
# Opportunities in Testing and Training Patients with Cardiovascular Disease

**Jeffrey Soukup, Ph.D., ACSM-CEP**

# Disclosures

- No Disclosures

# Objectives

- To review current statements by the AHA/ACC, European Association of Cardiovascular Prevention and Rehabilitation, ACSM and AACVPR, that suggest that exercise testing needs to be part of the exercise prescriptive process in CR

- To describe the limitations of relying on the 6MWT to predict changes in functional capacity and estimate peak VO2

- To describe the potential differences in performance outcomes with HIIT vs. MCT

- To describe two methods for performing HIIT

# PRE-POST FUNCTIONAL CAPACITY OUTCOME MEASURES

1. To list the guiding recommendations for pre-program exercise testing
2. To describe the limitations of relying on the 6MWT to predict changes in functional capacity and peak oxygen uptake

**ACC/AHA PRACTICE GUIDELINES—FULL TEXT**

# ACC/AHA 2002 Guideline Update for Exercise Testing

## A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing)


**COMMITTEE MEMBERS**

Raymond J. Gibbons, MD, FACC, FAHA, *Chair*

Gary J. Balady, MD, FACC, FAHA
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Aryan N. Mooss, MBBS, FACC, FAHA
Michael G. O'Reilly, MD, FACC
William L. Winters, Jr., MD, FACC, FAHA


This reference is dated but remains pertinent as these guidelines remain in effect

Exercise testing in cardiac rehabilitation is essential in development of the exercise prescription to establish a safe and effective training intensity, in risk stratification of patients to determine the level of supervision and monitoring required during exercise training sessions, and in evaluation of training program outcome (7,164,390)

**Class IIb**

1. **Evaluation of the patient's response to specific therapeutic interventions in which improvement of exercise tolerance is an important goal or end point.**
2. **Determination of the intensity for exercise training as part of comprehensive cardiac rehabilitation.**

Gibbons, R et al. *ACC/AHA 2002 Guideline Update for Exercise Testing: Summary Article. A Report of the American College of Cardiology/American Heart Association task Force on Practice Guidelines.* Am. J.Cardiol. 2002;40(8)1531-1540)

- European Association of Cardiovascular Prevention & Rehabilitation
  - "Cardiopulmonary exercise testing is a methodology that has profoundly changed the approach to patient's functional evaluation, linking performance and physiologic parameters to the underlying metabolic substratum and providing highly reproducible exercise capacity descriptors"

Mezzani et al. *European Society of Cardiology, Standards for the use of cardiopulmonary exercise testing for the functional evaluation of cardiac patients: a report from the Exercise Physiology section of the European Association for Cardiovascular Prevention and Rehabilitation*, European Journal of Cardiology Prevention and Rehabilitation, 16;249-267, 2009.

- American Heart Association
  - "Exercise testing remains a remarkably durable and versatile tool that provides valuable diagnostic and prognostic information regarding patients with cardiovascular disease"

  and

  - "the addition of ventilatory gas exchange measurements during exercise testing provides a wide array of unique and clinically useful incremental information that heretofore has been poorly understood and underutilized by the practicing clinician."

**AHA Scientific Statement**

**Clinician's Guide to Cardiopulmonary Exercise Testing in Adults**

**A Scientific Statement From the American Heart Association**

Gary J. Balady, MD, FAHA, Chair; Ross Arena, PhD, FAHA; Kathy Sietsema, MD; Jonathan Myers, PhD, FAHA; Lola Coke, RN, PhD; Gerald F. Fletcher, MD, FAHA; Daniel Forman, MD; Barry Franklin, PhD, FAHA; Marco Guazzi, MD, PhD; Martha Gulati, MD; Steven J. Keteyian, PhD; Carl J. Lavie, MD; Richard Macko, MD; Donna Mancini, MD; Richard V. Milani, MD, FAHA; on behalf of the American Heart Association Exercise, Cardiac Rehabilitation, and Prevention Committee of the Council on Clinical Cardiology; Council on Epidemiology and Prevention; Council on Peripheral Vascular Disease; and Interdisciplinary Council on Quality of Care and Outcomes Research

*Circulation. 2010; 122: 191-225*

- American College of Sports Medicine
  - "…exercise testing at baseline is essential for the development of an exercise prescription in patients who have suffered from MI with or without revascularization, as well as those patients who have undergone coronary revascularization alone."

Pescatello, L. (Senior Editor) *ACSM's Guidelines for Exercise Testing and Prescription* (9th edition) Lippincott, Williams & Wilkins, page 241, 2013)

- American Association of Cardiovascular & Pulmonary Rehabilitation
  - To establish a safe and effective program of comprehensive cardiovascular risk reduction and rehabilitation, each patient should undergo a careful medical evaluation and exercise test before participating in an outpatient Cardiopulmonary Rehabilitation program."
  - "The 6-minute walk test can be used as a surrogate test to assess exercise capacity when standard treadmill or cycle testing is not available."
    - **I do <u>not</u> agree with this**

AACVPR Guidelines Cardiac Rehabilitation & Secondary Prevention (5th edition), page 58.

# Significant correlation between 6MWD & Peak VO2

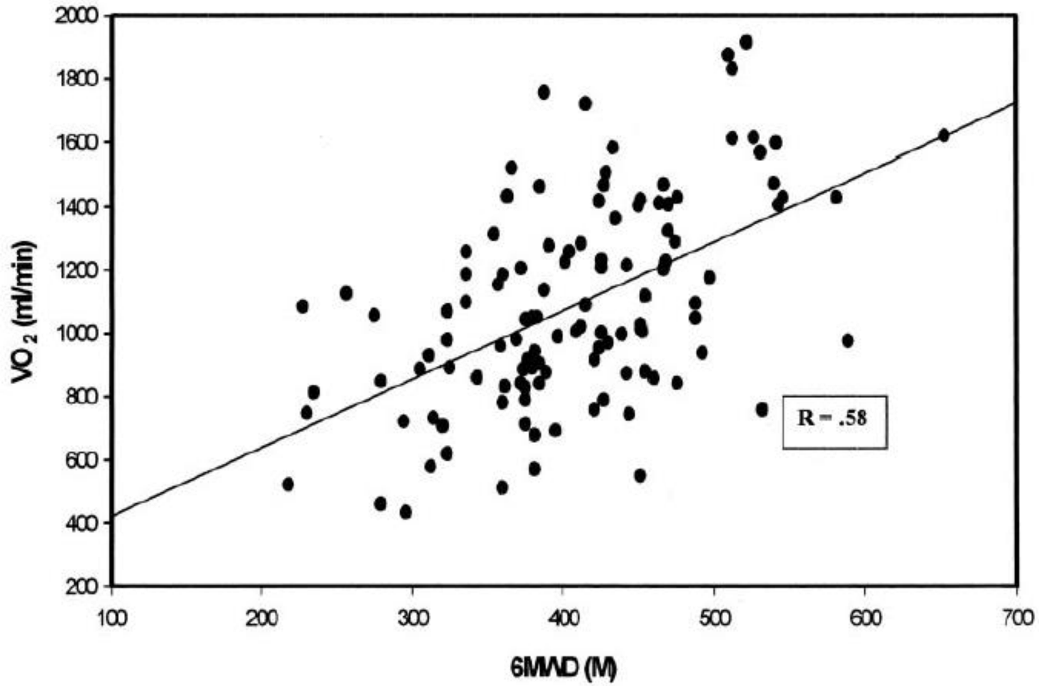


FIGURE 1. Plot of 6MWD by $\dot{V}O_2$.

Ross *et al. BMC Pulmonary Medicine* 2010, **10**:31
http://www.biomedcentral.com/1471-2466/10/31

BMC Pulmonary Medicine

RESEARCH ARTICLE Open Access

The six minute walk test accurately estimates mean peak oxygen uptake

Robert M Ross*[1], Jayasimha N Murthy[2], Istvan D Wollak[3] and Andrew S Jackson[4]

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# Interpreting Correlations

TABLE 5.6
Rule of Thumb for Interpreting the Size of a Correlation Coefficient

| *Size of Correlation* | *Interpretation* |
|---|---|
| .90 to 1.00 (–.90 to –1.00) | Very high positive (negative) correlation |
| .70 to .90 (–.70 to –.90) | High positive (negative) correlation |
| .50 to .70 (–.50 to –.70) | Moderate positive (negative) correlation |
| .30 to .50 (–.30 to –.50) | Low positive (negative) correlation |
| .00 to .30 (.00 to –.30) | Little if any correlation |

Taken from: Hinkle, Wiersma, and Jurs, Applied Statistics for the Behavioral Sciences (4th edition) page 120, 1998.

**Table 1: Sample and linear regression characteristics for all subjects contrasted by study.**

| Study | Sample Characteristics | | | | Linear Regression Statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Disease | n | peak VO2 Mean ± SD | 6 MWT Mean ± SD | Slope | Intercept | R | SEE | (SEE/Mean) × 100 |
| Cahalin 1996 (3) | CHF | 45 | 12.4 ± 4.5 | 310 ± 103 | 0.028 | 3.583 | 0.65 | 3.44 | 27.7 |
| Cahalin 1995 (2) | ESLD | 60 | 9.6 ± 3.8 | 294 ± 139 | 0.019 | 4.042 | 0.69 | 2.81 | 29.2 |
| Lucas 1999 (6) | CHF | 307 | 14.2 ± 4.9 | 391 ± 105 | 0.027 | 3.666 | 0.59 | 3.99 | 28.1 |
| Miyamoto 2000 (7) | PH | 27 | 13.9 ± 4.4 | 377 ± 115 | 0.026 | 4.213 | 0.68 | 3.25 | 23.4 |
| Opasich 2001 (8) | CHF | 269 | 14.5 ± 4.9 | 378 ± 95 | 0.027 | 4.498 | 0.59 | 3.42 | 23.6 |
| Roul 1998 (9) | CHF | 114 | 16.8 ± 4.5 | 437 ± 108 | 0.009 | 12.910 | 0.21 | 4.43 | 26.4 |
| Starobin 2006 (10) | COPD | 49 | 14.0 ± 4.4 | 436 ± 89 | 0.027 | 2.184 | 0.55 | 3.69 | 26.4 |
| Zugck 2000 (11) | DC | 112 | 15.6 ± 5.2 | 463 ± 107 | 0.033 | 0.113 | 0.69 | 3.78 | 24.2 |
| Faggiano 1997 (4) | CHF | 26 | 15.1 ± 3.9 | 419 ± 121 | 0.019 | 7.260 | 0.58 | 3.25 | 20.8 |
| Lipkin 1986 (5) | CHF | 26 | 14.0 ± 4.1 | 452 ± 147 | 0.019 | 5.271 | 0.70 | 2.95 | 21.0 |
| Baylor | CPD | 48 | 13.1 ± 3.4 | 354 ± 131 | 0.017 | 6.921 | 0.68 | 2.50 | 19.1 |
| All Data | All | 1,083 | 14.3 ± 4.8 | 393 ± 115 | 0.025 | 4.682 | 0.59 | 3.82 | 26.7 |

ESLD - End Stage Lung Disease; DC - Dilated Cardiomyopathy; CHF - Congestive Heart Failure; PH -Pulmonary Hypertension; COPD - Chronic Obstructive Pulmonary Disease; CPD - Various Cardiopulmonary Disorders. Peak VO2 - peak oxygen uptake (ml/kg/min.); 6 MWD- distance walked (meters) during the 6-minute walk test.

# In Certain Populations…

- The distance walked correlates moderately with peak oxygen uptake and there is a learning curve

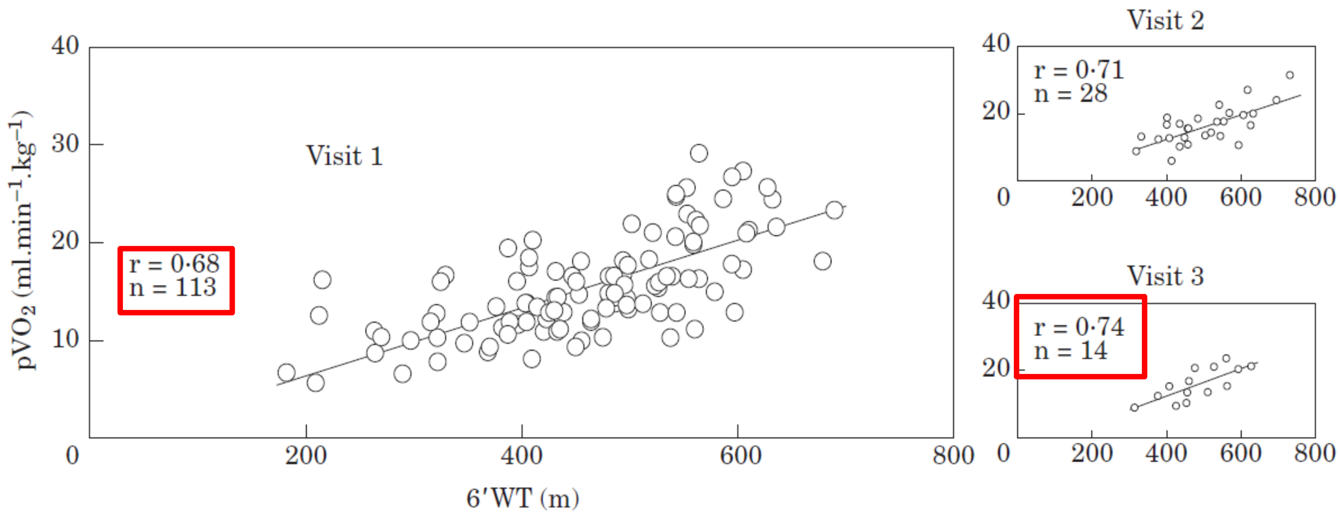


*Figure 2* **Relationship between the ambulated distance (6‘WT) and peak oxygen uptake (pVO$_2$) at the initial visit (visit 1) as well as the first (visit 2, after 263 ± 144 days) and second (visit 3, after 263 ± 144 days) follow-up visit.**

*European Heart Journal* (2000) **21**, 540–549
doi:10.1053/euhj.1999.1861, available online at http://www.idealibrary.com on IDEAL®

**Is the 6-minute walk test a reliable substitute for peak oxygen uptake in patients with dilated cardiomyopathy?**

**C. Zugck, C. Krüger, S. Dürr, S. H. Gerber, A. Haunstetter, K. Hornig, W. Kübler and M. Haass**

*Department of Cardiology, University of Heidelberg, Germany*

*Table 3 Exercise performance and relationship between peak oxygen uptake ($pVO_2$) and the 6-min walk test (6'WT) at the initial visit*

| | | $pVO_2$ | 6'WT |
|---|---|---|---|
| Cardiopulmonary exercise testing | | | |
| $pVO_2$ (ml . min$^{-1}$ . kg$^{-1}$) | 15·4 ± 5·4 | — | r=0·68* |
| $pVO_2$ (%) | 50 ± 16 | r=0·68* | r=0·61* |
| Exercise duration (min) | 12·5 ± 5·2 | r=0·87* | r=0·70* |
| Maximal work load (W) | 85 ± 39 | r=0·82* | r=0·68* |
| Maximal heart rate (beats . min$^{-1}$) | 140 ± 29 | r=0·47* | r=0·51* |
| Maximal systolic blood pressure (mmHg) | 154 ± 31 | r=0·50* | r=0·42* |
| Maximal diastolic blood pressure (mmHg) | 87 ± 21 | r=0·09 | r=0·16 |
| 6-min walk test | | | |
| Ambulated distance (m) | 466 ± 107 | r=0·68* | — |
| Maximal heart rate (beats . min$^{-1}$) | 98 ± 21 | r= – 0·04 | r=0·17 |
| Maximal systolic blood pressure (mmHg) | 132 ± 26 | r=0·14 | r=0·12 |
| Maximal diastolic blood pressure (mmHg) | 76 ± 13 | r=0·06 | r= – 0·07 |

Data are presented as means ± SD, $*P<0·01$.

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# VARIATIONS IN EXERCISE INTENSITY DO NOT ALTER CHANGES IN PEAK OXYGEN UPTAKE OR THE OXYGEN UPTAKE EFFICIENCY SLOPE DURING MODERATE CONTINUOUS TRAINING IN OUT-PATIENT CARDIAC REHABILITATION

[1]Colleen Daubert, [1]Jeffrey Soukup, [2]Amanda Kosmata, and [3]Beth Ann Scott. [1]Intensive Cardiac Rehabilitation Department, New Hanover Regional Medical Center, Wilmington, NC, [2]Cardiac Rehabilitation Department, Alleghany Health Network, Pittsburgh, PA. [3]Cardiopulmonary Services, Appalachian Regional Heathcare System, Boone NC,

**Table 3. Comparison of Pre and Post Program CPET Measures**

| | Pre-Program | | Post-Program | |
|---|---|---|---|---|
| | MIE (n=36) | VIE (n=54) | MIE (n=36) | VIE (n=54) |
| Test Duration (min) | 9.9 ± 1.1 | 9.6 ± 1.9 | 11.2 ± 3.4* | 11.8 ± 2.7* |
| Peak HR (beats·min$^{-1}$) | 143.0 ± 21.7 | 136.6 ± 17.7 | 142.6 ± 27.0 | 143.4 ± 22.0* |
| Percent of Max HR (%) | 93.6 ± 13.0 | 87.4 ± 10.6† | 93.3 ± 16.1 | 91.9 ± 13.1* |
| Peak RER | 1.15 ± 0.16 | 1.17 ± 0.13 | 1.17 ± 0.12 | 1.17 ± 0.10 |
| Peak $VO_2$ (mL·kg$^{-1}$·min$^{-1}$) | 23.5 ± 5.6 | 22.8 ± 4.6 | 26.0 ± 8.25* | 26.3 ± 6.7* |
| $VO_2$ at VAT (mL·kg$^{-1}$·min$^{-1}$) | 14.5 ± 3.5 | 14.4 ± 2.8 | 16.0 ± 4.9* | 16.0 ± 4.0* |
| OUES (ml·min$^{-1}$/log VE·min$^{-1}$) | 2114.9 ± 606.3 | 2048.4 ± 492.8 | 2295.8 ± 740.4* | 2263.4 ± 601.7* |

VO2 Reserve for MIE = ~51.4%
VO2 Reserve for VIE = ~71.9%

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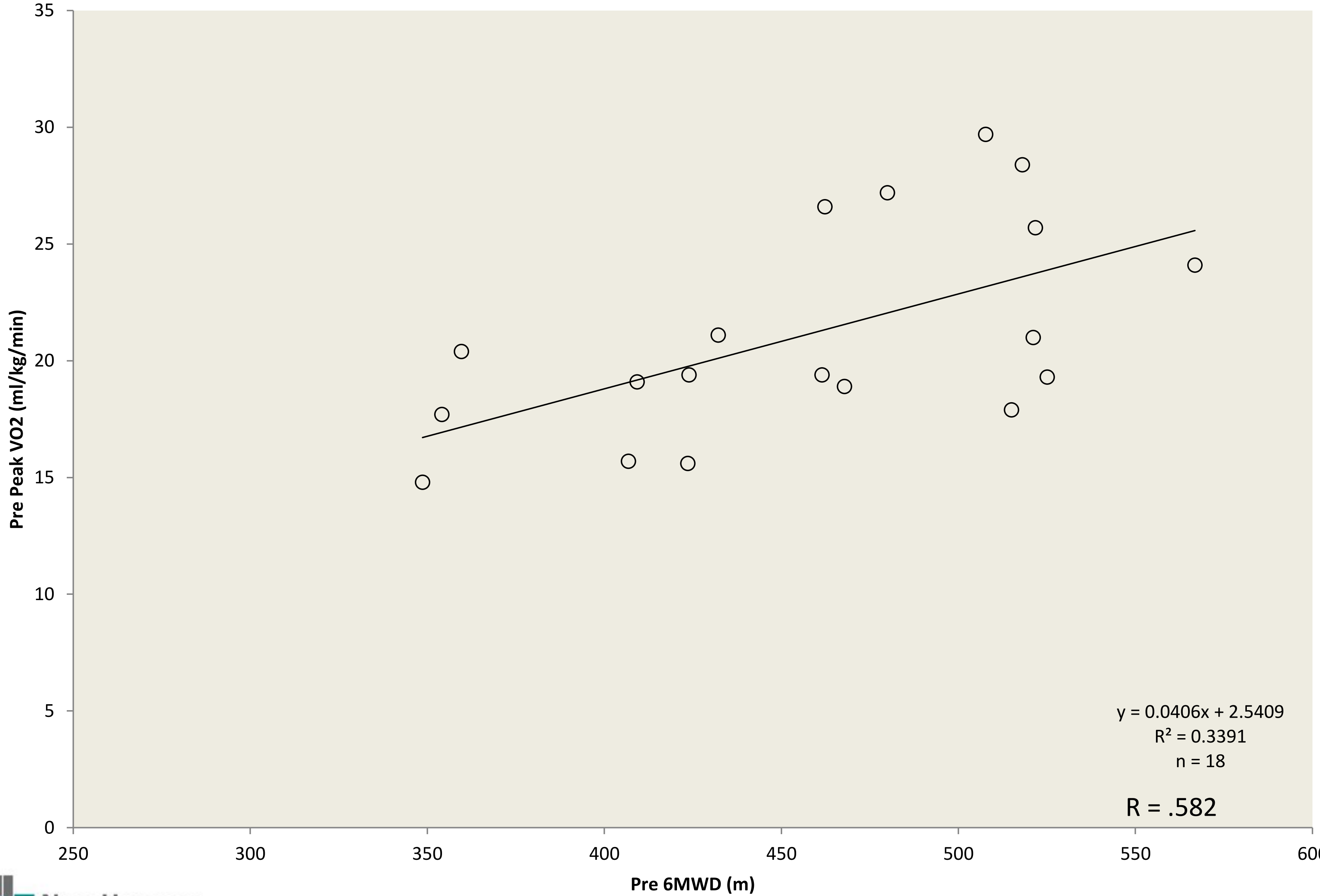
# Relation of 6MWT Distance and Peak VO2

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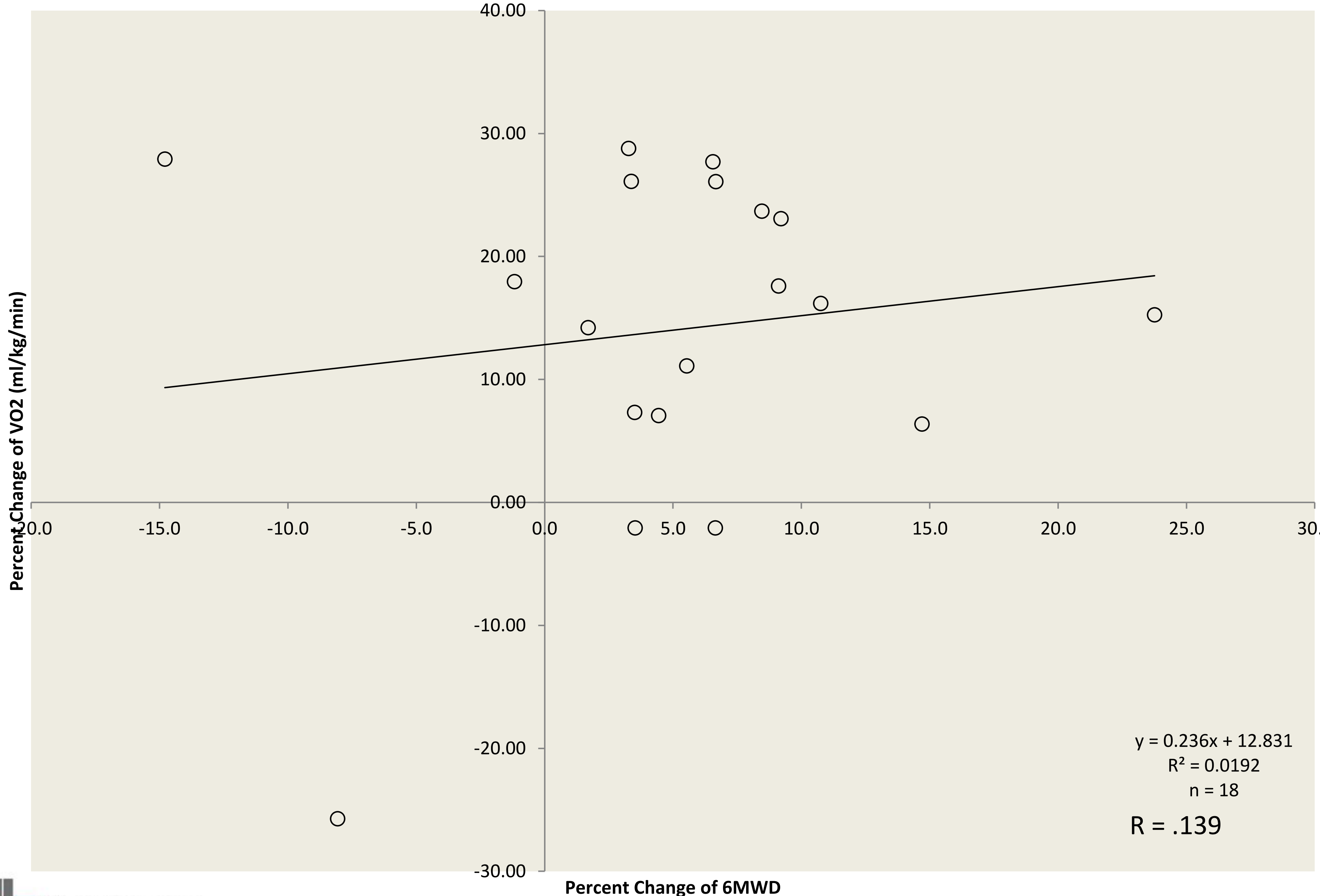
# According to Hinkel, Wiersma & Jurs…

- The $R^2$ equals the proportion of the total variance in Y that can be associated with the variance in X

- More specifically, the $R^2$ equals the proportion of the total variance in peak oxygen consumption that can be associated with the variance in 6MWD

- So, an R = 0.58 → $R^2$ = .3391 which means that 34% of the variation in peak VO2 can be associated with the variance in 6MWD

# Relation of Percent Changes of 6MWD and Peak VO2

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Taken from: Hinkle, Wiersma, and Jurs, Applied Statistics for the Behavioral Sciences ($4^{th}$ edition) page 120, 1998.

# The Six Minute Walk Test

- Is a valuable assessment of functional capacity and good index for therapeutic efficacy when:
  - the sample population is very low functioning (eg. oxygen uptake less than or = 15 mL/kg/min)
  - the sample population being compared is homogenous
    - pulmonary
    - HF
    - Aortic Stenosis
    - Cardiomyopthy
  - the testing protocol is standardized (ATS guidelines)
- Poorly predicts peak VO2 and should be used with caution to establish the exercise prescription for an individual patient

# HIGH INTENSITY INTERVAL TRAINING VS MODERATE CONTINUOUS TRAINING

1. To describe the potential differences in performance outcomes with HIIT vs. MCT
2. To describe two methods for performing HIIT

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# Potential Benefits of HIIT

- HIIT may provide greater improvement than MCT in:
  - Cardiorespiratory endurance
  - Preservation of coronary artery lumen diameter
  - Anti-inflammatory responses
  - LV geometry and myocardial performance

- HIIT has been shown to be safe in high-risk populations such as those with HF

- HIIT is referenced in ACSM's GETP 10 Exercise Training Considerations for Outpatient CR

**Table 3 • Cardiorespiratory Responses to Exercise at Baseline and Followup**

| Parameter | Higher-Intensity Interval Training (n = 15), Mean ± SD | | Moderate-Intensity Continuous Training (n = 13), Mean ± SD | | *P* Values for Between-Group Comparisons |
|---|---|---|---|---|---|
| | Baseline | Followup | Baseline | Followup | |
| Exercise duration, min | 13.3 ± 1.6 | 15.1 ± 1.7[a] | 13.5 ± 2.8 | 15.3 ± 1.9[a] | .900 |
| Peak heart rate, bpm | 145 ± 17 | 151 ± 17 | 138 ± 24 | 135 ± 26 | .101 |
| Peak systolic blood pressure, mmHg | 162 ± 17 | 169 ± 16 | 179 ± 29 | 164 ± 32 | .096 |
| Peak diastolic blood pressure, mmHg | 79 ± 9 | 75 ± 13 | 78 ± 13 | 78 ± 12 | .315 |
| Peak oxygen uptake | | | | | |
| $mL \cdot kg^{-1} \cdot min^{-1}$ | 22.4 ± 4.2 | 26.0 ± 5.9[a] | 21.8 ± 4.0 | 23.5 ± 4.6[a] | .050 |
| $L \cdot min^{-1}$ | 2025 ± 544 | 2309 ± 598[a] | 1982 ± 574 | 2119 ± 624[a] | .043 |
| Peak oxygen pulse ($mL \cdot beat^{-1}$) | 14.2 ± 3.5 | 15.8 ± 3.5[a] | 14.6 ± 3.2 | 16.2 ± 4.2[a] | .967 |
| Peak respiratory exchange ratio | 1.20 ± 0.10 | 1.23 ± 0.10 | 1.23 ± 0.08 | 1.22 ± 0.10 | .262 |
| Ventilatory efficiency slope ($V_E$-$CO_2$) | 28.7 ± 3.6 | 28.6 ± 3.2 | 29.3 ± 4.6 | 29.3 ± 5.2 | .912 |
| Change in heart rate from peak exercise to minute 1 of recovery, bpm | −25 ± 10 | −25 ± 9 | −28 ± 16 | −29 ± 16 | .577 |
| Perceived exertion at peak exercise | 16 ± 2 | 16 ± 2 | 17 ± 1 | 16 ± 2 | .483 |

Abbreviation: bpm, beats per minute. [a]$P \leq .05$, within-group change from baseline to followup.

MCT = 60-80% HRR, HIIT = W:80-90% HRR at 4 min & R:60-70% HRR at 3 min (isocaloric)

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Keteyian et al. JCRP 2014;34, 98-105.

# High-intensity interval training may reduce in-stent restenosis following percutaneous coronary intervention with stent implantation: A randomized controlled trial evaluating the relationship to endothelial function and inflammation

Peter S. Munk, MD,[a,b] Eva M. Staal, MD, PHD,[a,b] Noreen Butt, MD,[a] Kjetil Isaksen, MD,[a] and Alf I. Larsen, MD, PHD[a,b] *Stavanger and Bergen, Norway*

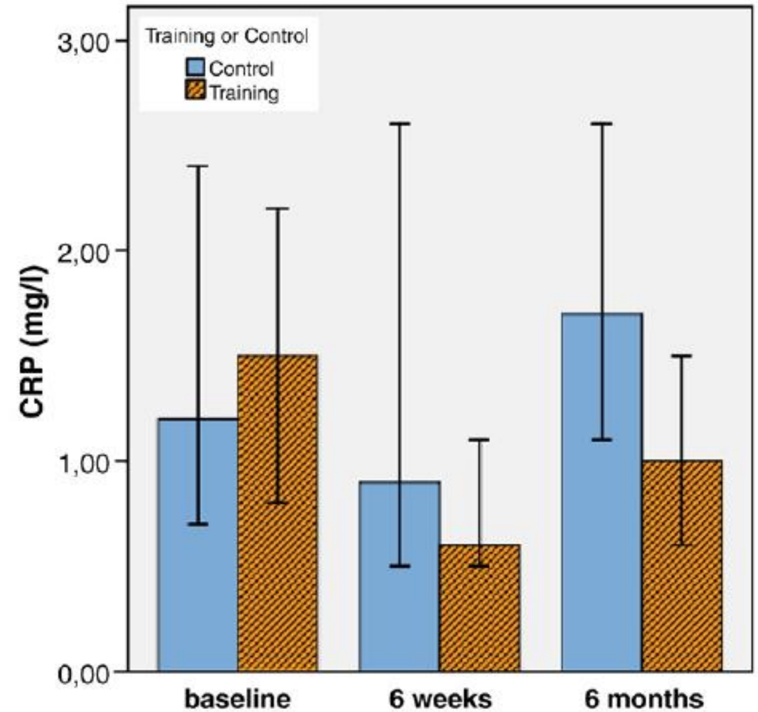
**Table III.** Angiographic results at 6 months

| | Control | Training | *P*-value |
|---|---|---|---|
| Minimal luminal diameter (mm) | 2.05 (0.55) | 2.24 (0.9) | .15 |
| Net lumen gain (mm) per patient | 1.05 (0.81) | 1.3 (0.73) | .03 |
| Late luminal loss (mm) per patient | 0.39 (0.38) | 0.10 (0.52) | .01 |

*P* values refer to changes between control and training group.

**Figure 3**

**CRP-levels during trial according to treatment group**




Levels of CRP during trial period according to treatment group. Median CRP levels with range according to treatment group. *P* = .03 for trend.

HIIT = W:90-95% peak HR at 4 min, R:60-70% peak HR at 3 min

Am Heart J. 2009;158:734-741

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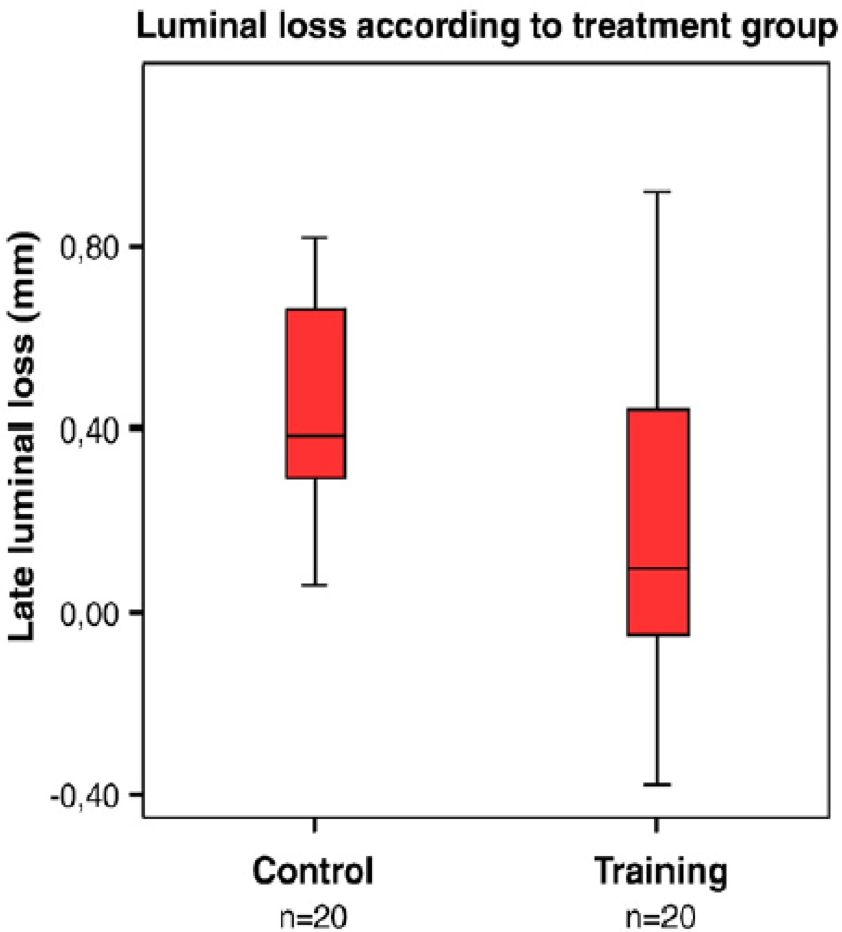
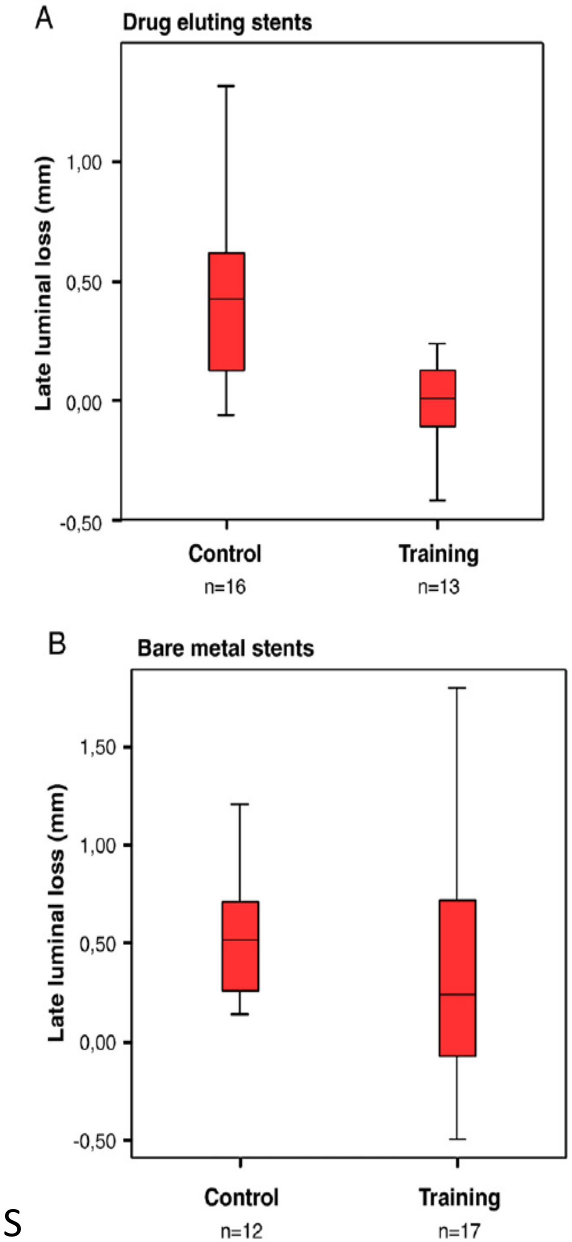



P = 0.01 for difference between groups




P<0.05 for DES; P>0.05 for BMS

# WHY DES Improvements vs. BMS

- Late luminal loss (LLL) = minimal luminal diameter (MLD) after the index procedure minus the MLD at 6 months

- LLL has been correlated to intimal hyperplasia
- Neointimal hyperplasia has been linked to:
  - low local shear stress
  - Inflammatory response to vessel injury

- DES – the drug that is released may be reducing the effect of low shear stress and/or reducing the inflammatory responses

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

## A Randomized Study

Ulrik Wisløff, PhD; Asbjørn Støylen, MD, PhD; Jan P. Loennechen, MD, PhD; Morten Bruvold, MSc; Øivind Rognmo, MSc; Per Magnus Haram, MD, PhD; Arnt Erik Tjønna, MSc; Jan Helgerud, PhD; Stig A. Slørdahl, MD, PhD; Sang Jun Lee, PhD; Vibeke Videm, MD, PhD; Anja Bye, MSc; Godfrey L. Smith, PhD; Sonia M. Najjar, PhD; Øyvind Ellingsen, MD, PhD; Terje Skjærpe, MD, PhD

**TABLE 2. Aerobic Capacity and Exercise Data**

| | Control | | MCT | | AIT | |
|---|---|---|---|---|---|---|
| | Baseline | Follow-Up | Baseline | Follow-Up | Baseline | Follow-Up |
| Peak treadmill test | | | | | | |
| $\dot{V}o_{2peak}$, mL · kg$^{-1}$ · min$^{-1}$ | 13.2±1.9 | 13.4±2.0 | 13.0±1.1 | 14.9±0.9* | 13.0±1.6 | 19.0±2.1*† |
| Peak heart rate, bpm | 129±23 | 127±21 | 132±18 | 130±21 | 129±19 | 127±22 |
| $[La^-]_b$ at $\dot{V}o_{2peak}$, mmol/L | 6.3±1.6 | 6.3±1.2 | 6.8±1.2 | 6.4±1.0 | 6.2±0.8 | 6.0±0.6 |
| RER at $\dot{V}o_{2peak}$ | 1.10±0.04 | 1.11±0.04 | 1.10±0.04 | 1.09±0.05 | 1.08±0.05 | 1.11±0.04 |
| Anaerobic threshold | | | | | | |
| % Of peak oxygen uptake | 64±6 | 65±4 | 61±3 | 68±4*‡ | 63±5 | 61±3 |
| mL · kg$^{-1}$ · min$^{-1}$ | 8.5±1.6 | 8.7±3.9 | 8.0±0.7 | 10.1±0.9*§ | 8.2±0.8 | 11.6±1.0*† |
| Work economy | | | | | | |
| mL · kg$^{-1}$ · min$^{-1}$ | 8.5±1.6 | 9.1±2.8 | 8.0±0.7 | 7.6±0.8§ | 8.2±0.8 | 7.0±0.6*† |
| Heart rate, bpm | 84±9 | 88±8 | 82±6 | 81±9 | 84±9 | 76±5*† |
| $[La^-]_b$, mmol/L | 2.81±0.4 | 3.0±0.8 | 2.9±0.3 | 2.5±0.4 | 2.7±0.3 | 1.6±0.4*† |

MCT = 70% peak HR, HIIT = W:90-95% peak HR at 3 min, R:50-60% peak HR at 3 min

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

Cardiovascular Research (2013) **99**, 55–64
doi:10.1093/cvr/cvt080

# Aerobic interval training attenuates remodelling and mitochondrial dysfunction in the post-infarction failing rat heart

Jasenka Kraljevic[1], Jasna Marinovic[1], Danijel Pravdic[2], Petra Zubin[1], Zeljko Dujic[1], Ulrik Wisloff[3], and Marko Ljubkovic[1]*

**Table 1** Cardiac morphological and functional parameters after surgery and exercise training

| Four-week post-surgery | Sham | MI-operated | |
|---|---|---|---|
| FS (%) | 53.1 ± 5.5 | 28.3 ± 5.7* | |
| LVDd (mm) | 5.82 ± 0.26 | 7.92 ± 0.59* | |
| LVDs (mm) | 2.73 ± 0.39 | 5.81 ± 0.91* | |
| AWTd (mm) | 1.76 ± 0.05 | 1.4 ± 0.39 | |
| AWTs (mm) | 2.78 ± 0.13 | 2.00 ± 0.48* | |
| PWTd (mm) | 1.70 ± 0.18 | 1.59 ± 0.19 | |
| PWTs (mm) | 2.88 ± 0.23 | 2.47 ± 0.35* | |
| $W_B$ (g) | 257.4 ± 11.5 | 259.9 ± 13.1 | |
| Number of animals | 16 | 31[a] | |
| **12-week post-surgery** | **Sham** | **MI-Sedentary** | **MI-Trained** |
| FS (%) | 58.3 ± 8.9 | 21.7 ± 5.5*,† | 30.4 ± 8.5# |
| LVDd (mm) | 5.86 ± 0.31 | 9.10 ± 0.98* | 7.84 ± 1.09* |
| LVDs (mm) | 2.46 ± 0.65 | 7.16 ± 1.17* | 5.50 ± 1.30# |
| AWTd (mm) | 1.52 ± 0.19 | 1.22 ± 0.61 | 1.49 ± 0.33 |
| AWTs (mm) | 2.78 ± 0.31 | 1.76 ± 0.83 | 2.36 ± 0.74 |
| PWTd (mm) | 1.78 ± 0.16 | 1.48 ± 0.40 | 1.81 ± 0.20 |
| PWTs (mm) | 2.84 ± 0.40 | 2.34 ± 0.50 | 2.63 ± 0.48 |

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**TABLE 3. LV Volumes and Resting Hemodynamics**

| | Control | | MCT | | AIT | |
|---|---|---|---|---|---|---|
| | Baseline | Follow-Up | Baseline | Follow-Up | Baseline | Follow-Up |
| LVDD, mm | 67.2±8.1 | 67.8±12.5 | 69.1±8.6 | 68.2±6.5 | 66.7±6.8 | 59.0±6.8*† |
| LVSD, mm | 56.2±9.2 | 56.7±13.7 | 56.6±8.8 | 53.9±7.4 | 53.9±6.7 | 46.1±8.2*† |
| LVEDV, mL | 250.5±64.4 | 242.1±62.3 | 245.5±53.1 | 230.3±41.0 | 248.1±79.6 | 202.9±72.0*† |
| LVESV, mL | 187.8±53.0 | 186.6±58.6 | 172.9±48.7 | 160.6±34.3 | 177.4±72.1 | 133.9±57.8*† |
| HR at rest, bpm | 60±11 | 59±11 | 55±10 | 54±12 | 65±14 | 61±13 |
| SV, mL | 53.4±15.3 | 55.0±13.7 | 63.5±12.7 | 63.1±15.7 | 57.1±14.3 | 67.0±19.9* |
| CO, L/min | 3.1±0.6 | 3.2±0.5 | 3.5±0.9 | 3.4±1.1 | 3.5±0.5 | 3.9±0.6* |
| EF, % | 26.2±8.0 | 26.6±9.7 | 32.8±4.8 | 33.5±5.7 | 28.0±7.3 | 38.0±9.8*† |

Data are mean±SD. LVDD indicates LV diastolic diameter; LVSD, LV systolic diameter; LVEDV, LV end-diastolic volume; LVESV, LV end-systolic diameter; HR, heart rate; SV, stroke volume; CO, cardiac output; and EF, ejection fraction.

*Different from baseline, $P<0.01$; †different from controls and moderately trained, $P<0.02$.

New Hanover Regional Medical Center

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

Scientific Review

# Influence of High-Intensity Interval Training Versus Continuous Training on Functional Capacity in Individuals With Heart Failure

## A SYSTEMATIC REVIEW AND META-ANALYSIS

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**Conclusion:** High-intensity interval training and continuous training provide benefits for patients, however, the quality of evidence still does not allow us to indicate whether there is a superiority of HIIT over conventional continuous exercise training using the variables analyzed.

Journal of Cardiopulmonary Rehabilitation and Prevention 2019;39:293-298

| Author (yr) | Population | Age (Mean) | Study Sample | Intervention | Reported Outcomes |
|---|---|---|---|---|---|
| Wisløff et al (2007)[17] | Patients with ischemic HF | HIIT: 76.5 ± 9 yr<br>Continuous aerobic training: 74.4 ± 12 yr | 20 men and 7 women with reduced LVEF | HIIT: 10-min warm-up at 50%-60% $\dot{V}O_2$ peak followed by four 4-min intervals at 90%-95% peak HR, each interval separated by 3-min active pauses at 50%-75% of peak HR; session ended with 3-min cooldown at 50%-70% peak HR; total exercise time = 38 min<br>Continuous aerobic training: 70%-75% peak HR; total exercise time = 47 min; 12 wk | Functional capacity, quality of life, systolic function |
| Iellamo et al (2013)[11] | Patients with ischemic HF | HIIT: 62.2 ± 8 yr<br>Continuous aerobic training: 62.2 ± 8 yr | 20 men with reduced LVEF and NYHA II-III | HIIT: 9-min warm-up, followed by 4-min intervals; 2-4 times at 75%-80% HRR, followed by 3-min active pauses at 45%-50% of HRR<br>Continuous aerobic training: 45%-60% of HRR; total exercise time: 30-45 min; 12 wk | Functional capacity, heart rate variability, baroreflex sensitivity |
| Smart and Steele (2012)[15] | Patients with HF | HIIT: 59.1 ± 11 yr<br>Continuous aerobic training: 62.9 ± 9.3 yr | 23 adults including both sexes with reduced LVEF | HIIT (cycle ergometer): 60%-70% of $\dot{V}O_2$ peak 1-min exercise and 1-min rest<br>Continuous aerobic training (cycle ergometer): 60%-70% $\dot{V}O_2$ peak; 16 wk | Functional capacity, cardiac function, endothelial function |
| Normandin et al (2013)[14] | Patients with HF | 61.0 ± 9.9 yr | 20 adults of both sexes with reduced LVEF and NYHA I-III | Acute effect (1 exercise session):<br>HIIT (cycle ergometer): 5-min warm-up at 50% PPO, followed by two 8-min interval training blocks; 30 sec at 100% PPO with 30-sec passive recovery; 4 min of passive recovery was allowed between the blocks with 1-min cooldown at 25% PPO after the last 30-sec exercise bout<br>Continuous aerobic training (cycle ergometer): 60% PPO; total exercise time = 22 min | Acute cardiopulmonary responses, inflammatory measures, BNP |

# HIIT at the Mayo Clinic

- HIIT for Everyone
- HIIT based on RPE responses using BORG scale
  - Hard = 15-17
  - Easy = 11-13
- Started when patient is able to complete 20 minutes of MCT
- Begin with 30 second intervals
- Adjust/advance per individual
- Goal is 4:4 hard:easy with total duration 35-45 minutes
- BP & HR continue to get monitored
- No telemetry in most cases

# ACSM GETP 10 exerpt:

- High-intensity interval training (HIIT) involves alternating 3–4 min periods of exercise at 80%–90% HRR with exercise at 60%–70% HRR. Such training for approximately 40 min, three times per week has been shown to yield a greater improvement in $\dot{V}O_{2peak}$ in patients with stable coronary heart disease (73) and HF (130). HIIT has also been shown to result in greater long-term improvements in $\dot{V}O_{2peak}$ in patients after CABG (83) compared to standard continuous, moderate intensity exercise. It appears that HIIT may be both a safe and very effective method of enhancing peak aerobic fitness in those with CVD (127).

ACSM GETP 10, 2017, page 236.

- Questions?