Physiological Adaptations to Interval Training in Health and Disease

Webinar • 13 November 2019

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Key Points

1) The use of intermittent exercise as a practical, time-efficient approach to fitness is not a new concept.

2) Cardiorespiratory fitness is a critical health marker and “guideline” physical activity may not be optimal.

3) Interval exercise training is infinitely variable, can be appropriately scaled, and may elicit superior responses.

4) Intensity is more important than volume, and brief vigorous exercise can be extremely effective.

― Lauri Pihkala, 1916

“This plan enables you to get fit: By yourself, At home... is not dependent on elaborate facilities or equipment (and) requires only 11 minutes a day.”
— Royal Canadian Air Force, 1961

Top 20 Worldwide Fitness Trends for 2018

1. High-intensity interval training
2. Group training
3. Wearable technology
4. Body weight training
5. Strength training
Interval training is equally effective or even more effective.

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1-MET / CRF = 13% ; mortality
Risk reduction comparable to:
- 7-cm ; in waist circumference
- 5-mm Hg ; in systolic BP
- 1 mmol ; in plasma glucose
(Kodama et al., JAMA, 2009)

The routine measurement of CRF in clinical settings is both important (and) estimates of CRF using nonexercise algorithms have pragmatic importance.”

How fit are you, really?
Test yourself now.
Sedentary obese adults performed ~150 min/wk of continuous exercise at 50% VO_{2max} for 24 wk.

"Our finding that low-intensity exercise performed for about 150 min/wk may not be sufficient to improve CRF for a substantive proportion of adults is reason for concern."


65 intervention studies stratified based on training duration and BMI

<table>
<thead>
<tr>
<th>Group</th>
<th>Training Duration</th>
<th>BMI Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal weight</td>
<td>≤12 wk</td>
<td>≤12 wk</td>
</tr>
<tr>
<td>Overweight/Obese</td>
<td>&gt;12 wk</td>
<td>&gt;12 wk</td>
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HIIT may serve as a time-efficient substitute or as a compliment to commonly recommended MICT in improving cardiometabolic health.

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What Is Interval Training?

Alternating periods of more intense effort and recovery in a single session

Aerobic Interval Training
- Sprint interval training (SIT)
  - Maximal efforts to failure
  - Near max to all out

High-intensity interval training (HIIT)
- ≥80% of HR_{max}
- Vigorous but not all out

Light-moderate intermittent exercise
- e.g., interval walking

Resistance Interval Training
- Maximal efforts to failure
- Light calisthenics

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Older (~60 y), obese (BMI = 30) T2D; 60 min/session, 5 d/wk for 4 months Continuous or Interval Walking (~66% HR_{max}) or non-training Control

"Interval walking is superior to energy-matched continuous walking (and) may therefore be a good option when considering which type of training…should be offered in primary care."

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High-Intensity Interval Training

![Graph of HIIT training](image)

Hard but submaximal efforts may yield better results (with some time savings)

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Absolute Intensity is Relative!

![Graph of intensity vs. time](image)

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HIIT Improves CRF Better than MICT in Clinical Populations

High-intensity interval training in patients with lifestyle-induced cardiometabolic disease: a systematic review and meta-analysis

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The risk of a cardiovascular event is low after both high-intensity exercise and moderate-intensity exercise.

![Cardiovascular Risk Table](image)

High-Intensity Interval Training for Patients With Cardiovascular Disease—Is It Safe? A Systematic Review

Clinical Perspective

What Is New?

- High-intensity interval training appears to be relatively safe to conduct in patients with cardiovascular disease, including coronary artery disease and heart failure, within tertiary-care cardiac rehabilitation settings.

![Clinical Perspective Image](image)

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What About Body Composition?

The effects of high-intensity interval training vs. moderate-intensity continuous training on body composition in overweight and obese adults: a systematic review and meta-analysis

"Short-term HIIT and MICT exercise both elicit modest improvements, and of similar magnitude, in body fat levels and waist circumference."

"Considering HIIT shows similar efficacy (within) less time commitment... HIIT can be considered a time-efficient alternative for managing overweight and obese individuals."


When total work and training frequency are matched, higher aerobic intensity leads to larger improvements in VO_{2max} (which) seem to be a function of increased SV resulting in increased Q.
Improvements in exercise performance with high-intensity interval training coincide with an increase in skeletal muscle mitochondrial content and function:

- 8-12 x 60-s intervals at ~100% PPO with 75-s recovery (6 sessions over 2 wk)

"The improvements in exercise performance occurred independent from any alterations in maximal cardiac capacity or blood characteristics and suggest that increases in mitochondrial content may facilitate improvements in respiratory capacity and oxygen extraction."

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Superior mitochondrial adaptations in human skeletal muscle after interval compared to continuous single-leg cycling matched for total work:

- Greater mitochondrial adaptations after interval vs continuous cycling despite same total work
- Exercise intensity and/or contraction pattern is important

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Human muscle fibre type-specific regulation of AMPK and downstream targets by exercise:

- 30 min continuous at ~75% or 6 x 1.5 min intervals at ~95% VO2peak

"increased activation of AMPK in interval vs. continuous exercise could be important for exercise type-specific adaptations"

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Exercise-induced metabolic fluctuations influence AMPK, p38-MAPK and CaMKII phosphorylation in human skeletal muscle:

- 30 min continuous or 30 x 1-min intervals (1-min recovery) at ~79% VO2peak

"metabolic fluctuations caused by the succession of on- and off-transients during intermittent exercise are critical (for adaptation)"
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**Sprint Interval Training**

<table>
<thead>
<tr>
<th>Protocol (weeks)</th>
<th>3 x 4 min sprints within 10 min</th>
<th>MICT</th>
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<tbody>
<tr>
<td><strong>Workload</strong></td>
<td>~500 W (~50 W)</td>
<td>~110 W</td>
</tr>
<tr>
<td><strong>RPE</strong></td>
<td>16 (hard)</td>
<td>13 (somewhat hard)</td>
</tr>
<tr>
<td><strong>Mean HR</strong></td>
<td>~83%</td>
<td>~73%</td>
</tr>
<tr>
<td><strong>Work/session</strong></td>
<td>~60 kJ</td>
<td>~300 kJ</td>
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**Inulin Sensitivity (IVGTT)**

A few brief hard efforts can yield similar results in much less time

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**The Interval Training “Sweet Spot”?**

A few brief vigorous efforts, not ‘all out’, and low total time commitment?

A return to SBX (1961)?

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**Physiological basis of brief vigorous exercise to improve health**

5 x (60-s at ~95% VO_{2max} with 90-s recovery) = <15 min; 3x/wk for 6 wk (n=136)

"With a total time-commitment of <15 min per session and reliance on a practical ergometer protocol, 5-by-1 HIT offers a new solution to modulate cardio-metabolic risk factors in adults with pre-existing risk factors for type 2 diabetes"
Effects of low-volume high-intensity interval training in a community setting: a pilot study

Sedentary healthy adults trained 2x/wk for 8 wk

“Low volume HIIT can be feasibly implemented in the real world... practical (non all-out) HIIT regimens requiring <30 min/wk may induce significant improvements in VO2max and cardiometabolic risk markers.”

Brief Intense Stair Climbing Improves Cardiorespiratory Fitness

3 x 20-s sprints over 10-min period (RPE ~15/20 or “hard”), 2x/wk for 6 wk

On top of ‘move as often as possible and sit less’, public health and clinical practice could emphasise simple messages analogous to ‘huff and puff regularly’.

Interval Training: Take Home Messages

1) Elicits large improvements in cardiopulmonary fitness, often superior to continuous exercise.
2) Modest changes in other health indices, comparable to traditional exercise but in less time.
3) Mounting evidence that practical, time-efficient models are viable and efficacious in “real world” settings.
4) There is no single best approach and intervals offer variety that broadens the options to chose from.