Energy-System First Aid: Wearables and Heart Rate-Guided Rehabilitation

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Project ECHO®

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Financial Disclosures

Dr. Davenport declares no direct or indirect commercial or financial conflicts of interest involved with the content of this presentation.

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Our Agenda for Today

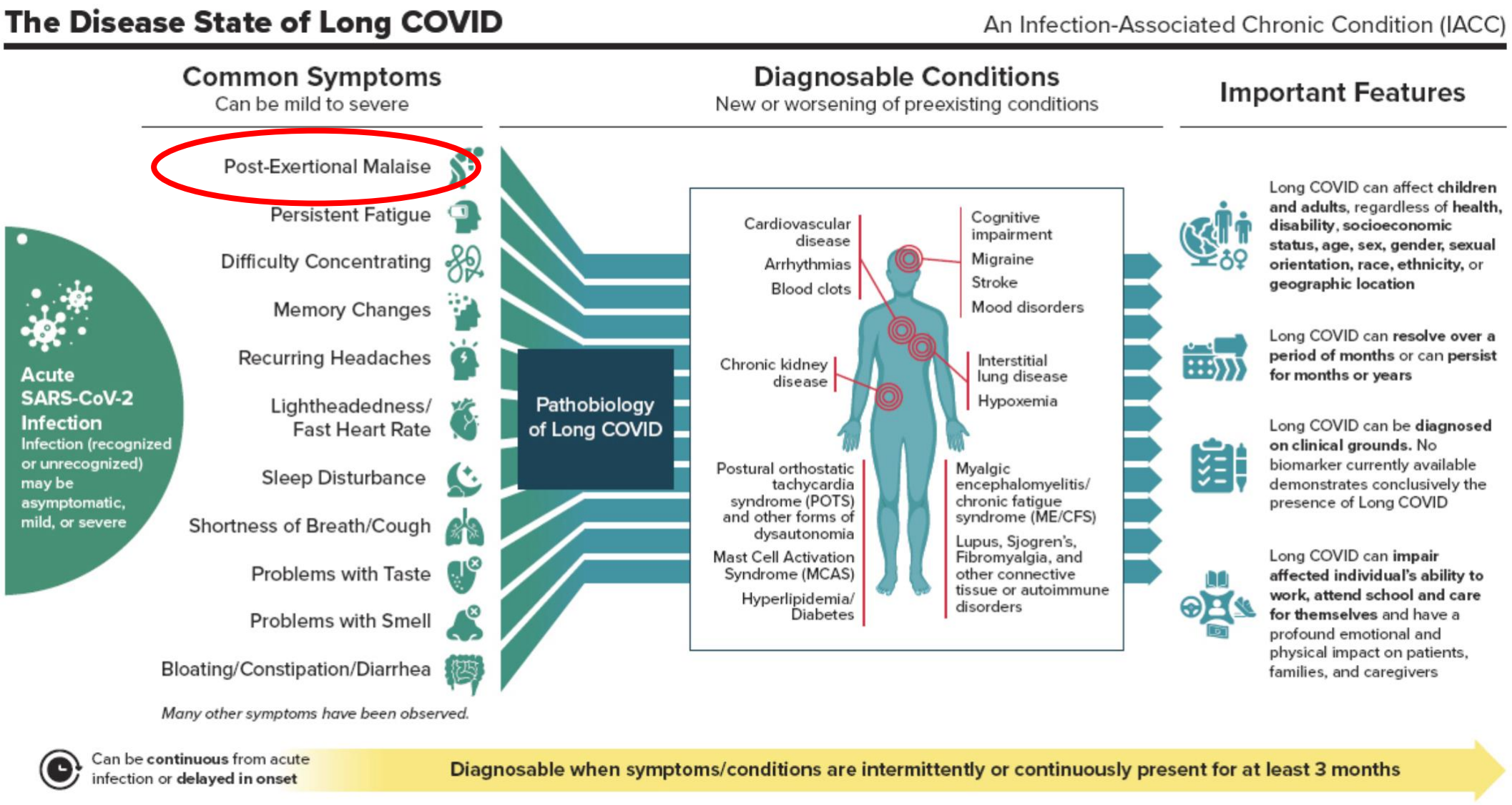
Session Objectives

By the end of this session, participants will be able to:

1. Explain the principles of “Energy System First Aid” and their application in helping individuals with post Covid myalgic encephalomyelitis achieve symptom stabilization
2. Discuss the utility of heart rate and heart rate variability (HRV) as tools for pacing through monitoring autonomic function
3. Apply heart rate-guided pacing strategies using validated thresholds to minimize post-exertional malaise and optimize functional outcomes
4. Integrate data from wearable sensors into individualized symptom management plans for people with Long Covid

Session Outline

- What is PEM?
- Does Working Out…Work Out?
- Energy System First Aid
- Why and How to Use Heart Rate Derived Data
- Cautions
- Recommendations for Interpretation and Application



National Academies of Sciences E, and Medicine,. *A Long COVID Definition: A Chronic, Systemic Disease State with Profound Consequences*. 2024. https://doi.org/10.17226/27768

What is Post-exertional Malaise (PEM)?

- Marked, rapid physical and/or cognitive fatigability in response to exertion
- Low threshold of physical and mental fatigability (lack of stamina) resulting in a substantial reduction in pre-illness activity level
- Post-exertional symptom exacerbation
- Post-exertional exhaustion
- Recovery period is prolonged

Carruthers BM, van de Sande MI, De Meirleir KL, et al. Myalgic encephalomyelitis: International Consensus Criteria. *J Intern Med*. Oct 2011;270(4):327-38. doi:10.1111/j.1365-2796.2011.02428.x

Frequency of ME/CFS in Long Covid

Pooled prevalence of PEM was 25% among community dwelling adults (95% confidence interval: 17-36%)

Incidence rates per 100,000:

- Post Covid: 2.66
- Uninfected: 0.93

Hazard ratio (infected vs. uninfected): 4.93

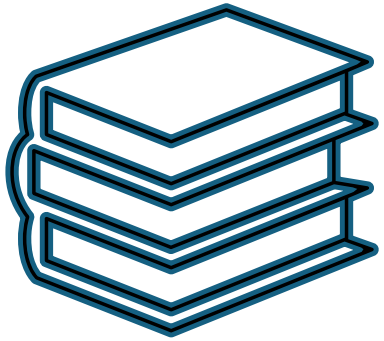
Prevalence of PEM:

- Infected participants (15.9%, 717/4515)
- Post-acute infected participants (29.1%, 2113/7270)

Pouliopoulou DV, Hawthorne M, MacDermid JC, et al. Prevalence and impact of postexertional malaise on recovery in adults with post-covid-19 condition: a systematic review with meta-analysis. *Arch Phys Med Rehabil*. Feb 5 2025;doi:10.1016/j.apmr.2025.01.471

Vernon SD, Zheng T, Do H, et al. Incidence and prevalence of Post-COVID-19 myalgic encephalomyelitis: a report from the observational RECOVER-Adult Study. *J Gen Intern Med*. Jan 13 2025;doi:10.1007/s11606-024-09290-9

Summary of Research Findings on Graded Exercise in Long Covid



- Systematic review including 14 trials (1,244 patients)
- Moderate certainty of a moderate effect in half of trials included (389 participants)
  - Mixed-modality programs consisting of breathing, inspiratory muscle training, aerobic, and resistance exercise
  - Clinician-administered and online, supervised and non-supervised
  - Primary outcome measure was 6-minute walk test
- Significant uncertainty and imprecision regarding the probability of experiencing exercise-induced adverse events

Pouliopoulou DV, Macdermid JC, Saunders E, et al. Rehabilitation Interventions for Physical Capacity and Quality of Life in Adults With Post-COVID-19 Condition: A Systematic Review and Meta-Analysis. JAMA Netw Open. Sep 5 2023;6(9):e2333838. doi:10.1001/jamanetworkopen.2023.33838

Screening and Measurement of PEM in Long Covid Exercise Studies

Points

PEM is common in the community but infrequently observed in exercise studies

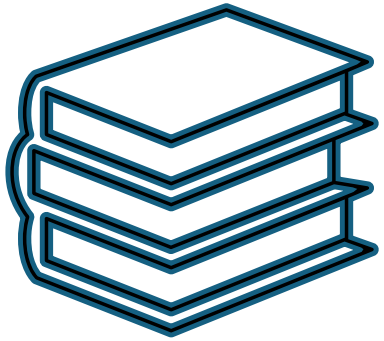
Counterpoints

Few, studies acknowledge PEM, use contemporary case definitions for ME, and adhere to accepted guidelines for identifying PEM

Heterogeneity in data sets

Jason LA, Unger ER, Dimitrakoff JD, et al. Minimum data elements for research reports on CFS. Brain Behav Immun. Mar 2012;26(3):401-6. doi:10.1016/j.bbi.2012.01.014

Summary of Research Findings on Graded Exercise in ME/CFS

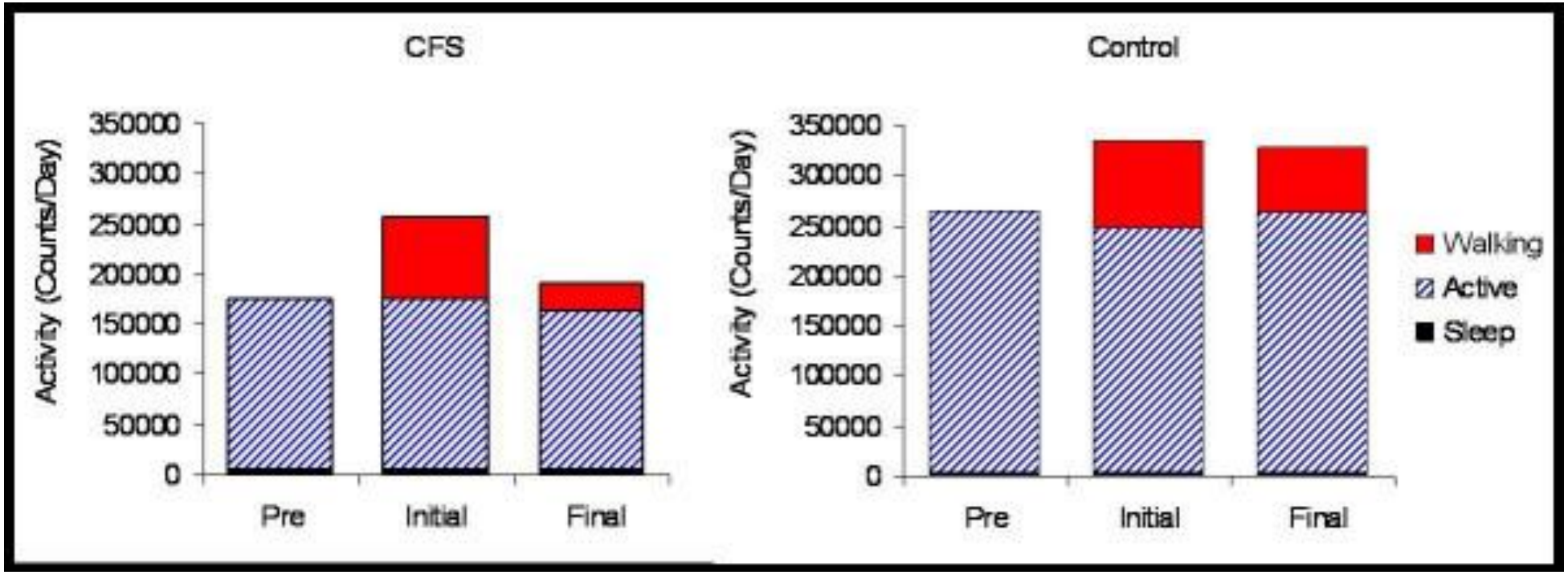


- **Low level of evidence for beneficial effect** on physiological functioning and health perceptions
- Graded exercise **most likely to worsen** symptoms and **least likely to be considered appropriate** for needs
- Pacing **least likely to worsen** and **most likely to be considered appropriate** for needs
- But do people with ME/CFS really demonstrate **functional improvements**?

Davenport TE, Stevens SR, VanNess MJ, Snell CR, Little T. Conceptual model for physical therapist management of chronic fatigue syndrome/myalgic encephalomyelitis. *Phys Ther*. Apr 2010;90(4):602-14. doi:10.2522/ptj.20090047

ME Association. No decisions about me without me. ME Association. Accessed October 9, 2025. https://meassociation.org.uk/wp-content/uploads/2015-ME-Association-Illness-Management-Report-No-decisions-about-me-without-me-30.05.15.pdf

Graded Exercise and Observed Activity Increases: A Self-Fulfilling Prophecy?



Black CD, McCully KK. Time course of exercise induced alterations in daily activity in chronic fatigue syndrome. Dyn Med. 2005;4:10. Published 2005 Oct 28. doi:10.1186/1476-5918-4-10

Why Are Responses to Exercise So Unusual?

We normally expect deconditioned people and people living with a whole host of disabling health conditions to **repeat their measurements on two CPETs** spaced 24 hours apart

Yet, **differences** in CPET measurements between patients with ME/CFS and matched controls are **very large and even larger** on the second test, especially during submaximal levels of exertion

Davenport TE, Stevens SR, Stevens J, Snell CR, Van Ness JM. Properties of measurements obtained during cardiopulmonary exercise testing in individuals with Myalgic Encephalomyelitis/Chronic Fatigue Syndrome. Work. 2020;66(2):247-256. doi: 10.3233/WOR-203170. PMID: 32568145.

Table 3
Standardized effect sizes (Cohen's *d*) comparing change in metabolic measurements completed during two peak exercise tests completed 24 hours apart in controls and individuals with Myalgic Encephalomyelitis/Chronic Fatigue Syndrome (ME/CFS)

Test #1, peak	
VO_2 (ml/kg/min)	0.8
Workload (W)	1.1
Heart rate (beats/min)	1.6
Minute ventilation (L/min)	0.8
Respiratory rate (breaths/min)	0.5
Respiratory exchange ratio	0.0
Systolic blood pressure (mmHg)	0.9
Test #1, ventilatory anaerobic threshold	
VO_2 (ml/kg/min)	0.4
Workload (W)	0.5
Heart rate (beats/min)	0.5
Systolic blood pressure (mmHg)	0.5
Test #2, peak	
VO_2 (ml/kg/min)	0.8
Workload (W)	1.4
Heart rate (beats/min)	1.6
Minute ventilation (L/min)	1.3
Respiratory rate (breaths/min)	0.6
Respiratory exchange ratio	0.4
Systolic blood pressure (mmHg)	0.8
Test #2, ventilatory anaerobic threshold	
VO_2 (ml/kg/min)	0.9
Workload (W)	0.8
Heart rate (beats/min)	1.3
Systolic blood pressure (mmHg)	0.9

What to **DO**? Basic Principles of First Aid for Energy Systems

- 3 C's
  - **C**heck
  - **C**all
  - **C**are
- Not necessarily curative, but stabilizing so additional evaluation and intervention might take place
- Set the environment for potential recovery

Davenport TE, Stevens SR, Stevens J, Snell CR, Van Ness JM. Lessons from Myalgic Encephalomyelitis/Chronic Fatigue Syndrome for Long COVID Part 3: "Energy System First Aid" for People With Postexertional Symptom Exacerbation. *JOSPT Blog* blog. April 8, 2022. https://www.jospt.org/do/10.2519/jospt.blog.20220216/full/

Energy System First Aid

Check

Evidence-based Assessment for PEM/PESE
Brief → Comprehensive

Call

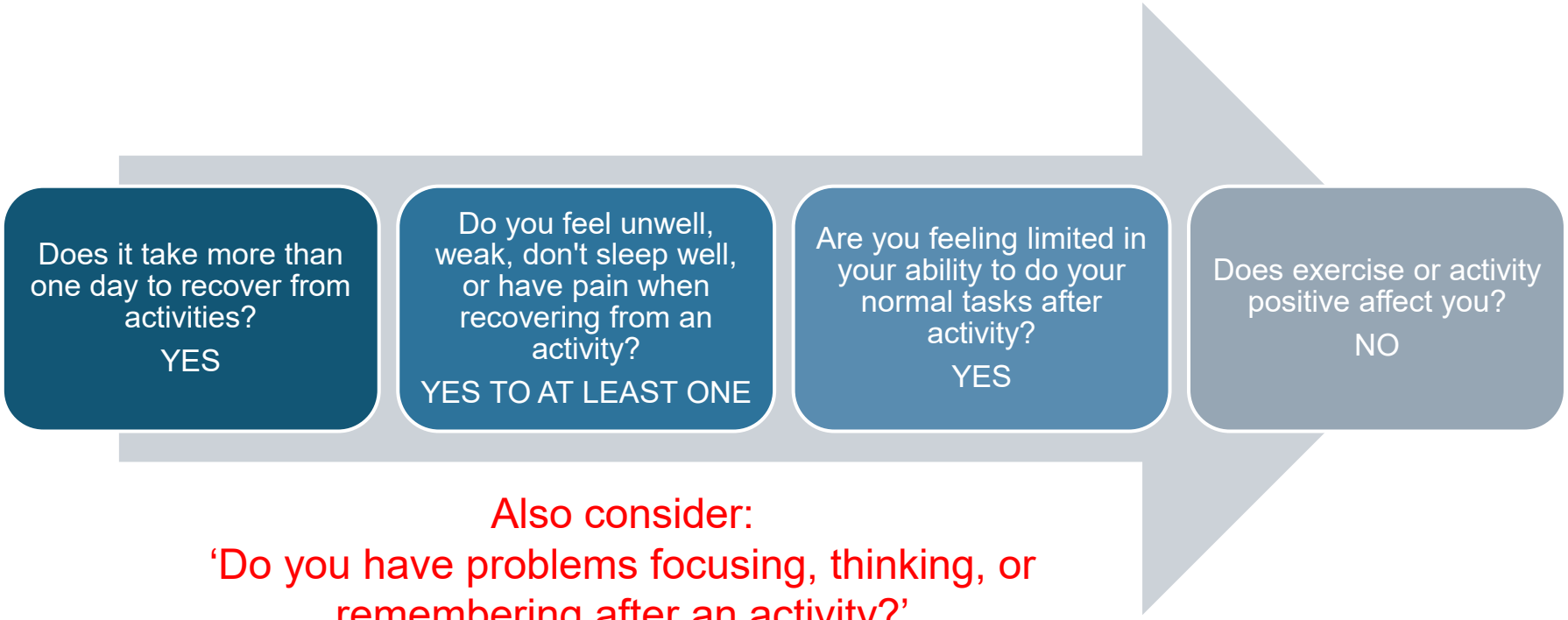
Multidisciplinary team

Care

Protect Dysfunctional Energy Systems
Use the Energy Systems That Work

Davenport TE, Stevens SR, Stevens J, Snell CR, Van Ness JM. Lessons from Myalgic Encephalomyelitis/Chronic Fatigue Syndrome for Long COVID Part 3: "Energy System First Aid" for People With Postexertional Symptom Exacerbation. *JOSPT Blog* blog. April 8, 2022. https://www.jospt.org/do/10.2519/jospt.blog.20220216/full/

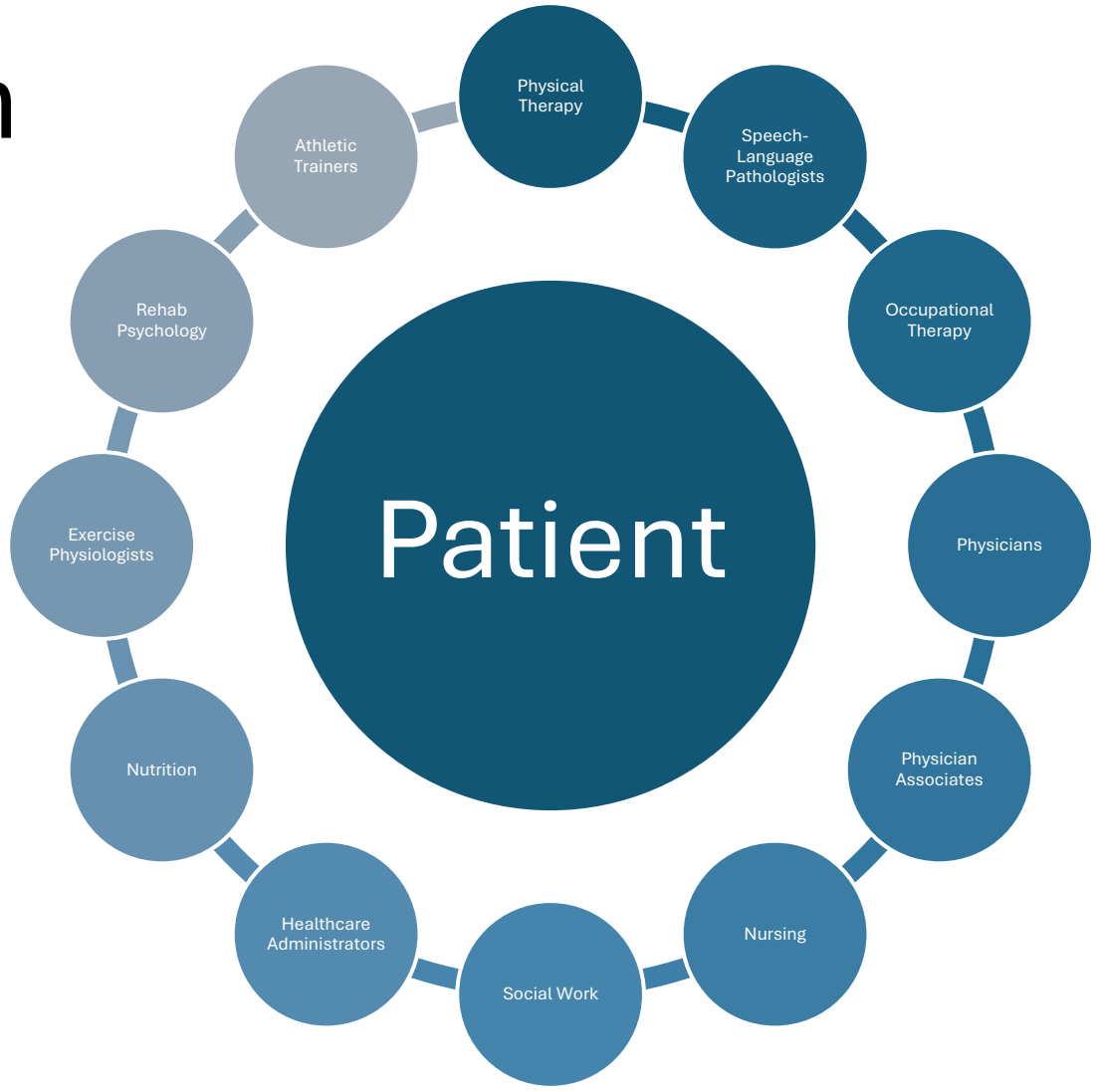
Check
Brief Assessment for PEM



Also consider:
'Do you have problems focusing, thinking, or remembering after an activity?'
YES

Davenport TE, Stevens SR, Stevens J, Snell CR, Van Ness JM. Lessons from Myalgic Encephalomyelitis/Chronic Fatigue Syndrome for Long COVID: Postexertional Symptom Exacerbation is an Abnormal Response to Exercise/Activity. *JOSPT Blog* blog. April 8, 2022. https://www.jospt.org/do/10.2519/jospt.blog.20220202/full/

Call
Multidisciplinary Team



Care

Use the Energy Systems that Work
Protect the Energy System that Don't
Functional Support through Symptom Management

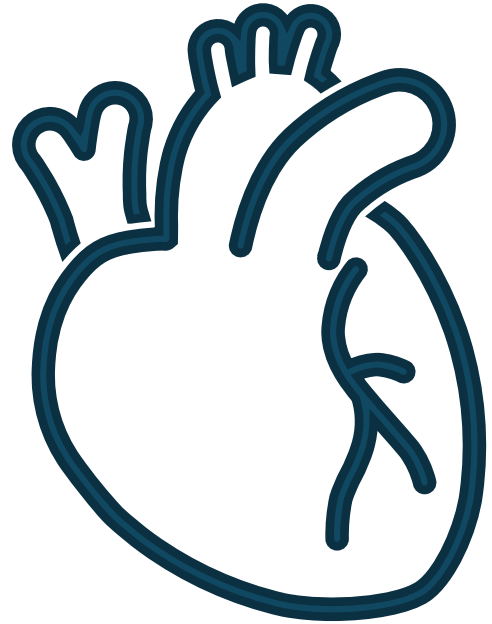
Activities may be completed without symptoms on one day, but then may exceed VAT during a crash day because VO_2 and workload at VAT decrease in the post-exertional state

Educate in energy conservation through:

- Pacing
- Changing positions
- Joint protection
- Activity planning

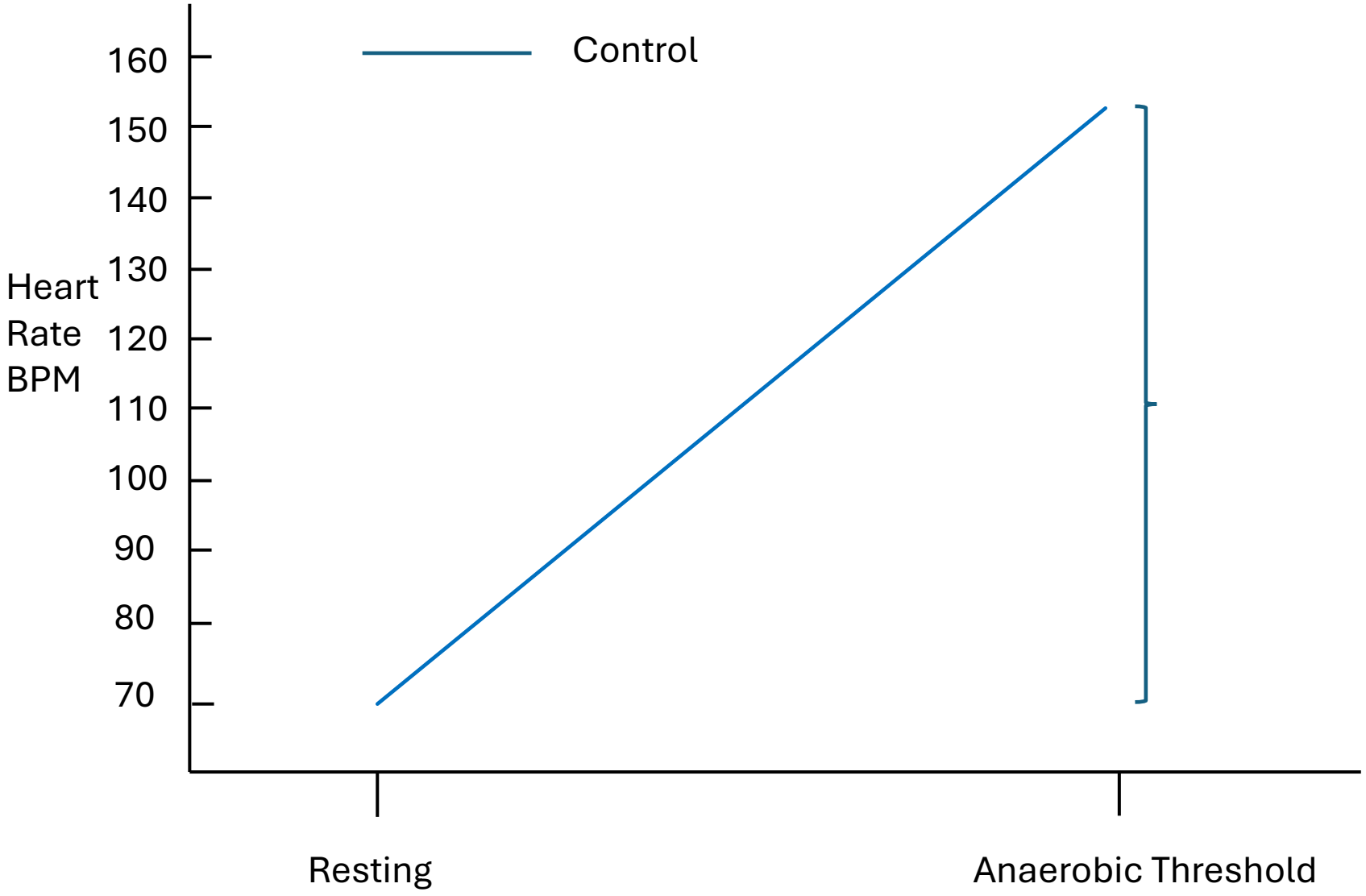
Davenport TE, Lehnen M, Stevens SR, VanNess JM, Stevens J, Snell CR. Chronotropic Intolerance: An Overlooked Determinant of Symptoms and Activity Limitation in Myalgic Encephalomyelitis/Chronic Fatigue Syndrome? Front Pediatr. 2019 Mar 22;7:82. doi: 10.3389/fped.2019.00082. PMID: 30968005; PMCID: PMC6439478.

Why Use Information Based on Heart Rate for Pacing?



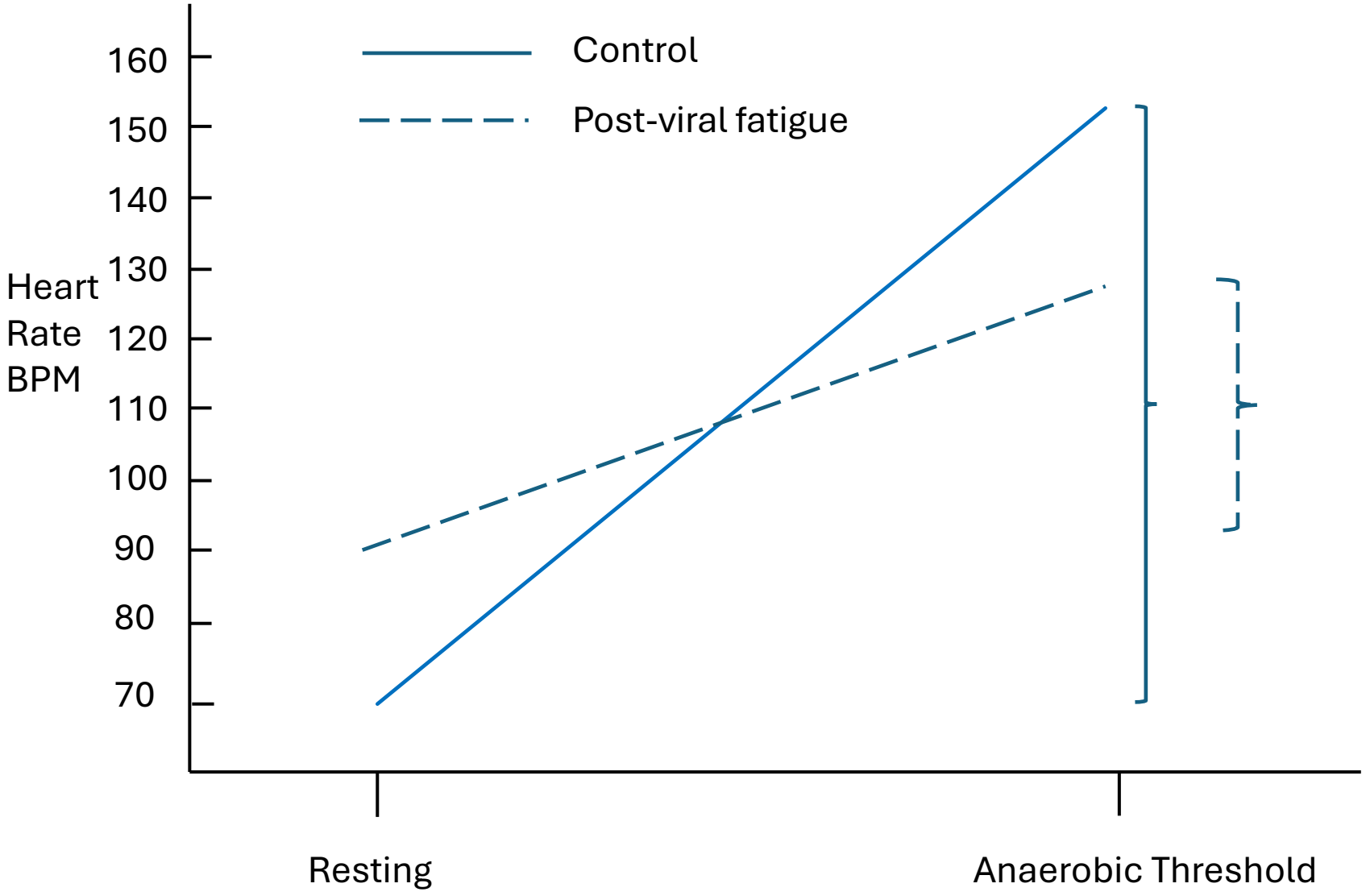
- Linear relationship between heart rate and workloads

- Measurements are:
  - Feasible
  - Reliable
  - Relatively inexpensive
  - Commercially available
  - Actionable
  - Responsive



Normal HR Response to Exercise

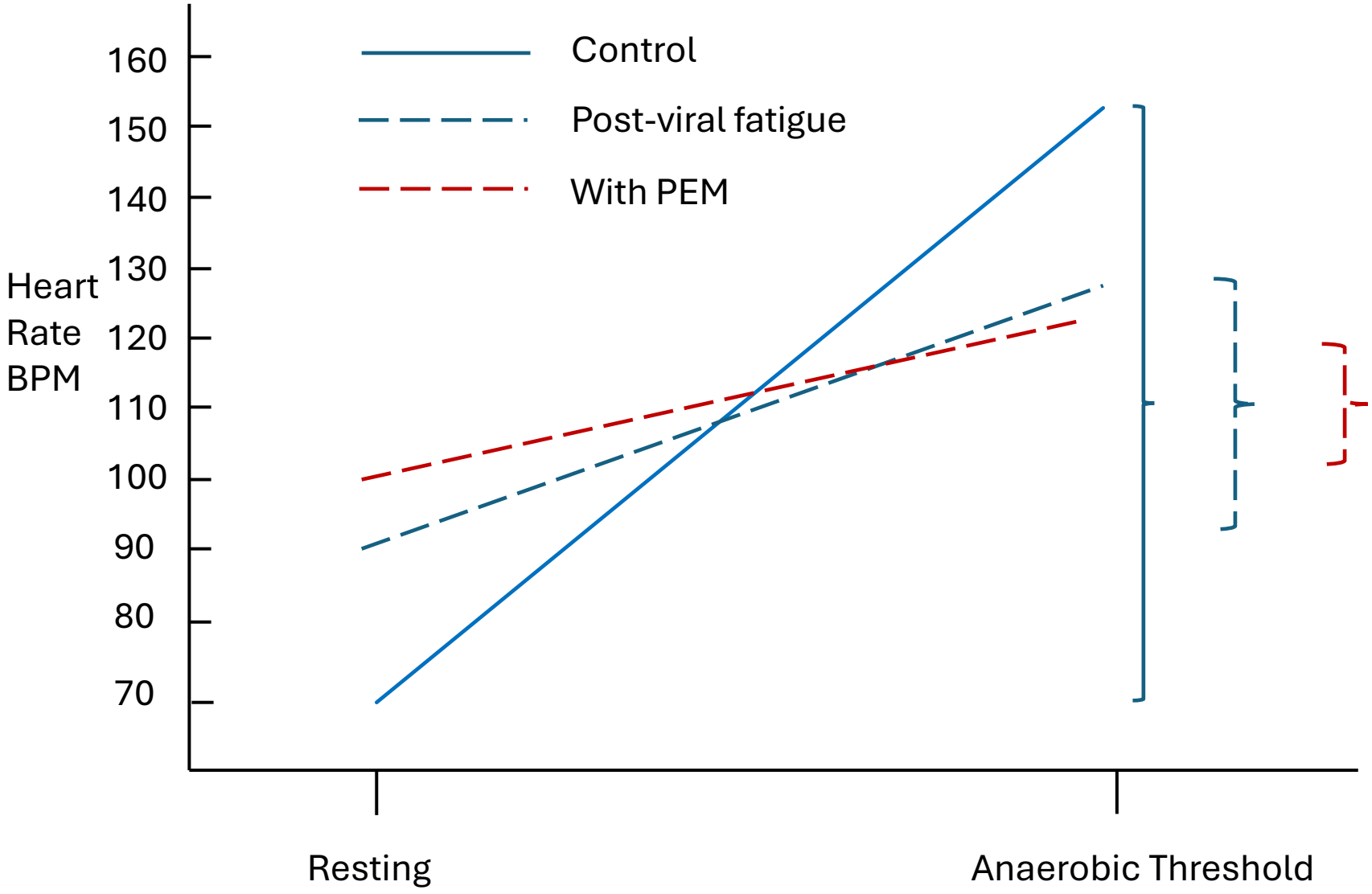
Davenport TE, Lehnen M, Stevens SR, VanNess JM, Stevens J, Snell CR. Chronotropic Intolerance: An Overlooked Determinant of Symptoms and Activity Limitation in Myalgic Encephalomyelitis/Chronic Fatigue Syndrome?. Front Pediatr. 2019;7:82. Published 2019 Mar 22. doi:10.3389/fped.2019.00082



"Blunted" HR Response: Chronotropic Incompetence

Davenport TE, Lehnen M, Stevens SR, VanNess JM, Stevens J, Snell CR. Chronotropic Intolerance: An Overlooked Determinant of Symptoms and Activity Limitation in Myalgic Encephalomyelitis/Chronic Fatigue Syndrome?. Front Pediatr. 2019;7:82. Published 2019 Mar 22. doi:10.3389/fped.2019.00082

Effect of Post Exertional Malaise on HR: Increased Chronotropic Incompetence



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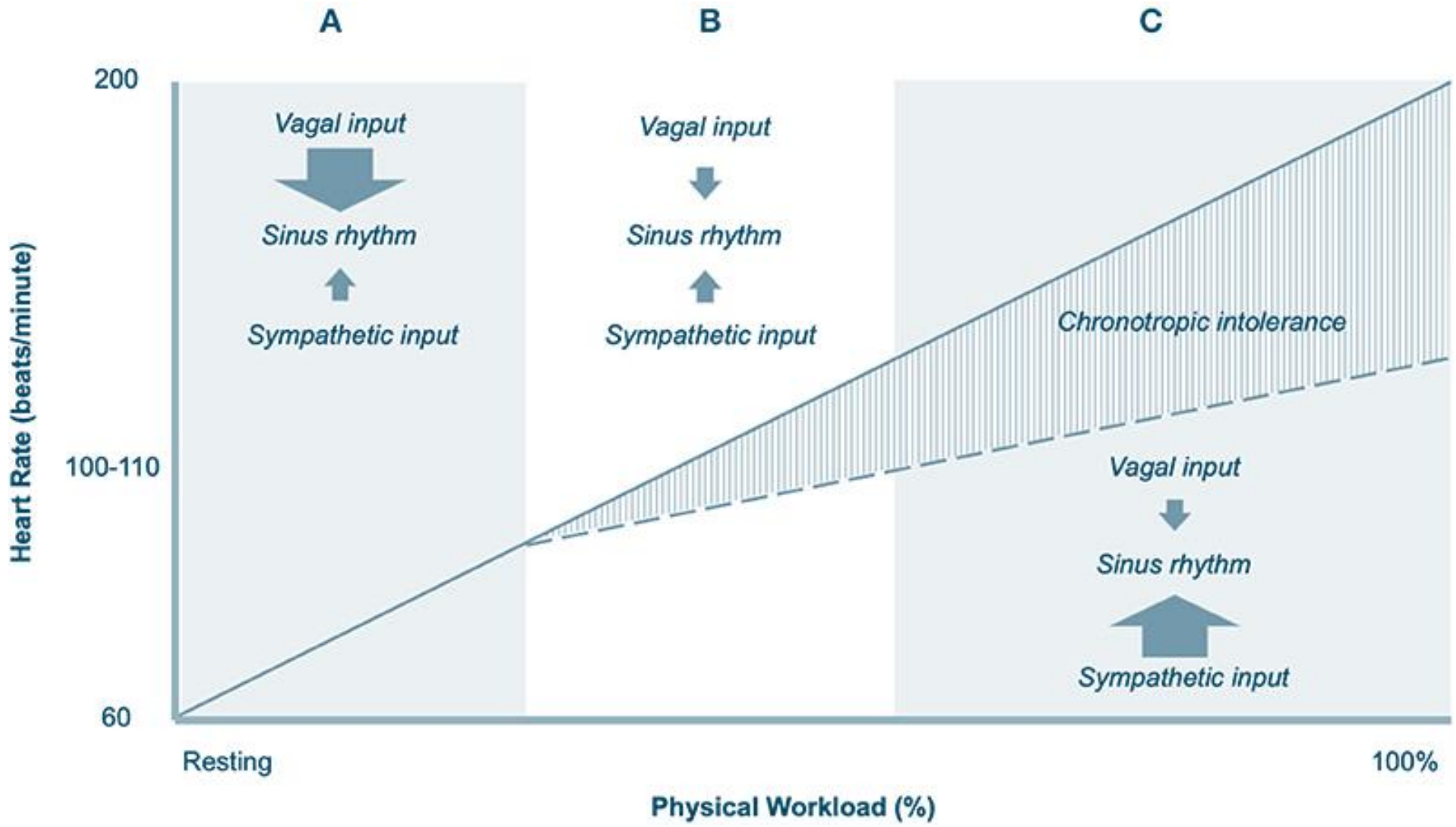

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Extent of Chronotropic Incompetence Varies Based on Self-Reported Functional Disability

	None ($n = 20$)	Mild ($n = 67$)	Moderate ($n = 72$)	Severe ($n = 20$)
PEAK EXERTION (MEASURED HEART RATE)				
Predicted HR	179	177	177	173
Actual HR	163	147	133	117
% Predicted	91.1	83.1	75.1	67.6
70% EXERTION (CALCULATED HEART RATE)				
Predicted HR	126	124	124	121
Actual HR	114	102	93	82
% Predicted	90.4	82.3	75.0	67.8

(The authors used the Holmes criteria to identify ME/CFS). At both peak exertion and ventilatory anaerobic threshold, the difference between age-predicted heart rate and observed heart rate increased as American Medical Association metabolic impairment category worsened. HR, heart rate.

Davenport TE, Lehnen M, Stevens SR, VanNess JM, Stevens J, Snell CR. Chronotropic Intolerance: An Overlooked Determinant of Symptoms and Activity Limitation in Myalgic Encephalomyelitis/Chronic Fatigue Syndrome?. Front Pediatr. 2019;7:82. Published 2019 Mar 22. doi:10.3389/fped.2019.00082

What are Patients Doing?

An international survey of experiences and attitudes towards pacing using a heart rate monitor for people with myalgic encephalomyelitis/chronic fatigue syndrome

Nicola Clague-Baker[a,b,*], Todd Davenport[c], Mohammad Madi[d], Kathryn Dickinson[e], Karen Leslie[b], Michelle Bull[b] and Natalie Hilliard[b]
[a]*Physiotherapy Department, School of Health Sciences, Institute of Population Health, University of Liverpool, Liverpool, UK*
[b]*Physios for ME, UK*
[c]*Department of Physical Therapy, School of Health Sciences, University of the Pacific, Stockton, CA, USA*
[d]*Department of Physical and Occupational Therapy, Faculty of Applied Medical Sciences, The Hashemite University, Zarqa, Jordan*
[e]*HRM4Pacing, UK*

Received 8 September 2022
Accepted 16 December 2022

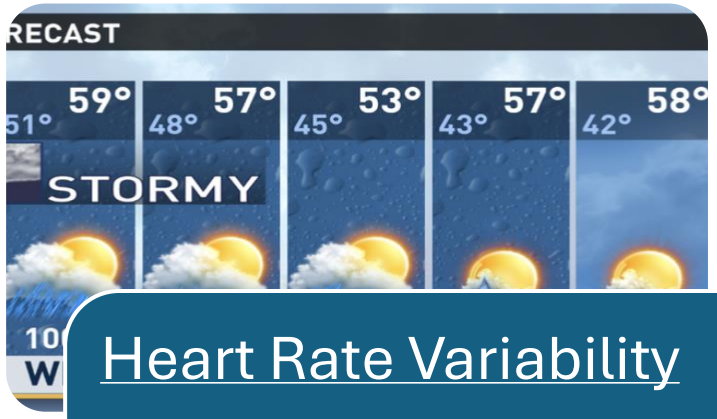
Clague-Baker N, Davenport TE, Madi M, et al. An international survey of experiences and attitudes towards pacing using a heart rate monitor for people with myalgic encephalomyelitis/chronic fatigue syndrome. Work. 2023;74(4):1225-1234. doi:10.3233/WOR-220512

- n=488 respondents with ME
- Internationally distributed survey
- Participants reported:
  - Using over 100 different devices
  - 17 methods of identifying pacing thresholds
  - Difficult to implement but generally positive effect on quality of life
  - **Most frequently identified challenge was lack of support from clinicians**

How to Use Cardiac Data from Wearables

Heart Rate

- Marker of moment-to-moment exertion
- Feedback can be instantaneous
- Enables on-the-fly adjustments in functioning



Heart Rate Variability

- Marker of overall trend in sympathetic/parasympathetic balance
- Information about trends in functioning
- Anticipatory adjustments

Real-Time Heart Rate Guidelines

Take from VAT HR on a second CPET from 2-day CPET

- 55% age-predicted HR_{max}
- Rest + 15 beats

Most conservative approach is to aim low and then titrate heart rate threshold upward to prevent a crash

Maximum Heart Rate Prediction Equations

Tanaka equation: 207 – (.7 * age)

More accurate for people over age 40 and women

Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. J Am Coll Cardiol. 2001;37(1):153-156. doi:10.1016/s0735-1097(00)01054-8

Brawner equation: 164 – (.7 * age)

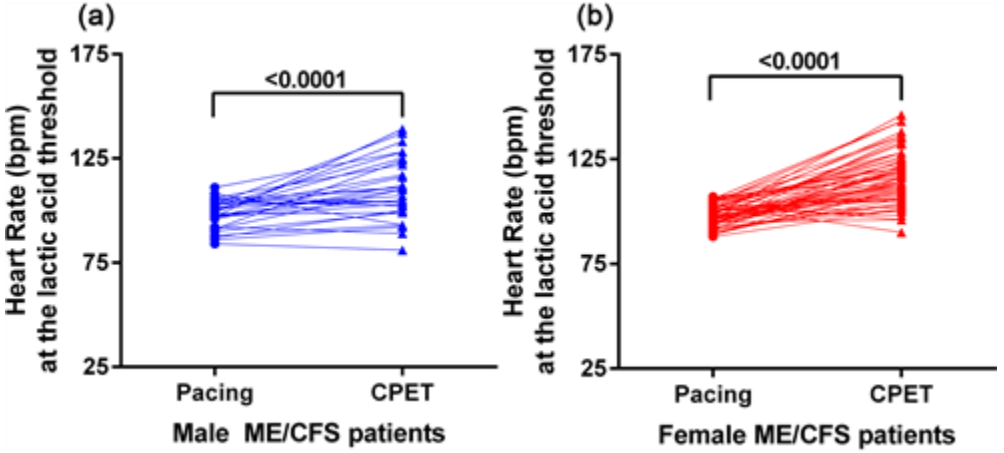
More accurate for people on beta-adrenergic blockade (beta blockers)

Brawner CA, Ehrman JK, Schairer JR, Cao JJ, Keteyian SJ. Predicting maximum heart rate among patients with coronary heart disease receiving beta-adrenergic blockade therapy. Am Heart J. 2004;148(5):910-914. doi:10.1016/j.ahj.2004.04.035

Validity of the “55% Guideline”

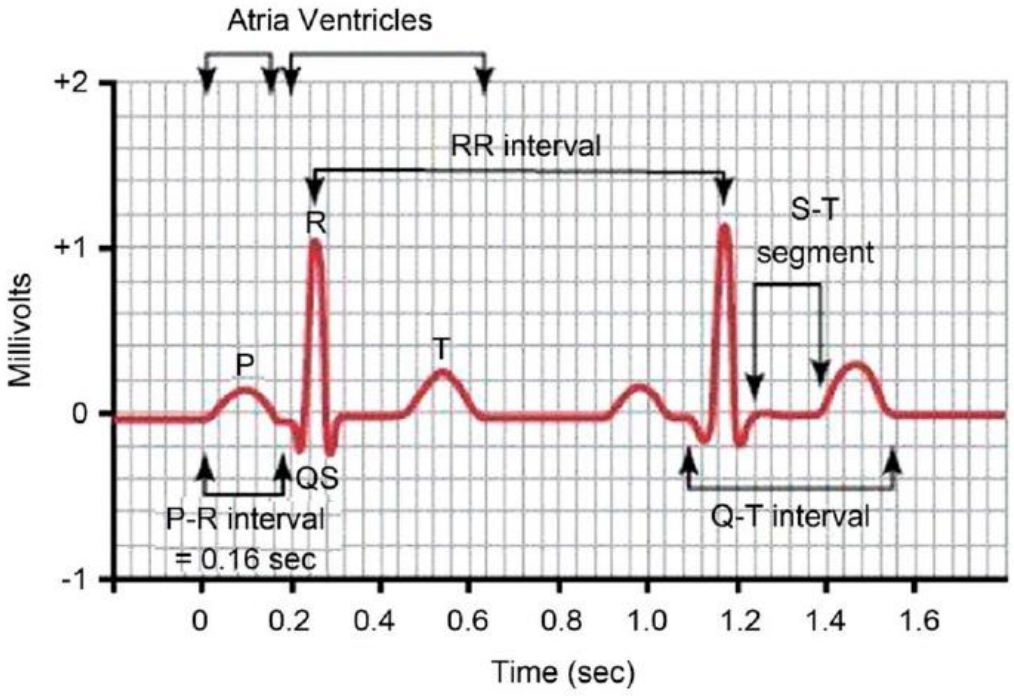
- 55% calculated value was almost always below the heart rate at lactate threshold (LT)
  - Variation across formulas was 28 bpm under LT (study) to 9-19 bpm over LT (18 studies)

- 55% guideline is not a good *predictor* of LT, but it is a specific guideline to *under-shoot* LT



Van Campen, F. C. (2020). Validity of 2-Day Cardiopulmonary Exercise Testing in Male Patients with Myalgic Encephalomyelitis/Chronic Fatigue Syndrome. Advances in Physical Education, 10, 68-80. https://doi.org/10.4236/ape.2020.101007

Heart Rate Variability



Steere, K. Evidence-based clinical utility of heart rate variability across populations, including Long COVID. Cardiopulmonary Physical Therapy Journal. 2025; 36(1):p 58-69.

1965
Hon & Lee
Fetal distress preceded by changes in inter-beat intervals before change in HR

1970s
Sayers and others
Data regarding physiological rhythms imbedded in beat-to-beat HR signal

1970s-1980s
Ewing et al
Development of simple bedside tests for RR differences in clinical populations

1981
Akselrod et al
Power spectral analysis quantitatively evaluate beat-to-beat control

Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Circulation. 1996;93(5):1043-1065.

Power Spectral Analysis of HRV

- Variations in heartbeat (power) are divided into frequencies
  - High frequency (HF): 0.15 to 0.40 Hz – parasympathetic activity
  - Low frequency (LF): 0.04 to 0.15 Hz – probably a mixture of sympathetic and parasympathetic activity
  - Very low frequency (VLF): <0.04 Hz – unknown mechanism of variation

Steere, K. Evidence-based clinical utility of heart rate variability across populations, including Long COVID. Cardiopulmonary Physical Therapy Journal. 2025; 36(1):p 58-69.

- HF and LF appear correlated with autonomic modulation, so they're the measures that are used in analysis

Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. Circulation. 1996;93(5):1043-1065.

- The LF/HF ratio is often used to derive "a number" for HRV but it's not so simple

Billman GE. The LF/HF ratio does not accurately measure cardiac sympatho-vagal balance. Front Physiol. 2013;4:26. Published 2013 Feb 20. doi:10.3389/fphys.2013.00026

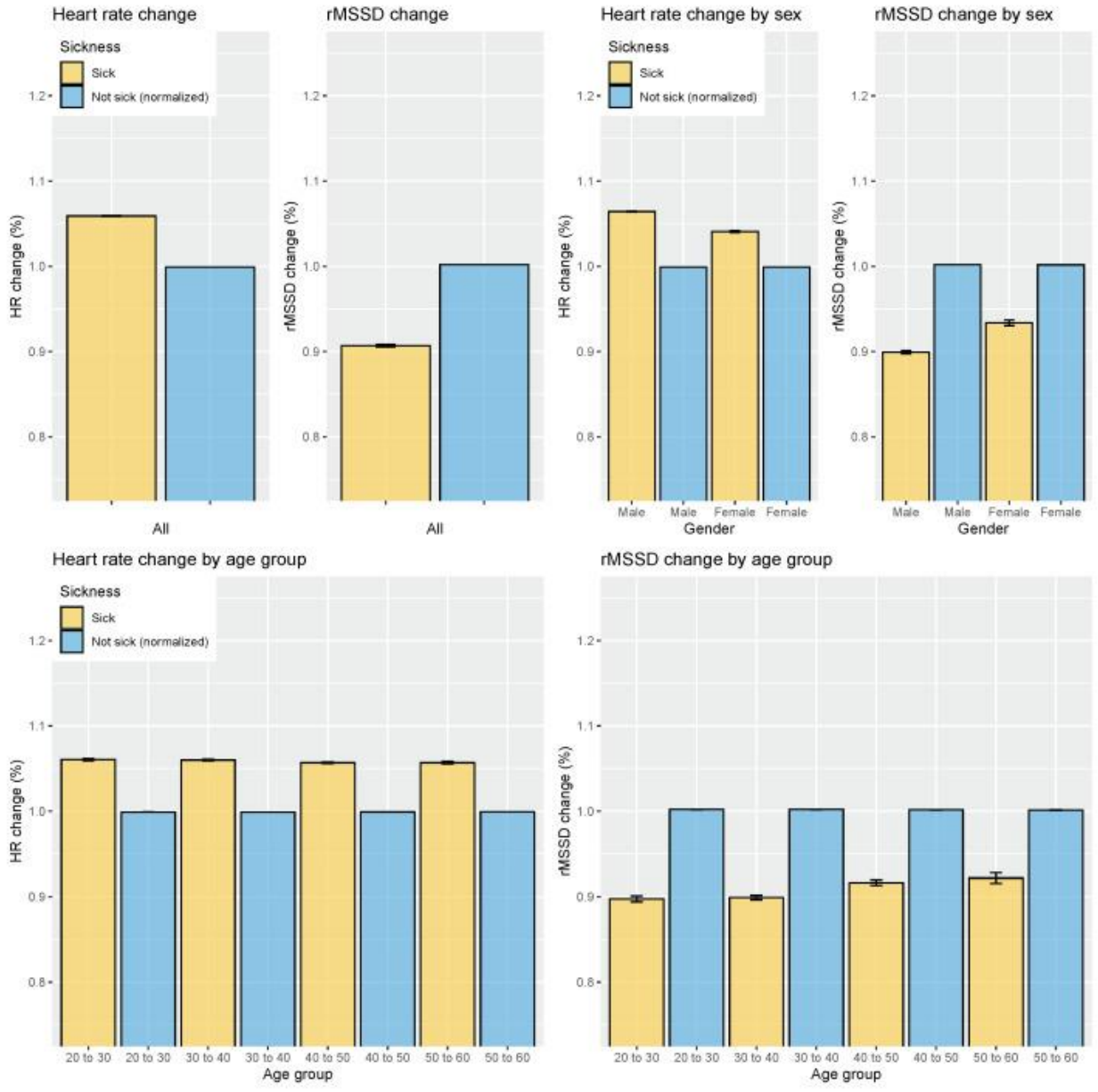
Effect of Illness on Resting HR and HRV

Cross-sectional study of 28,175 healthy individuals

1- to 5-minute sample using cell phone camera obtained in the morning

HR and HRV varies based on illness

HRV appears more specific and slightly better signal to noise ratio than resting HR



Altini M, Plews D. What Is behind Changes in Resting Heart Rate and Heart Rate Variability? A Large-Scale Analysis of Longitudinal Measurements Acquired in Free-Living. Sensors (Basel). 2021;21(23):7932. Published 2021 Nov 27. doi:10.3390/s21237932

Cautions with Using HR and HRV

Device-Related Challenges

- **Gold Standard vs. Wearables**
  - ECG is the gold standard for HRV measurement
  - Wearables (e.g., wristbands, rings, finger sensors) often use photoplethysmography (PPG), which is less accurate, especially during movement
- **Chest Straps**
  - These offer better validity and reliability than wrist or finger devices due to proximity to the heart and snug fit
- **Motion Artifacts (MA)**
  - PPG devices are highly susceptible to MA, especially during physical activity, which can distort HRV readings

Signal Acquisition and Processing Errors

- **Artifact Detection**
  - Errors in identifying and correcting artifacts (e.g., ectopic beats, poor sensor fit) can significantly skew HRV results
- **R-Peak Detection**
  - Accurate detection of the R peak in the QRS complex is critical
  - Even small errors can alter HRV metrics
- **Algorithm Transparency**
  - Many third-party software tools use proprietary algorithms for data cleaning and analysis, making it difficult to assess accuracy or validity

Data Transformation and Analysis Issues

- **Time vs. Frequency Domain**
  - Different HRV metrics reflect different aspects of autonomic function. Some (e.g., RMSSD, HF power) are well understood, while others (e.g., LF power, LF/HF ratio) are more controversial
- **Recording Duration**
  - Short or ultra-short recordings (<5 minutes) may not accurately reflect HRV, especially during or after physical activity
- **Spectral Analysis Methods**
  - Fast Fourier Transform (FFT) and autoregressive models can yield different results, particularly in special populations

Steere, K. Evidence-based clinical utility of heart rate variability across populations, including Long COVID. Cardiopulmonary Physical Therapy Journal. 2025; 36(1):p 58-69.

Cautions with Using HR and HRV

Biological and Contextual Influences

- **Breathing Patterns**
  - Natural vs. paced breathing can affect HRV, especially frequency domain metrics
- **Body Position and Activity Level**
  - HRV varies with posture and physical exertion
  - Comparisons must control for these factors
- **Comorbidities and Medications**
  - Conditions like cardiovascular disease, diabetes, and long COVID, as well as medications (e.g., beta-blockers), can alter HRV
- **Age and Sex Differences**
  - HRV declines with age and differs between sexes, affecting interpretation

Interpretation Challenges

- **Wide Normative Ranges**
  - HRV values vary widely across individuals, making single-point comparisons unreliable
- **Single Scores**
  - Some apps provide a single scores for HR and HRV using proprietary formulas, which lack transparency and scientific validation
- **Biopsychosocial Factors**
  - Psychological stress, social context, and lifestyle can influence HRV, complicating interpretation

Steere, K. Evidence-based clinical utility of heart rate variability across populations, including Long COVID. Cardiopulmonary Physical Therapy Journal. 2025; 36(1):p 58-69.

Cautions with Using HR and HRV

- May vary based on age, physical activity, menstrual cycle, illness, and other factors
- “Noisy” measurements
- Sensitive but not specific indicators of stress response in otherwise healthy individuals

Altini M, Plews D. What is behind changes in resting heart rate and heart rate variability? a large-scale analysis of longitudinal measurements acquired in free-living. Sensors (Basel). 2021;21(23):7932. Published 2021 Nov 27. doi:10.3390/s21237932

Recommendations

Use validated devices and transparent algorithms

Evaluate trends over time rather than isolated readings

Interpret HR and HRV in context with physical condition, symptoms, and other clinical data

Avoid over-reliance on HR and HRV as standalone diagnostic tools

Recommended Sequence for Using RHR and HRV

2-minute sample obtained first thing in the morning

- After waking and before rising

Maintain a symptom log

- Morning RHR
- Morning HRV
- Type of day it was (end of the day)

From the log, identify trends

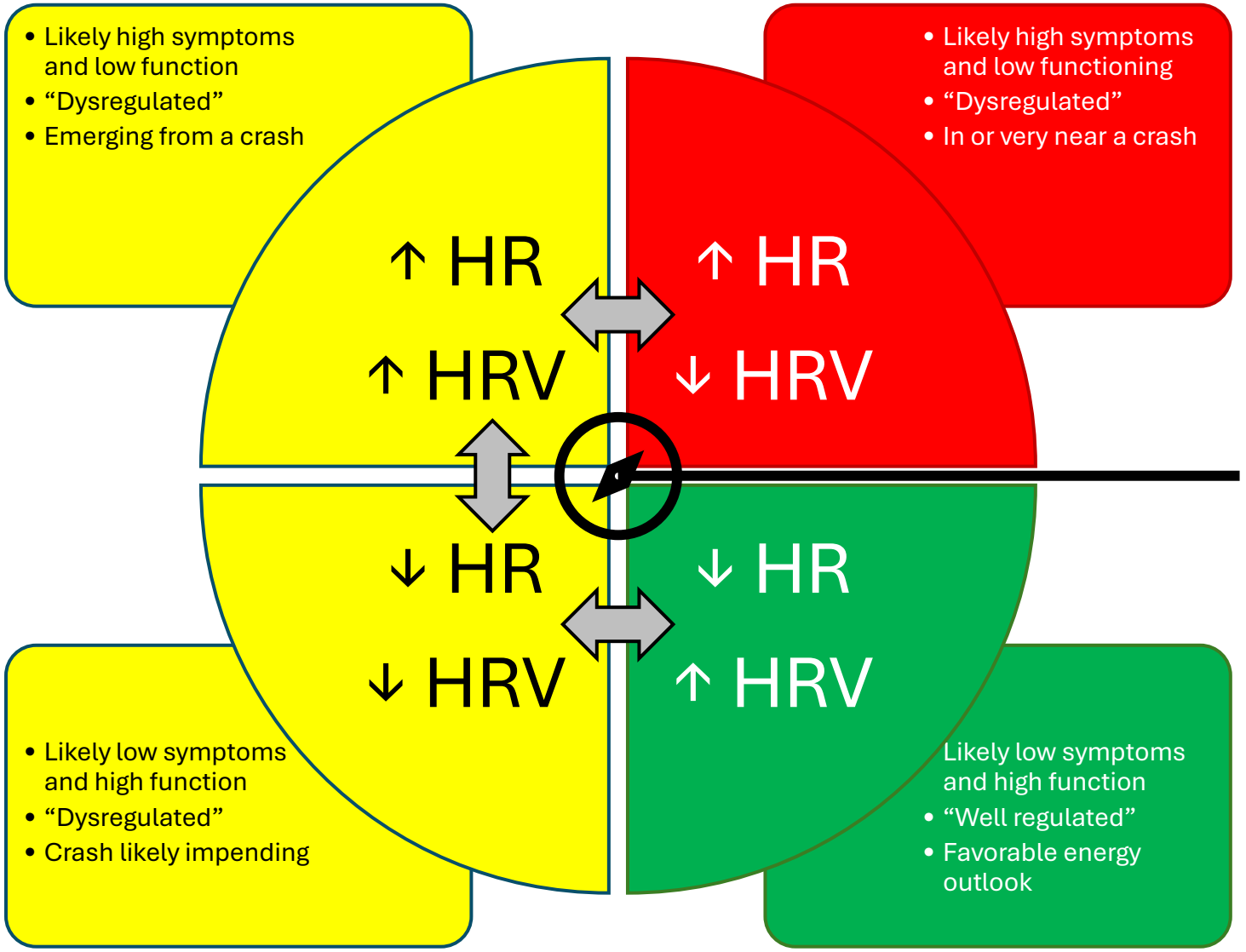
- HRV generally will be higher on ‘good days’ and lower on ‘crash days’
- RHR will be lower on ‘good day’s and higher on ‘crash days’

Values will depend on the patient and level of impairment

- Normative values will not apply!

https://workwellfoundation.org/pacing-with-a-heart-rate-monitor-to-minimize-post-exertional-malaise-pem-in-me-cfs-and-long-covid/

Clinical Suggestion: A General HR-HRV Interpretation Framework for PEM



Other Useful Data from Wearables

- Cardiorespiratory measurements
  - Number of periods spent above “training zone” (VAT)
  - Time spent above “training zone” (VAT)
- Function
  - Steps/activity
  - Sleep
- Aggregate Readiness Scores

Summary

- PEM is a critical safety consideration in rehabilitation management of Post COVID ME
- Graded exercise poses risks for people with Post COVID ME, so pacing strategies are safer and have greater acceptability to patients
- Heart rate and HRV data vary in accuracy and precision
- HR and HRV trends should be interpreted contextually over time
- Validated devices and transparent algorithms are preferred but equipment and expertise are not commonly available
- Clinicians can still meaningfully integrate wearable data with patient-reported outcomes to personalize care

Questions, Answers, and Case Discussion