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

Abbie Smith-Ryan, PhD, CSCS*D, FISSN
Assistant Professor
Exercise & Sport Science
Allied Health Science
Overview – High Intensity Interval Training

- What is it?
- What literature says
- Clinical Connections
- Real world application
- Recommendations
THE SEVEN-SECOND WORKOUT

500 lbs.

20 m.p.h.

50° incline

Tabata Training

CrossFit

Top fitness

Nancy Hellmich, USA Today
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 training

- Sprint Interval Training:
  - Wingate Repeated Sprint Style Training
    - 30 seconds all-out cycling against a high resistance
    - 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

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.

What we know

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
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 VO$_{2\text{max}}$ More Than Moderate Training


JAN HELGERUD$^{1,2}$, KJETIL HØYDAL$^1$, EIVIND WANG$^1$, TRINE KARLSEN$^1$, PÅL R BERG$^1$, MARIUS BJERKAAS$^1$,
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

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

- 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

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
### REE

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>IP</th>
<th>30min</th>
<th>60min</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEE</td>
<td>1725 ± 231</td>
<td>2088 ± 235</td>
<td>1728 ± 183</td>
<td>1668 ± 183</td>
</tr>
<tr>
<td>HIIT</td>
<td>1614 ± 307</td>
<td>2817 ± 534*$^#$</td>
<td>1795 ± 272*</td>
<td>1739 ± 274*</td>
</tr>
<tr>
<td>HIRT</td>
<td>1663 ± 293</td>
<td>2131 ± 316</td>
<td>1789 ± 255</td>
<td>1705 ± 241</td>
</tr>
</tbody>
</table>

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

### RER

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>IP</th>
<th>30min</th>
<th>60min</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEE</td>
<td>0.84 ± 0.07</td>
<td>0.88 ± 0.06</td>
<td>0.82 ± 0.05</td>
<td>0.82 ± 0.05</td>
</tr>
<tr>
<td>HIIT</td>
<td>0.84 ± 0.05</td>
<td>0.97 ± 0.09*$^#$</td>
<td>0.74 ± 0.05*$^#$</td>
<td>0.78 ± 0.04*</td>
</tr>
<tr>
<td>HIRT</td>
<td>0.85 ± 0.06</td>
<td>0.87 ± 0.06</td>
<td>0.77 ± 0.06$</td>
<td>0.79 ± 0.05$</td>
</tr>
</tbody>
</table>

* 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

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

MELANIE S. HOOD1, JONATHAN P. LITTLE1, MARK A. TARNOPOLSKY2, FRANK MYSLIK1, and MARTIN J. GIBALA1

- Seven men & women
- Age: 45 ± 5 yrs
- BMI: 27 ± 5 kg·m²
- VO₂: 30 ± 3 ml/kg/min⁻¹

- 2 weeks (6 sessions)
  - 10 x 1 min cycling @ 80-85% HRR (60% VO₂ peak power)

- Muscle biopsy before; 72 hr post training
Significant improvement in:
- Muscle oxidative capacity
- GLUT4
- Insulin sensitivity
10 OW/OB Men
- BMI: 31.0 ± 3.7 kg·m²
- RER
- Insulin Sensitivity
- VO₂max

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
Significant improvement in:
- insulin sensitivity
- RER – fat oxidation
- SBP
- VO\textsubscript{2}\text{max}
Overweight/Obese

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

• Compliance High – No AEs

<table>
<thead>
<tr>
<th>Blood Draw</th>
<th>VO\text{peak}</th>
<th>Randomization</th>
<th>CON</th>
<th>CON</th>
<th>CON</th>
<th>CON</th>
<th>CON</th>
<th>CON</th>
<th>CON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood Draw</td>
<td>VO\text{peak}</td>
<td>Randomization</td>
<td>CON</td>
<td>CON</td>
<td>CON</td>
<td>CON</td>
<td>CON</td>
<td>CON</td>
<td>CON</td>
</tr>
</tbody>
</table>

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 |

- Compliance High – No AEs

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: \(32.0 \pm 6.0 \, \text{kg} \cdot \text{m}^2\)
  - %Body Fat: \(38.0 \pm 5.3 \%\)
  - \(\text{VO}_2\text{peak}: 24.3 \pm 6.8 \, \text{ml/kg/min}^{-1}\)
Overweight/Obese

- Twenty five Men
- BMI: 32.0 kg·m²; %BF: 28.3%
- VO₂peak: 31.2 ml/kg/min⁻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
Aerobic interval training vs. continuous moderate exercise as a treatment for the metabolic syndrome - “A Pilot Study”


Arnt Erik Tjønna, MSc¹, Sang Jun Lee, PhD², Øivind Rognmo, MSc¹, Tomas Stølen, MSc¹,

Significant improvement in:
- $\text{VO}_2\text{max}$

Removal of more risk factors:
- FMD (endothelial function)
- Insulin Signaling in fat, muscle
- $\downarrow$ glucose; lipogenesis
The effects of high-intensity intermittent exercise training on fat loss and fasting insulin levels of young women

Forty-Five women
- Age: 20 ± 2 yrs
- BMI: 23 ± 2 kg·m²

15-week intervention
- HIIE: 8 sec sprint; 12 sec rest x 60
- Steady State: 40 min @ 60% VO₂
- CON

Body Composition (DXA)
- Insulin, glucose, leptin
Significant improvement in:
- Fat mass/Abdominal Fat
- Insulin
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$_2$max (46% vs. 14% MIT) & significant improvement in endothelial function (FMD) for INT only.
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$_2$max
Thirty Transplant Patients
- 15 autologous
- 15 allogeneic

- 6 weeks IET; 3 x week
  - 5 x 3 min @ 65-85% HRR

Feasibility
- VO$_2$peak

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 (VO₂, 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
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 & VO₂
High Intensity Interval Training in a Real World Setting: A Randomized Controlled Feasibility Study in Overweight Inactive Adults, Measuring Change in Maximal Oxygen Uptake

Helen Lunt¹, Nick Draper², Helen C. Marshall², Florence J. Logan¹, Michael J. Hamlin³,

Exercise group allocation

<table>
<thead>
<tr>
<th></th>
<th>Low intensity walking (WALK)</th>
<th>Aerobic interval training (AIT)</th>
<th>Maximal volitional intensity training (MVIT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>% of sessions attended</td>
<td>75%</td>
<td>59%</td>
<td>75%</td>
</tr>
<tr>
<td>Theoretical amount of time (min/week) allocated to exercise sessions over the 12 week study⁹</td>
<td>144</td>
<td>120</td>
<td>90⁵</td>
</tr>
<tr>
<td>Actual amount of time (min/week; mean, range) spent exercising over the 12 week study⁹</td>
<td>116 (40–144)</td>
<td>74 (7–117)</td>
<td>45 (0–62)</td>
</tr>
</tbody>
</table>
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
Gaps – What we don’t know

- What are the long term effects?
- How long do 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·m$^2$
    - Glucose > 110 mg/dL
    - HDL < 30
  - BP, Lipids, Body Fat, Visceral Fat, VO$_2$max
    - 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
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

<table>
<thead>
<tr>
<th>Workout 1</th>
<th>Workout 4</th>
<th>Workout 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm-up: 5 min</td>
<td>Warm-Up: 5 min</td>
<td>Warm-up: 3-5 min</td>
</tr>
<tr>
<td>HIIT: 15-30 x</td>
<td>HIIT: 50-60 x</td>
<td>HIIT: 8 mph:</td>
</tr>
<tr>
<td>30 sec on.</td>
<td>10 sec on.</td>
<td>2 x 1 min on:off</td>
</tr>
<tr>
<td>30 sec off.</td>
<td>10 sec off.</td>
<td>9 mph:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 1 min on:off</td>
</tr>
<tr>
<td><strong>Workout 2</strong></td>
<td><strong>Workout 5</strong></td>
<td></td>
</tr>
<tr>
<td>Warm-up: 5 min</td>
<td>Warm-up: 5 min</td>
<td></td>
</tr>
<tr>
<td>HIIT: 10 x</td>
<td>HIIT: 30-45 x</td>
<td></td>
</tr>
<tr>
<td>1 min on.</td>
<td>20 sec on.</td>
<td></td>
</tr>
<tr>
<td>1 min off.</td>
<td>10 sec off</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 1 min on:off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Workout 3</strong></td>
<td><strong>Workout 6</strong></td>
<td><strong>Workout 2</strong></td>
</tr>
<tr>
<td>Warm-up: 5 min</td>
<td>Warm-up: 5 min</td>
<td></td>
</tr>
<tr>
<td>HIIT: 5-6 x</td>
<td>HIIT: 8-10 x</td>
<td></td>
</tr>
<tr>
<td>2 min on.</td>
<td>1.5 min on.</td>
<td></td>
</tr>
<tr>
<td>1 min off.</td>
<td>1 min off.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>2 x 30 sec on:off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Choose one velocity/workload and maintain throughout. Rest can be active or standstill.*
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

Quest Team

Pilot & Feasibility Program

QUESTIONS:

abbiesmith@unc.edu