 684–691

EG Trapp[1], DJ Chisholm[2], J Freund[1] and SH Boutcher[1]

Significant improvement in:

- Fat mass/Abdominal Fat
- Insulin



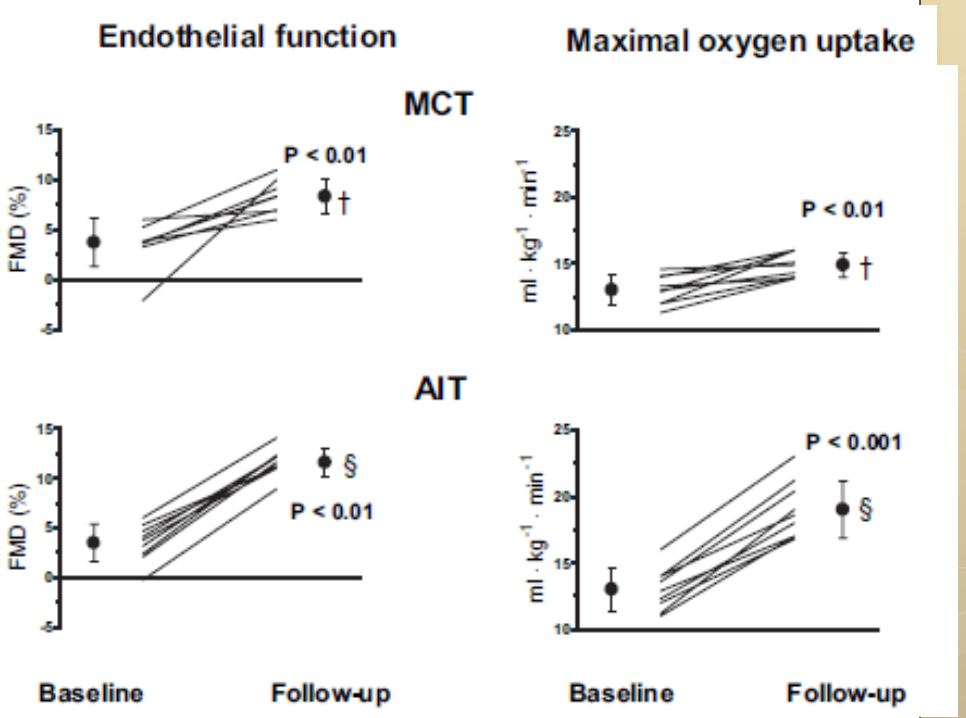
Superior Cardiovascular Effect of Aerobic Interval Training Versus Moderate Continuous Training in Heart Failure Patients

(*Circulation*. 2007;115:3086-3094.)

A Randomized Study

Ulrik Wisløff, PhD; Asbjørn Støylen, MD, PhD; Jan P. Loennechen, MD, PhD; Morten Bruvold, MSc;

- 27 Patients with stable post-infarction heart failure.
- Randomized:
  - CON
  - Moderate Intensity Training: 70%HR- 45min
  - Aerobic Interval training: 95%HR; 4 x 4 min
    - 3 x week for 12 weeks



INT group elicited > improvements in VO_2max (46% vs. 14% MIT) & significant improvement in endothelial function (FMD)for INT only.

Effect of a multimodal high intensity exercise intervention in cancer patients undergoing chemotherapy: randomised controlled trial

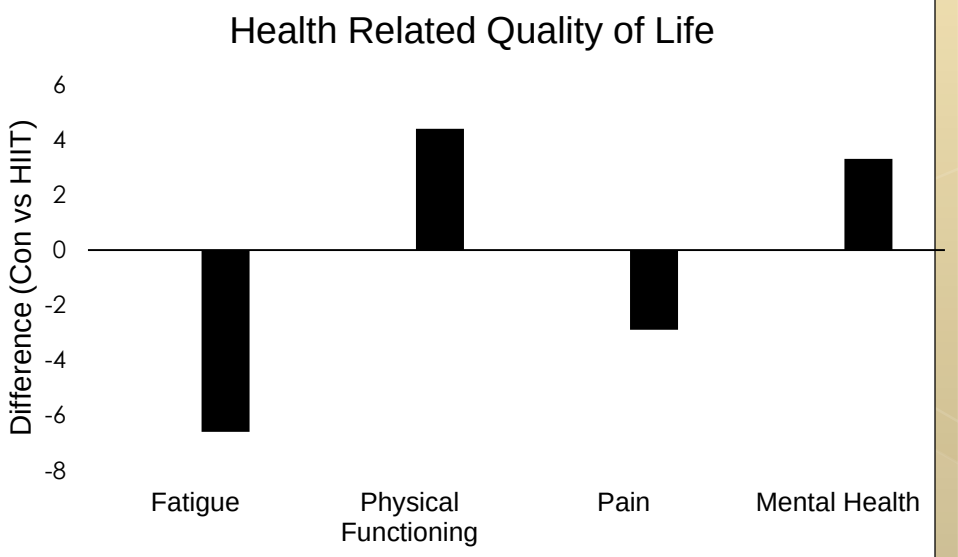
BMJ 2009;339:b3410

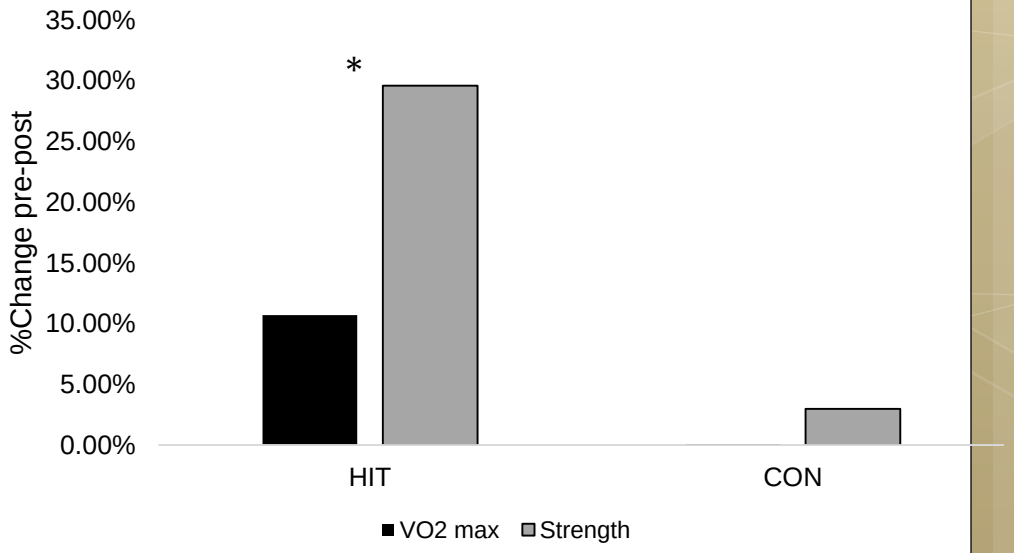
Lis Adamsen, professor clinical nursing,[1,2] Morten Quist, research physiotherapist ,[2] Christina Andersen,

- 235 Patients with brain/bone metastases

- Conventional Care
- High intensity cardiovascular & resistance training (6 weeks)
  - 70-100%1RM
  - 85-95% HRmax - intervals

- Cancer QOL
- Medical Outcomes Survey
- Strength
- VO_2max

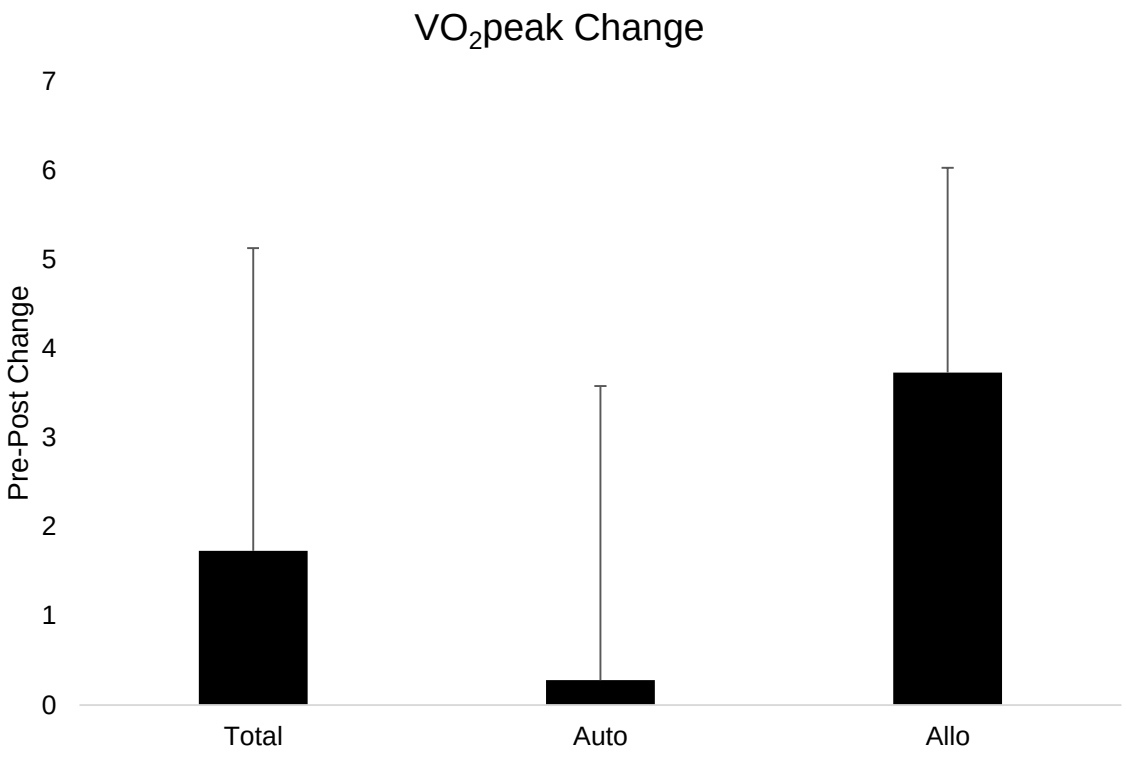




Adamsen et al. Effect of a multimodal high intensity exercise intervention in cancer patients undergoing chemotherapy. BMJ. 2009.

LCCC 1311: Evaluation of Cardiorespiratory Performance After Interval Exercise Training (IET) Prior to Hematopoietic Cell Transplantation

- Thirty Transplant Patients
  - 15 autologous
  - 15 allogeneic
  - 6 weeks IET; 3 x week
    - 5 x 3 min @ 65-85% HRR
- Feasibility
- VO_2peak



Wood, B, Smith-Ryan. et al. Evaluation of cardiorespiratory performance after interval exercise training prior to hematopoietic cell transplantation.

Women

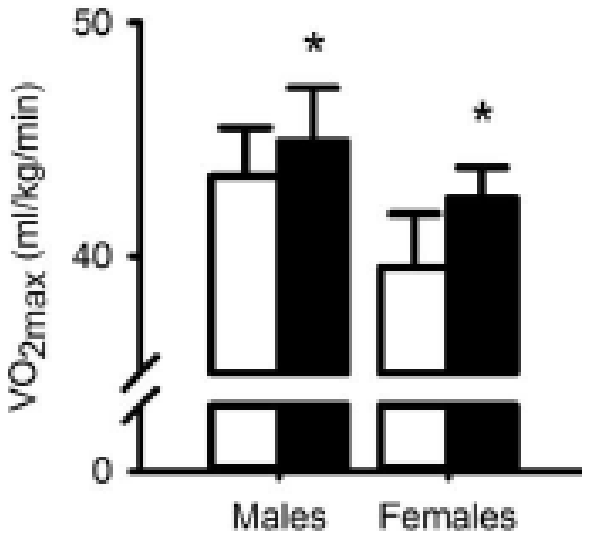
Greater muscle protein synthesis and mitochondrial biogenesis in males compared with females during sprint interval training

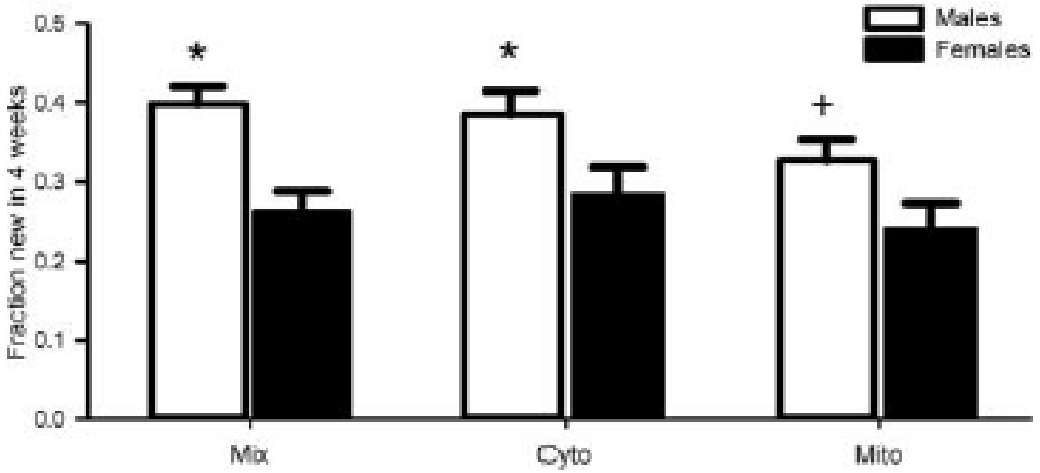
FASEB J. 28, 2705–2714 (2014).

Rebecca L. Scalzo,* Garrett L. Peltonen,* Scott E. Binns,* Mahalakshmi Shankaran,†

-No differences in performance (VO_2, peak power)–accounting for FFM

-Sex difference in protein synthesis & mitochondrial oxidation





Scalzo et al. Greater muscle protein synthesis and mitochondrial biogenesis in males compared with females. FASEB. 2014.

Real World Application

High Intensity Interval Training in a Real World Setting: A Randomized Controlled Feasibility Study in Overweight Inactive Adults, Measuring Change in Maximal Oxygen Uptake

PLOS | ONE

Helen Lunt[1,6]*, Nick Draper[2], Helen C. Marshall[2], Florence J. Logan[1], Michael J. Hamlin[3],

- Forty nine OW/OB inactive adults
- Group based activity (12 wks; 3 x per week)
  - Aerobic Interval: 4 x 4 min jog @ 85-95% HR; 3 min recovery
  - Maximal Volitional Interval: 3 x 30 sec all out; 4 min recovery
  - Active Control: 33 min walk @ 65-75% HR
- Compliance & VO_2

Lunt et al. High intensity interval training in a real world setting: a randomized controlled feasibility study. PLOS One. 2014

High Intensity Interval Training in a Real World Setting: A Randomized Controlled Feasibility Study in Overweight Inactive Adults, Measuring Change in Maximal Oxygen Uptake

PLOS | ONE

Helen Lunt[1,6]*, Nick Draper[2], Helen C. Marshall[2], Florence J. Logan[1], Michael J. Hamlin[3],

	Exercise group allocation		
	Low intensity walking (WALK)	Aerobic interval training (AIT)	Maximal volitional intensity training (MVIT)
% of sessions attended	75%	59%	75%
Theoretical amount of time (min/week) allocated to exercise sessions over the 12 week study[a]	144	120	90[b]
Actual amount of time (min/week; mean, range) spent exercising over the12 week study[a]	116 (40–144)	74 (7–117)	45 (0–62)

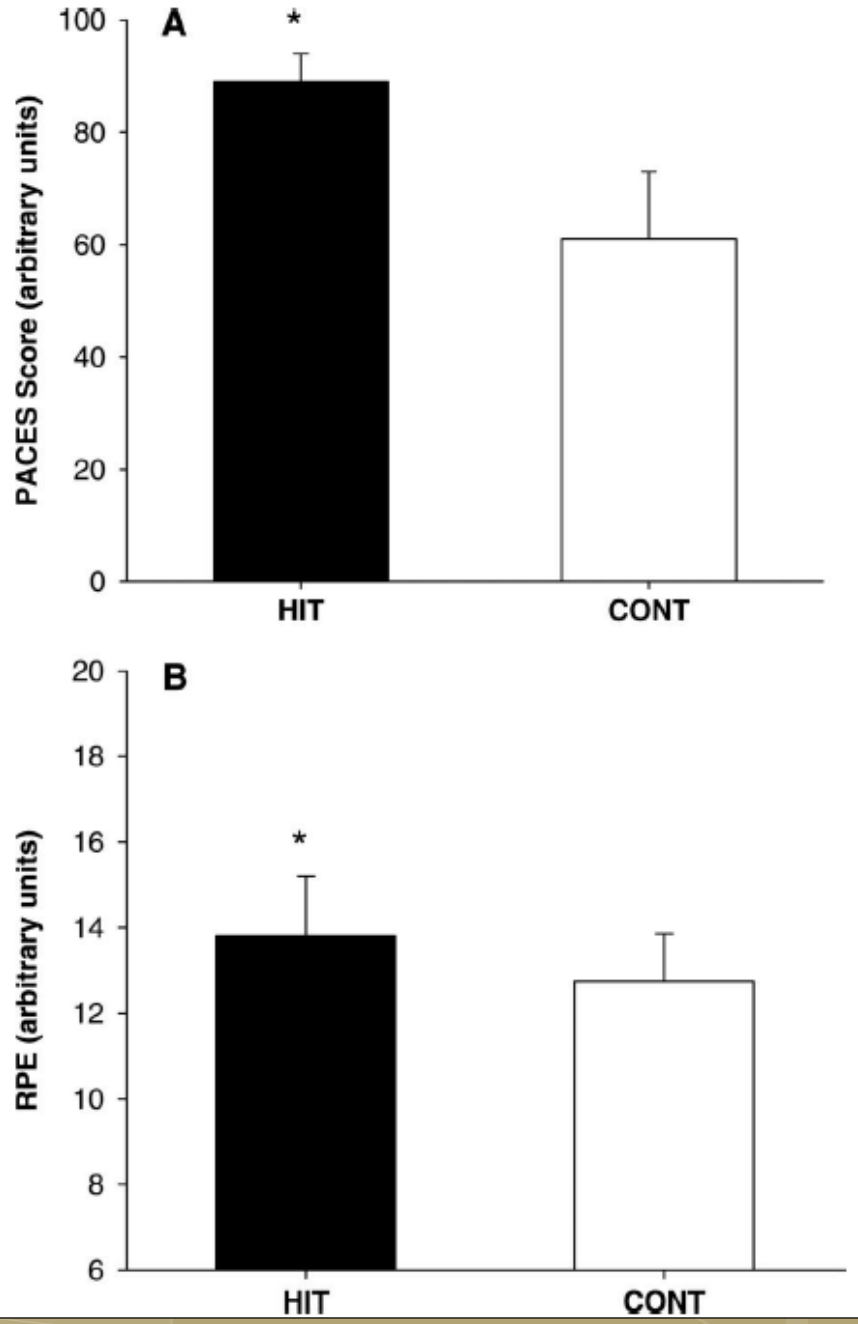
Lunt et al. High intensity interval training in a real world setting: a randomized controlled feasibility study. PLOS One. 2014

High-intensity interval running is perceived to be more enjoyable than moderate-intensity continuous exercise: Implications for exercise adherence

Journal of Sports Sciences, March 15th 2011; 29(6): 547–553

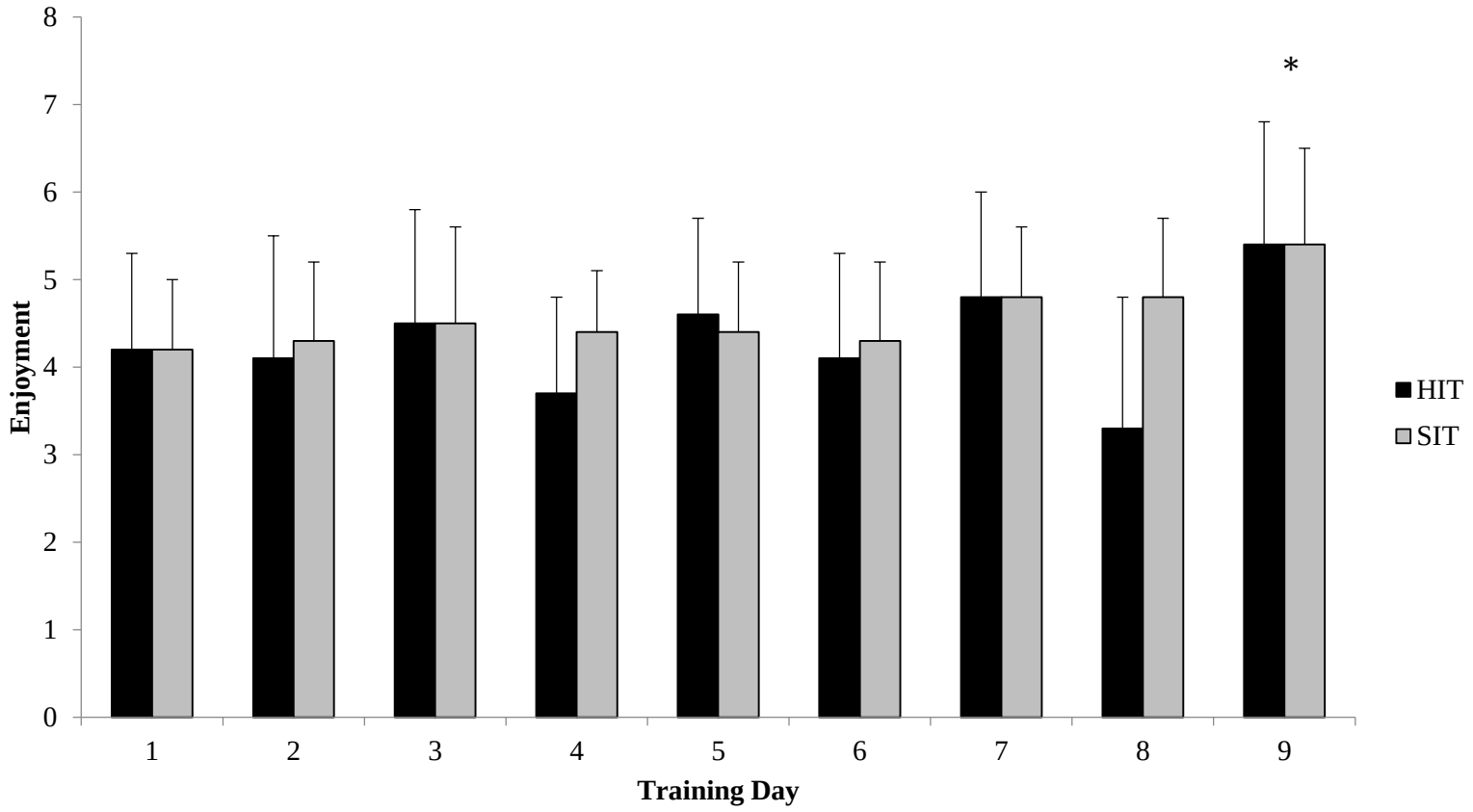
JONATHAN D. BARTLETT, GRAEME L. CLOSE, DON P. M. MACLAREN,

- 8 men
- One session HIT vs. Continuous training
- Physical activity enjoyment scale



Bartlett et al. High-intensity interval running is perceived to be more enjoyable than moderate intensity continuous exercise. J Sp Sci. 2011

Enjoyment



Smith-Ryan. Enjoyment of high-intensity interval training in an overweight/obese cohort. In Review.2015

Gaps – What we don’t know

- What are the long term effects?
- How long to the physiological adaptations last after cessation?
- What are the effects when combined with diet changes?
- What are the true clinical benefits – i.e. exercise as medicine?

Exercise as Medicine

- Exercise as Medicine
  - 30 Patients with 1+ risk factors for CVD
    - BP > 130/85 mmHG
    - BMI >30 $kg \cdot m^2$
    - Glucose >110 mg/dL
    - HDL <30
  - BP, Lipids, Body Fat, Visceral Fat, VO_2max
    - Sleep, Mood, Satiety, Enjoyment
  - 12-week at home HIIT intervention + Daily Meal Replacement
    - Heart Rate Based Training
    - FitBit activity monitors
  - Follow-up at 6 months & 12 months

NIH National Center for Advancing Translational Sciences

How to

- Either:
  - 1) Calculate Heart Rate Reserve: HRmax – HRrest
    - HRmax – measured during a high intensity bout or estimated
  - 2) Identify intensity
    - Ex. Exercise HR = % target intensity (HRmax – HRrest) + HRrest
    - 80% HRR with HR max of 185 bpm and HR rest of 50 bpm
      - 0.8*(185-50=135)+50 = 158 bpm
- OR
  - 1) Pick a Mode (ex. Cycle)
  - 2) Identify interval length (ex. 1 min)
  - 3) Choose a workload/intensity that cannot be maintained for 1:05 min

HIIT How To

- Start slow, switch up work:rest ratio, alternate mode

Workout 1	Workout 4	Workout 1
Warm-up: 5 min HIIT: 15-30 × 30 sec on. 30 sec off.	Warm-Up: 5 min HIIT: 50-60 × 10 sec on. 10 sec off.	Warm-up: 3-5 min HIIT: 8 mph: 2 × 1min on:off 9 mph: 2 × 1min on:off 10 mph: 2 × 1min on:off 11 mph: 2 × 1 min on:off
Workout 2	Workout 5	
Warm-up: 5 min HIIT: 10 × 1 min on. 1 min off.	Warm-up: 5 min HIIT: 30-45 × 20 sec on. 10 sec off	
Workout 3	Workout 6	Workout 2
Warm-up: 5 min HIIT: 5-6 × 2 min on. 1 min off.	Warm-up: 5 min HIIT: 8-10 × 1.5 min on. 1 min off.	Warm-up: 3-5 min HIIT: 10 mph: 2 × 30sec on:off 11 mph: 2 × 30sec on:off 12 mph: 2 × 30sec on:off 11 mph: 2 × 30sec on:off 10 mph: 2 × 30sec on:off
*Choose one velocity/workload and maintain throughout. Rest can be active or standstill.		

Summary

- HIIT elicits rapid positive changes in:
  - Cardiorespiratory Fitness
  - Insulin Sensitivity
  - Mitochondrial Biogenesis
- Men & Women appear to respond similarly
    - Men > MPS
    - Women > Fat Oxidation
- To date, modest improvements in fat mass result, with significant improvements in lean body mass
- Two weeks (6 sessions) result in said adaptations
- 3-10 minutes of intense total work ≥ 45 min of aerobic work

Thank You

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Pilot & Feasibility Program

Lab Team

QUESTIONS:

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