

## Physiological Adaptations to Interval Training in Health and Disease


Webinar • 13 November 2019

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www.martingibala.com 


### 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.

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### Key Points

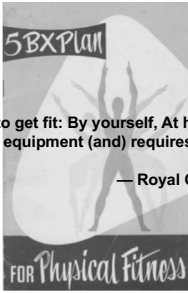
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“Fast and short repetitions with suitable recoveries... are superior to even speed running around the track for the development of endurance.”


— Lauri Pihkala, 1916

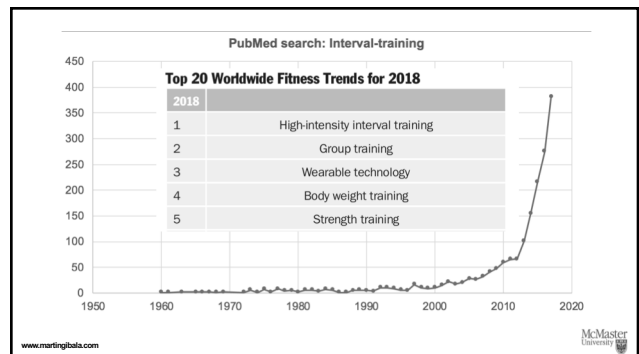
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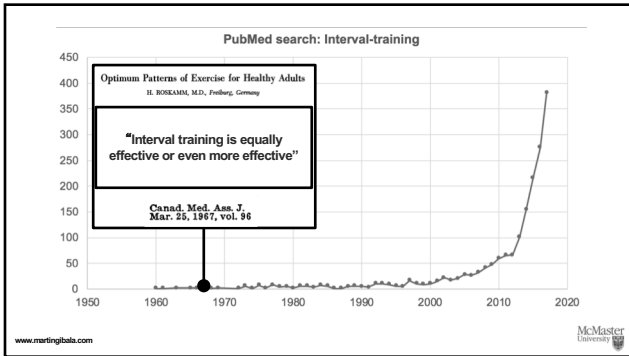


“This plan enables you to get fit: By yourself, At home... is not dependent on elaborate facilities or equipment (and) requires only 11 minutes a day.”

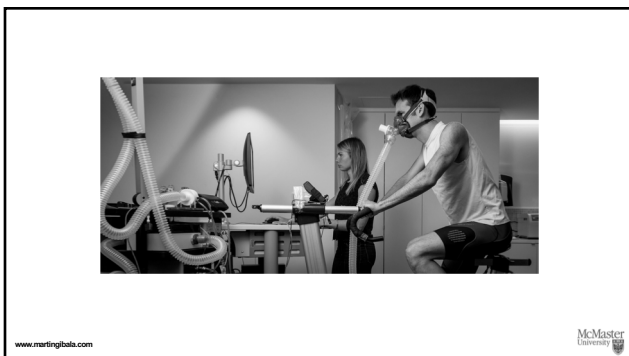
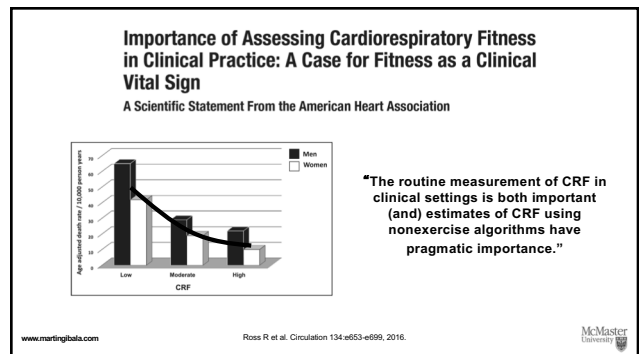
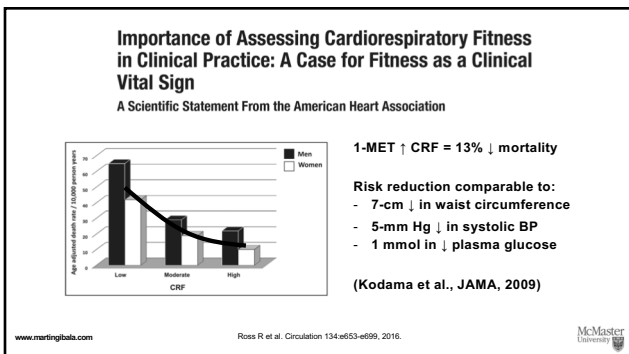
— Royal Canadian Air Force, 1961

www.martingibala.com <https://www.thejobandmail.com/opinion/article-the-1965-exercise-booklet-that-changed-my-life/> 





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Separate Effects of Intensity and Amount of Exercise on Interindividual Cardiorespiratory Fitness Response

**Sedentary obese adults performed ~150 min/wk of continuous exercise at 50% VO<sub>2max</sub> 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.”

www.marlingbala.com      Ross et al. Mayo Clin Proc 90:1506-14, 2015.      McMaster University

Effects of high-intensity interval training on cardiometabolic health: a systematic review and meta-analysis of intervention studies

**65 intervention studies stratified based on training duration and BMI**

“HIIT may serve as a time-efficient substitute or as a complement to commonly recommended MICT in improving cardiometabolic health.”

www.marlingbala.com      Batacan et al. Br J Sports Med 51:484-503, 2017.      McMaster University

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**What Is Interval Training?**

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

<p><b>Aerobic Interval Training</b> (e.g., “cardio”-style exercise)</p> <p><b>Sprint interval training (SIT)</b> ‘near max’ to ‘all out’</p> <p><b>High-intensity interval training (HIIT)</b> ≥80% of HR<sub>max</sub></p> <p><b>Light-moderate intermittent exercise</b> e.g., interval walking</p>	<p><b>Resistance Interval Training</b> (e.g., bodyweight exercise)</p> <p><b>Maximal efforts to failure</b></p> <p>-----</p> <p><b>Vigorous but not all out</b></p> <p>-----</p> <p><b>Light calisthenics</b></p>
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**What Is Interval Training?**

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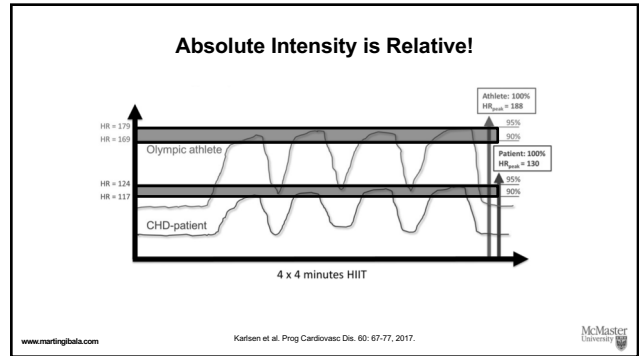
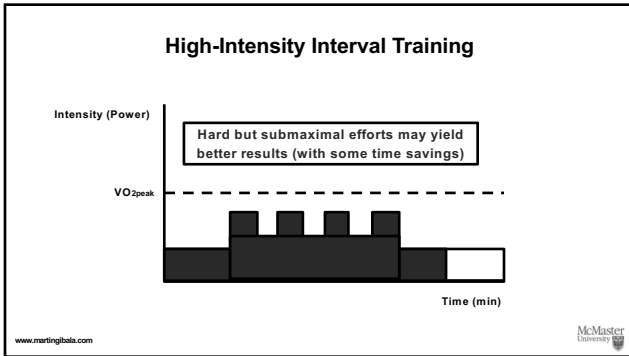
**The Effects of Free-Living Interval-Walking Training on Glycemic Control, Body Composition, and Physical Fitness in Type 2 Diabetic Patients**

A randomized, controlled trial

Older (≈ 60 y), obese (BMI ≈ 30) T2D; 60 min/session, 5 d/wk for 4 months  
Continuous or Interval Walking (~66% HR<sub>max</sub>) 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.”

www.marlingbala.com      Karstoft K et al. Diabetes Care 36: 228-236, 2013.      McMaster University



### 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

Aerobic Interval vs. Continuous Training in Patients with Coronary Artery Disease or Heart Failure: An Updated Systematic Review and Meta-Analysis Focus on Secondary Outcomes

High-intensity interval training versus moderate intensity continuous training within cardiac rehabilitation: a systematic review and meta-analysis

Effectiveness of high-intensity interval training on glycemic control and cardiorespiratory fitness in patients with type 2 diabetes: a systematic review and meta-analysis

Weston et al. Br J Sports Med 2014; Harrman et al. Open Access J Sports Med 2018; Paltyn et al. Sports Med 2016; Liu et al. Aging Clin Exp Res 2018.

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### Cardiovascular Risk of High- Versus Moderate-Intensity Aerobic Exercise in Coronary Heart Disease Patients

Olivind Rognum, PhD; Trine Moholdt, PhD; Hilde Bakken, BSc; Torstein Hole, MD, PhD; Per Mølstad, MD, PhD; Nils Erling Myhr, BSc; Jostein Grimsmo, MD, PhD; Ulrik Wisloff, PhD

Center	Patients, n	Total Training, h	Moderate Intensity, h	High Intensity, h
Ålesund	775	25 720 (1)	15 232	10 488 (1)
Feiring	2629	85 208 (2)	63 032 (1)	22 176 (1)

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

Mycardial infarction	0	0	
Risk of events	1/58 607	1/129 456	1/23 182

Circulation 126: 1436-1440, 2012.

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

**Clinical Perspective**

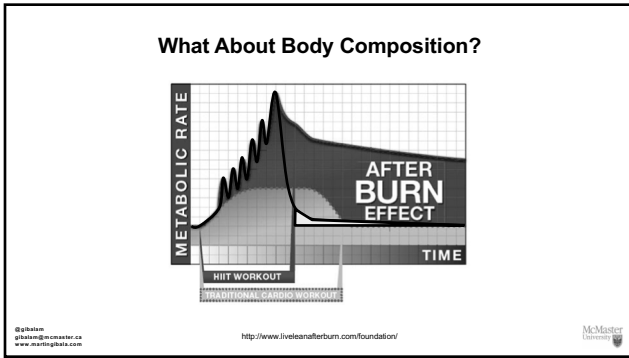
**What Is New?**

- 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.

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Weiniger et al. J Am Heart Assoc. 2018;7:e003005.

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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

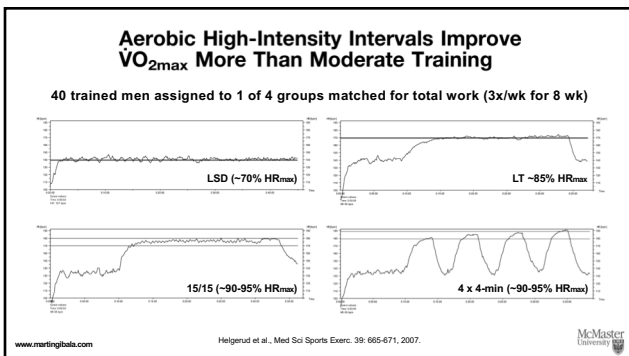
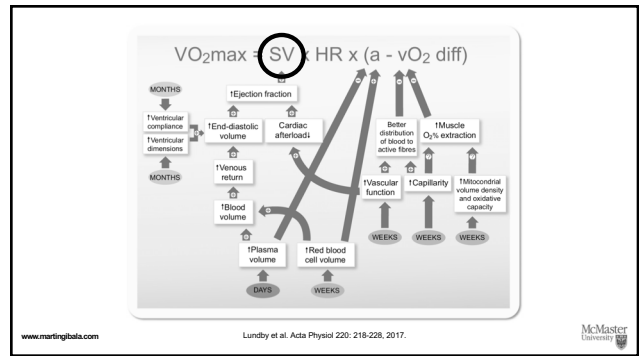
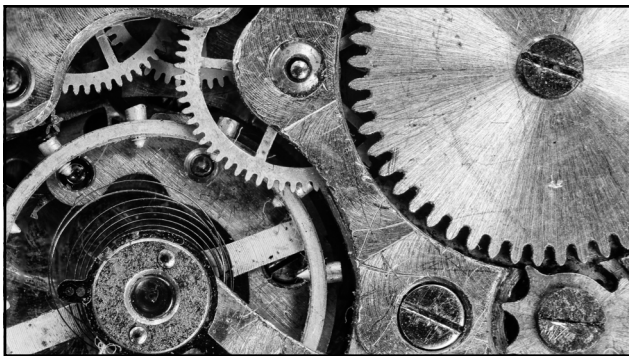
“Short-term HIIT and MICT exercise both elicit modest improvements, and of similar magnitude, in body fat levels and waist circumference.”

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

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Wevege et al. *Obes Rev* 18: 635-646, 2017.

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### Aerobic High-Intensity Intervals Improve $VO_{2max}$ More Than Moderate Training

40 trained men assigned to 1 of 4 groups matched for total work (3x/wk for 8 wk)

The bar chart shows final  $VO_{2max}$  for four groups. The 15/15 and 4x4 min groups show significantly higher  $VO_{2max}$  compared to LSD and LT. Statistical significance is indicated by asterisks (\*\*\*) and a circled box around the 15/15 and 4x4 min groups.

“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.”

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Helgerud et al., *Med Sci Sports Exerc*. 39: 665-671, 2007.

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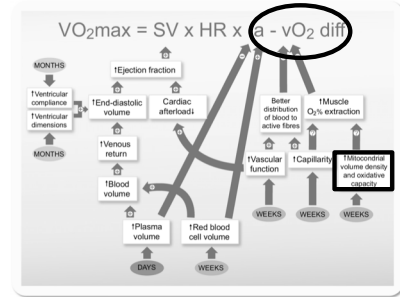
Improvements in exercise performance with high-intensity interval training coincide with an increase in skeletal muscle mitochondrial content and function

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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Jacobs et al. J Appl Physiol 115: 785-793, 2013.

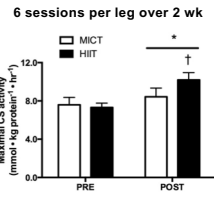
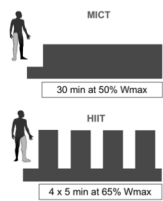


www.marlingbala.com

Lundby et al. Acta Physiol 220: 218-228, 2017.



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

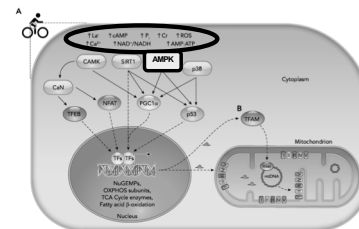
www.marlingbala.com

MacInnis et al. J Physiol 595: 2955-2968, 2017.



High-Intensity Exercise and Mitochondrial Biogenesis: Current Controversies and Future Research Directions

David J. Bishop,<sup>1,2</sup>  
 Javier Botella,<sup>1</sup>  
 Amanda J. Genders,<sup>1</sup>  
 Matthew J.-C. Lee,<sup>1</sup>  
 Nicholas J. Saner,<sup>1</sup> Jujiao Kuang,<sup>3</sup>  
 Xu Yan,<sup>1</sup> and Cesare Granata<sup>1</sup>



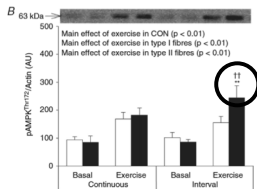
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Bishop et al. Physiology 34: 56-70, 2019.



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

30 min continuous at ~70% or 6 x 1.5 min intervals at ~95% VO<sub>2peak</sub>



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

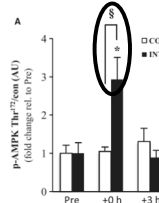
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Kristensen et al. J Physiol 590: 2053-2069, 2015.



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 ~70% VO<sub>2peak</sub>



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

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Combes et al. Physiol Rep 3: e12462, 2015.



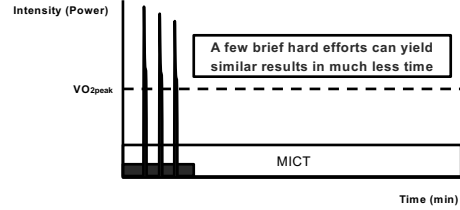
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### Sprint Interval Training



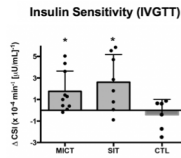
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Twelve Weeks of Sprint Interval Training Improves Indices of Cardiometabolic Health Similar to Traditional Endurance Training despite a Five-Fold Lower Exercise Volume and Time Commitment

PLOS ONE  
335,991 Views  
3,692 Downloads

	SIT	MICT
Protocol (3x/wk)	3 x 20-s sprints within 10 min	50 min continuous
Workload	~ 500 W (50 W)	~ 110 W
RPE	16 (hard)	13 (somewhat hard)
Mean HR	~83%	~73%
Work/session	~60 kJ	~300 kJ

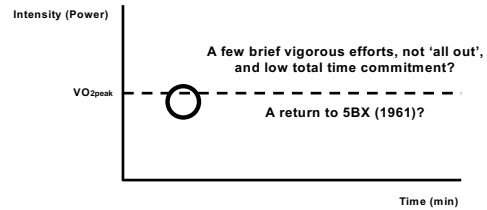


www.martingibala.com

Gillen et al. PLoS One 11: e0154075, 2016.



### The Interval Training "Sweet Spot"?



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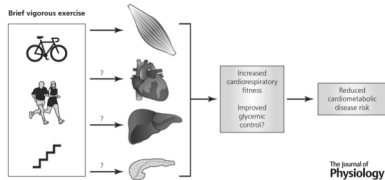


Topical Review | Full Access

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

Martin J. Gibala, Jonathan P. Little

First published: 06 November 2019 | <https://doi.org/10.1113/JP276849>



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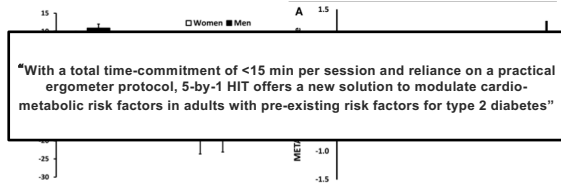
2019 Nov 6. doi: 10.1113/JP276849. [Epub ahead of print]



frontiers in Endocrinology

### A Practical and Time-Efficient High-Intensity Interval Training Program Modifies Cardio-Metabolic Risk Factors in Adults with Risk Factors for Type II Diabetes

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



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Phillips et al. Front. Endocrinol. 8:229, 2017.



### 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  $VO_{2max}$  and cardiometabolic risk markers.”

www.marlingibala.com Reijic D et al. Eur J Appl Physiol 118:1153-1167, 2018. McMaster University

### Brief Intense Stair Climbing Improves Cardiorespiratory Fitness

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

www.marlingibala.com Allison et al. Med Sci Sports Exerc 49:298-307, 2017. McMaster University

The New York Times Editorial

### Even a 20-Second Exercise ‘Snack’ Can Improve Fitness

As little as 20 seconds of brisk stair climbing, done several times a day, might be enough to increase aerobic fitness.

### Short and sporadic bouts in the 2018 US physical activity guidelines: is high-intensity incidental physical activity the new HIIT?

www.marlingibala.com https://www.nytimes.com/2019/01/23/well/move/20-second-exercise-fitness-interval-training.html Szamatac et al. Br J Sport Med 2019 Feb 20; pii: bjsports-2018-100397. McMaster University

The New York Times Editorial

### Even a 20-Second Exercise ‘Snack’ Can Improve Fitness

As little as 20 seconds of brisk stair climbing, done several times a day, might be enough to increase aerobic fitness.

“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’.”

www.marlingibala.com https://www.nytimes.com/2019/01/23/well/move/20-second-exercise-fitness-interval-training.html Szamatac et al. Br J Sport Med 2019 Feb 20; pii: bjsports-2018-100397. McMaster University

### A scoping review of the psychological responses to interval exercise: is interval exercise a viable alternative to traditional exercise?

“emerging data support the viability of interval exercise as an alternative to continuous exercise...”

While interval exercise may not be ideal or preferred by all, it may provide a viable option for many.”

Sterk et al., Health Psych Rev 11: 324-344, 2017.

### Interval Training: Take Home Messages

- 1) Elicits large improvements in cardiorespiratory 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 choose from.

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