Heart rate monitoring for PVFS and PwME

Suzan Jackson, Kathryn Dickinson, Angela Flack, Jenny, Eleanor Alba and Melinda West Maxwell

Professor Todd Davenport

Workwell Foundation & University of the Pacific

Dr Nicola Clague-Baker, Dr Michelle Bull, Natalie Hilliard and Karen Leslie – Physios for ME

Two podcasts

Podcast 1 – theory of HR monitoring

- Cardiorespiratory fitness
- Abnormalities with Cardiorespiratory fitness in people with ME
- Physiological principles for HR monitoring
- How to do HR monitoring
- Difficulties with HR monitoring
- HR variation

Podcast 2 – experiences of HR monitoring

- PwME experiences of HR monitoring

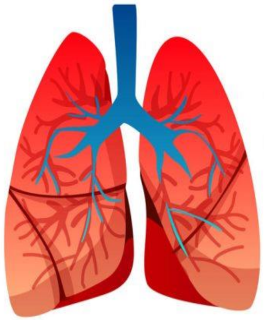
What is cardiorespiratory fitness?

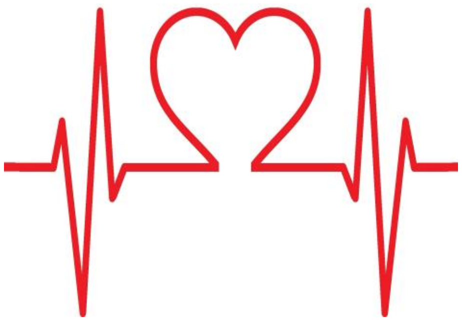
- Cardiovascular fitness is the ability of the heart, blood cells and lungs to supply oxygen-rich blood to the working muscle tissues and the ability of the muscles to use oxygen to produce energy for movement.
- is conferred by the central capacity of the circulatory and respiratory systems to supply oxygen, and the peripheral capacity of the skeletal muscle to utilise oxygen

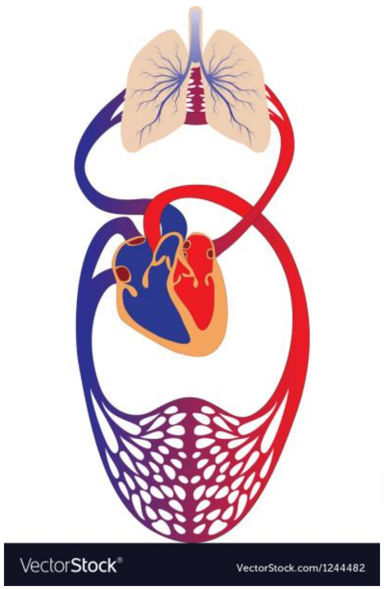
(Mead and van Wijck, 2013)

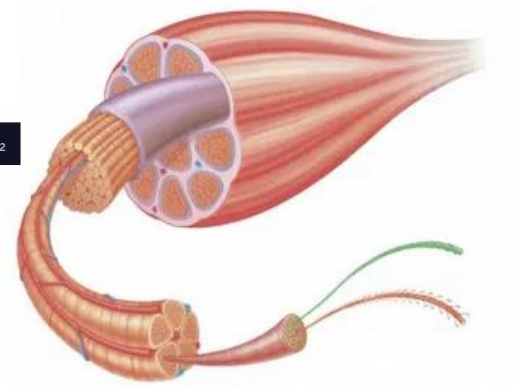
Cardiorespiratory fitness is dependent on:

- Healthy lungs
- Healthy heart
- Healthy circulatory system
- Healthy muscles – including mitochondria
- Healthy brain and nervous system



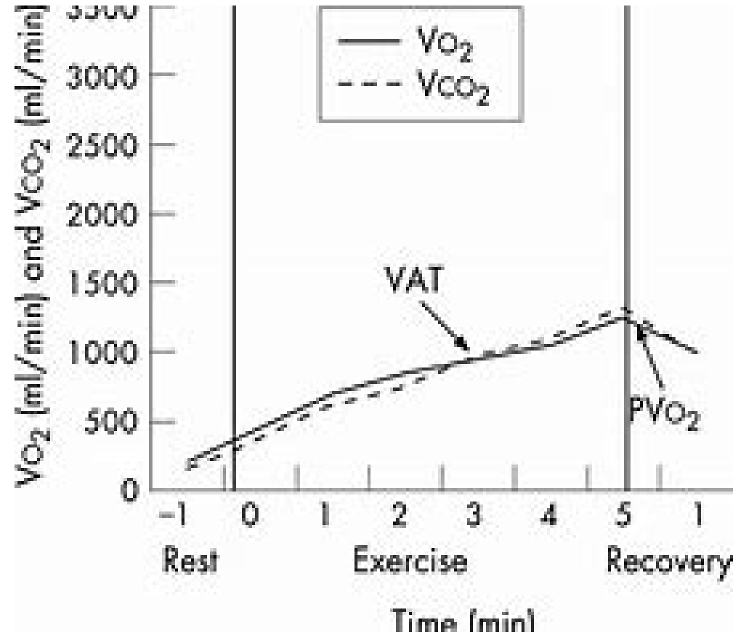






Measuring cardiorespiratory fitness/performance

- Cardiopulmonary exercise tests (CPET)
- Amount of O_2 utilized and amount of CO_2 produced is measured during a maximum test
- Normal CPET tests show a gradual increase in O_2 uptake and CO_2 production with O_2 being higher than CO_2
- The point at which aerobic metabolism switches to anaerobic metabolism is where the CO_2 is higher than O_2 and is called the ventilatory anaerobic threshold (VAT)



PwME have Reduced Cardiorespiratory Performance **<u>NOT</u> because of deconditioning**

Abnormalities measured with 2 day CPET:

- Reduced maximum oxygen consumption
- Reduced max cardiac output, BP and HR
- Reduced ventilatory anaerobic threshold (VAT)
- Increased intracellular acidosis

(Carruthers et al 2012)

(https://www.healthrising.org/blog/2019/01/17/decoding-2-day-cpet-chronic-fatigue-syndrome/)

HR During a Single CPET: Results of a Systematic Review and Meta-analysis

Time Point	Measure	ME/CFS		Control		P-Value	Effect Size	Confidence Interval	
		n	Mean ± SD	n	Mean ± SD			Lower	Upper
Peak Effort	$VO2_{max}$ (ml/kg/min)	975	22.5 ± 2.7	500	31.4 ± 3.5	<0.001	-2.96	-3.11	-2.81
	HR_{max}	1053	157.1 ± 12.2	569	172.4 ± 9.0	<0.001	-1.37	-1.48	-1.26
	$Workload_{max}$ (watts)	607	101.9 ± 11.8	353	165.7 ± 18.4	<0.001	-4.38	-4.61	-4.14
	RER	755	1.12 ± 0.07	334	1.16 ± 0.04	<0.001	-0.78	-0.91	-0.65
VAT	$VO2_{VT}$ (ml/kg/min)	324	13.0 ± 2.7	144	17.8 ± 3.8	<0.001	-1.53	-1.75	-1.31
	HR_{VT}	778	125.8 ± 22.3	378	136.3 ± 14.2	<0.001	-0.53	-0.65	-0.40
	$Workload_{VAT}$ (watts)	506	73.9 ± 4.1	287	114.1 ± 8.7	<0.001	-6.50	-6.84	-6.14

(Davenport et al, 2020 – manuscript in preparation)

Data presented at the 2020 Combined Sections Meeting of the American Physical Therapy Association

WORKWELL FOUNDATION

		WOMEN							
		Age 20–29				Age 30–39			
%		Balke Treadmill (time)	Max $\dot{V}O_2$ (mL/kg/min)	12-Min Run (miles)	1.5-Mi Run (time)	Balke Treadmill (time)	Max $\dot{V}O_2$ (mL/kg/min)	12-Min Run (miles)	1.5-Mi Run (time)
99	Superior	27:23	54.5	1.83	9:30	25:37	52.0	1.76	9:58
95		24:00	49.6	1.69	10:28	22:26	47.4	1.63	11:00
90	Excellent	22:00	46.8	1.61	11:10	21:00	45.3	1.57	11:33
85		21:00	45.3	1.57	11:33	20:00	43.9	1.53	11:58
80		20:01	43.9	1.53	11:58	19:00	42.4	1.49	12:24
75	Good	19:00	42.4	1.49	12:24	18:02	41.0	1.45	12:53
70		18:04	41.1	1.46	12:51	17:01	39.6	1.41	13:24
65		18:00	41.0	1.45	12:53	16:18	38.5	1.38	13:47
60		17:00	39.5	1.41	13:24	15:43	37.7	1.36	14:08
55	Fair	16:17	38.5	1.38	13:48	15:10	36.9	1.34	14:28
50		15:50	37.8	1.37	14:04	15:00	36.7	1.33	14:34
45		15:00	36.7	1.33	14:34	14:00	35.2	1.29	15:14
40		14:36	36.1	1.32	14:50	13:20	34.2	1.27	15:43
35	Poor	14:00	35.2	1.29	15:14	13:00	33.8	1.25	15:58
30		13:15	34.1	1.26	15:46	12:03	32.4	1.21	16:42
25		12:30	33.0	1.23	16:21	11:47	32.0	1.20	16:56
20		12:00	32.3	1.21	16:46	11:00	30.9	1.17	17:38
15	Very poor	11:01	30.9	1.17	17:38	10:00	29.4	1.13	18:37
10		10:04	29.5	1.13	18:33	9:00	28.0	1.09	19:43
[illegible]		8:43	27.6	1.08	20:03	[illegible]	[illegible]	[illegible]	[illegible]
1		6:00	23.7	0.97	23:58	5:27	22.9	0.95	24:56
		n = 1,280				*n* = 4,257			

Total *n* = 5,537

(American College of Sports Medicine, 2014)

Side Note: VO_2max Interpretation

WORKWELL FOUNDATION

HR During Dual CPET: Results of a Systematic Review and Meta-analysis

Study	Case definition criteria	Test 1				Test 2			
		n	Observed	Predicted	% Predicted	*n*	Observed	Predicted	% Predicted
HEART RATE AT PEAK EXERTION IN PATIENTS WITH ME/CFS									
Hodges et al. (46)	Fukuda, CCC, ICC	10	154	183	84.2	10	151	183	82.5
Keller et al. (28)	Fukuda	22	160	176	90.9	22	150	176	85.2
Vermeulen et al. (65)	Fukuda	15	158	184	85.7	15	155	184	84.2
	Sample weighted mean	–	158.1	180.0	87.9	–	151.8	180.0	84.3
	95% confidence interval	–	157.2–159.0	178.8–181.3	86.9–88.9	–	151.1–152.6	178.8–181.3	83.9–84.7
MEASUREMENTS AT PEAK EXERTION IN CONTROL SUBJECTS									
Hodges et al. (46)	Fukuda, CCC, ICC	10	161	181	89.0	10	162	181	89.5
Vermeulen et al. (65)	Fukuda	15	167	184	90.8	15	168	184	91.3
	Sample weighted mean	–	164.6	182.8	90.0	–	165.6	182.8	90.6
	95% confidence interval	–	162.9–166.3	182.0–183.6	89.5–90.5	–	163.9–167.6	182.0–183.6	88.1–93.6
HEART RATE AT VENTILATORY ANAEROBIC THRESHOLD IN PATIENTS WITH ME/CFS									
Hodges et al. (46)	Fukuda, CCC, ICC	10	134	128	104.6	10	133	128	103.8
Keller et al. (28)	Fukuda	22	113	123	91.7	22	108	123	87.7
Vermeulen et al. (65)	Fukuda	15	110	129	85.4	15	112	129	87.0
	Sample weighted mean	–	116.5	126.0	92.4	–	114.5	126.0	90.9
	95% confidence interval	–	112.8–120.2	125.2–126.9	89.6–95.2	–	110.8–118.4	125.2–126.9	88.1–93.6
MEASUREMENTS AT VENTILATORY ANAEROBIC THRESHOLD IN CONTROL SUBJECTS									
Hodges et al. (46)	Fukuda, CCC, ICC	10	137	127	108.1	10	146	127	108.3
Vermeulen et al. (65)	Fukuda	15	111	129	86.2	15	118	129	91.6
	Sample weighted mean	–	121.4	128.0	95.0	–	129.2	128.0	101.0
	95% confidence interval	–	95.9–146.9	127.4–128.5	88.9–101.0	–	121.4–137.0	127.4–128.5	95.4–107.6

n, sample size; ME/CFS, myalgic encephalomyelitis/chronic fatigue syndrome; CCC, Canadian Consensus Criteria; ICC, International Consensus Criteria.

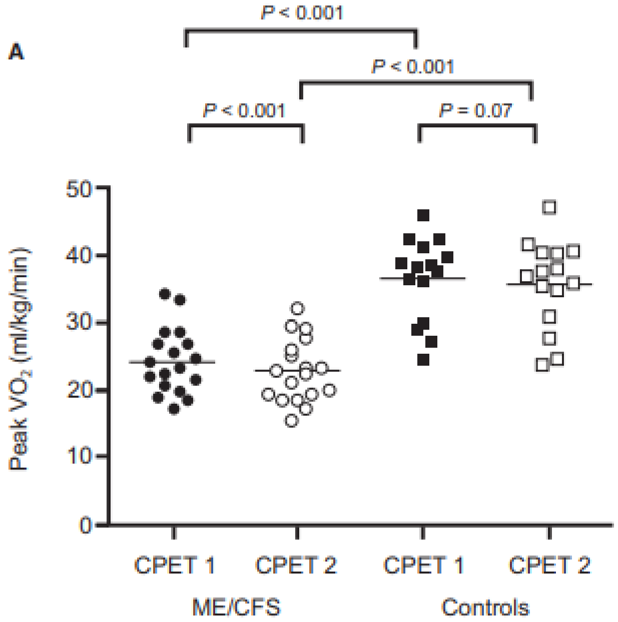
(Davenport et al 2019 – Frontiers in Pediatrics)

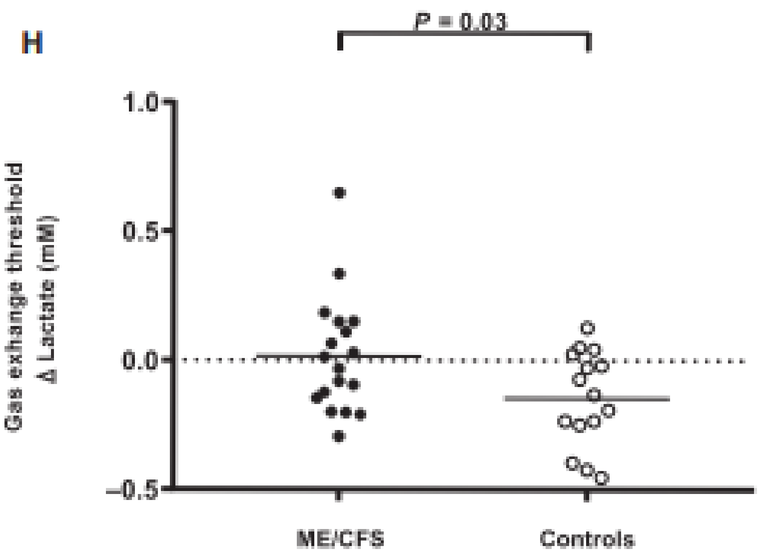
WORKWELL FOUNDATION

2 day CPET test for pwme

On both tests, all pwme have lower VO_2 peak

On the second tests all pwme had higher levels of lactic acid production





(Lien et al 2019)

Why?

Cardiac changes –

- Due to orthostatic intolerances – Dysautonomia or beta-2 adrenergic receptors in blood vessels or hypermobility – relaxing of collagen
- Neurally mediated hypotension (NMH) – low BP on upright (drop >25mmHG)
- Postural Tachycardia Syndrome (POTS) – increase in HR (>30bpm)

Metabolic changes –

(Carruthers et al, 2012)

- Dysautonomia
- Red blood cells affected
- Mitochondrial damage – rely on anaerobic metabolism
- Reduction in ATP production

Leads to Post-exertional Malaise (PEM)

PEM – Not Just Fatigue!

Length of time to PEM onset post-exertion[a] (N = 145)	N (%)	Duration of PEM post-exertion[b] (N = 146)	N (%)
Immediately	23 (16%)	**1–6 hours**	2 (1%)
About 1 hour later	13 (9%)	**6–12 hours**	3 (2%)
1–3 hours later	12 (8%)	**12–24 hours**	9 (6%)
3–24 hours later	10 (7%)	**1 day**	11 (8%)
More than 24 hours later	16 (11%)	**2 days**	18 (12%)
It can vary	61 (42%)	**3–7 days**	29 (20%)
Not sure	7 (5%)	**More than 1 week**	5 (3%)
Not applicable	3 (2%)	**It can vary**	65 (45%)
		Not applicable	4 (3%)

(Chu et al 2018)

PEM Timecourse

Immediate

Symptoms after physical activity are the direct result of exceeding the anaerobic threshold. Examples include fatigue, **out of breath**, dizziness and nausea. For healthy individuals, immediate symptoms from exercise stress resolve quickly but for people with ME/CFS they begin to worsen. [7]

Short-term

Lasts 2-4 days and reflects "overdoing activities" that exceed the anaerobic threshold for an extended period or multiple times per day exhausting the ability of the body to supply daily energy needs. [8] Symptoms of short-term PEM include muscle/joint pain, **brain fog**, headache and sleep disturbance. These symptoms reflect dysfunctional neurological and cardiopulmonary responses. [3]

Long-term

Lasts 7 days or more and reflects a sustained immune response consistent with a damaged aerobic energy system. [6, 9] Signs may include weakness, a decrease in function, **flu-like** and cardiopulmonary symptoms. [10, 11]

A Hypothetical Timecourse of PEM

PwME may use HR monitoring to stay under their anaerobic threshold, manage potential lactic acidosis, and use the energy system that works

How?

- The most accurate way of determining your Ventilatory Anaerobic Threshold (VAT) is doing a CPET

- If a CPET is not available…

How?

- Calculate 55% of your maximum heart rate and this would potentially be your VAT
- (220 - your age) x 0.55 = anaerobic threshold or VAT, in beats per minute
- If you are 30 your VAT ≈ (220 – 30) x 0.5 = 105 bpm
- If you are 45 your VAT ≈ (220 – 45) x 0.5 = 96 bpm

Aim to keep below this threshold when you do activities. It is a place to start.

(Davenport et al 2010)

Alternative calculation for women:

- 206 - 88% of age = MHR.
- AT at 55% of MHR

If you are 30 your VAT ≈ [206 – (30 x .88)] x 55% = 99

If you are 45 your VAT ≈ [206 – (45 x .88)] x 55% = 92

- http://www.cfsselfhelp.org/library/pacing-numbers-using-your-heart-rate-to-stay-inside-energy-envelope

Alternative methods

Some people:

- use 60% maximum HR as their AT
- start with 100bpm as their AT
- Stay within 10-20% of their resting heart rate (RHR)
- Use zones – ie. spend the majority of their time in 10-20% of RHR over 24 hours

RHR – 50 bpm. Stay in yellow and blue zones for majority of time

https://livewithcfs.blogspot.com/2011/02/heart-rate-and-post-exertional-crashes.html

https://holisticcfs.wordpress.com/dysautonomia-pots/

Bad day

Zone		Time
5	4.5%	58:52
4	12.2%	2:39:10
3	51.3%	11:06:06
2	30.5%	6:36:22
1	1.5%	19:02

PwME use auditory or visual alarms on their HR monitors to tell them when they are going too high

Well paced day

Zone		Time
5	0.1%	1:04
4	0.5%	8:06
3	16.8%	4:07:43
2	51.4%	12:37:13
1	31.2%	7:39:10

https://holisticcfs.wordpress.com/dysautonomia-pots/

Difficulties

- Up to 75% of PwME may have Orthostatic Intolerances due to dysautonomia –

eg. Postural Tachycardia Syndrome (POTS) –

> 30bpm (> 40bpm under 19 years) on standing within 10 mins

Can be associated with increased or decreased BP changes, more often decreased.

Therefore minor exertion increases HR over AT

PEM increases POTS

- Management of POTS – see www. potsuk.org

https://livewithcfs.blogspot.com/2011/02/heart-rate-and-post-exertional-crashes.html

Difficulties

- Holding arms up (brushing teeth/hair)
- Utilising core muscles
- Valsalva (bearing down, sneezing)
- Standing still

All increase HR

- Stress,
- heat,
- dehydration,
- air pressure,
- humidity,
- food reactions and
- medications (including cannabis)

All affect HR

https://holisticcfs.wordpress.com/dysautonomia-pots/

Benefits of HR monitoring

- Can keep below anaerobic threshold using an alarm is really helpful
- Can determine if going into PEM – RHR too high or too low
- Increases awareness of how hard the heart is working for you and for your family, friends, medics and physios/AHPs
- Stimulus to recognize the need to rest
- Can start to see patterns

UNIVERSITY OF THE PACIFIC

WORKWELL FOUNDATION

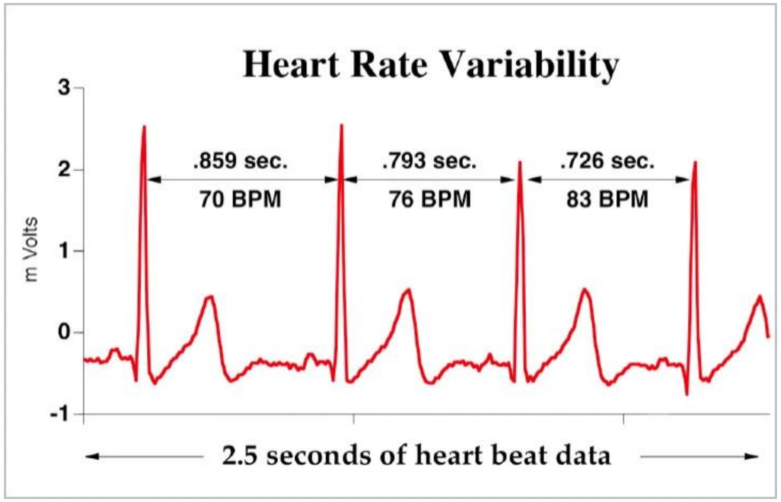
Activity Log

Time	Activity	HR	RPE	Body Position	Under AT
8:00am	Meal	90	10	Sit	Yes
8:30	Dishes	120	15	Stand	No
9:00	Shower	140	15	Stand	No
10:00	Rest	85	10	Lie	Yes

(Davenport et al 2010)

http://www.cfsselfhelp.org/library/pacing-numbers-using-your-heart-rate-to-stay-inside-energy-envelope

HR variation



- Variation in the time interval between consecutive heartbeats in milliseconds.
- There should be constant variability which demonstrates how well a healthy body responds to stress.
- Non-invasive marker of autonomic nervous system activity
- rMSSD and HF are markers of the parasympathetic activity

- **Increased HR variation the better the ANS**

HR variation

- Average HRV of elite users is 63.
- Pwme may go as low as 8 esp in PEM.
- COPD and CHF between 20 and 30

In healthy –

- deep breaths drops HR and increases HRV – trains the parasympathetic system
- laying still increases HRV
- shallow breathing drops HRV

In PEM –

- deep breaths raise HR and drops HRV
- laying still drops HRV rather than raising it
- shallow breathing raises HRV

https://holisticcfs.wordpress.com/dysautonomia-pots/

PwME – how to use HR variation

- An average HRV is calculated by the device

- Day to day, 7 day and monthly comparisons help pwme determine how their body is compared to the previous day
- Also overnight HRV shows quality of sleep
- They can then adjust what they do during the day

- Can demonstrate benefit of rest when HR might not change but HRV can change

- Need to be measured at the same time each day and in the same position – ideally lying down and in the am
- Some people take readings before and after standing and if a large variance they see it as a measure of a bad day

https://holisticcfs.wordpress.com/dysautonomia-pots/

Warning signs

- RHR – 8% rise in am can be a warning to be careful

https://forums.phoenixrising.me/threads/the-consult-part-ii-of-the-heart-rate-based-exercise-activity-management-video-series.59940/

- HRV – low HRV indicates a potential bad day

https://holisticcfs.wordpress.com/dysautonomia-pots/

- Importance of rest – rest 3 times as long as the activity takes (although some people say up to 6 times)

Types of HR monitors – chest straps

Chest strap – polar H7 and H10 - Most have own apps

HR only:

- **iphones**: Heart Graph provide audio tones and alarms and graphs time in zones, max hr and average heart rate over time.
- **Android** - pulsometer RR, ‘heart rate alarm’, motifit ‘fitIV pulse monitor’, SGT sports gear tracker.
- Chest straps tend to wear out every ~4-6 months.

HRV apps:

- **EliteHRV**, which compare resting HR & HRV across time.
- **HRV4Training** can also do morning HR & HRV readings using phone camera

HRV (long sessions):

- **SweetbeatHRV** provides great sleep data on iOS

Oura ring for overnight HRV

https://holisticcfs.wordpress.com/dysautonomia-pots/

Types of HR monitors – wrist based

- Wrist-based watches vary in quality and accuracy.
- Watches or armbands generally don't provide HRV
- Most watches don't provide a graph which gives context and depth to what are otherwise isolated HR metrics.
- Watches need to be charged every 18hrs-5 days

- Apple watch series 3, Mio Alpha 2.0, Huawei Band 2 Pro Activity tracker, Fitbit Alta HR, Garmin vivosmart HR, Polar a370
- HRPacing Fitbit App

Key messages – can you cope with a chest strap? If not use wrist based
Waterproof? Battery life? An alert?

https://holisticcfs.wordpress.com/dysautonomia-pots/

Cost of some HR monitors

Monitor	Cost
Polar H10 chest strap works with most watches	£86 - £100
Polar H9 chest strap	£54
Polar a370	£122 - £300
Garmin HRM dual chest strap	£47
Garmin vivosmart 3	£135
Mio Alpha 2 watch	£150
Apple watch series 3	£195
Huawei Band 2 Pro Activity tracker	£40
Fitbit Alta HR	£125

https://uk.pcmag.com/heart-rate-monitors/88267/the-best-heart-rate-monitors

Useful websites

- https://workwellfoundation.org/
- www.physiosforme.com
- www.meassociation.org.uk
- www.potsuk.org
- https://holisticcfs.wordpress.com/
- http://www.cfsselfhelp.org/library/pacing-numbers-using-your-heart-rate-to-stay-inside-energy-envelope
- https://www.healthrising.org/blog/2013/08/13/heart-rate-monitor-program-improves-heart-functioning-in-chronic-fatigue-syndrome-mecfs/
- https://holisticcfs.wordpress.com/dysautonomia-pots/
- Live with ME/CFS https://livewithcfs.blogspot.com/2011/02/heart-rate-and-post-exertional-crashes.html
- https://forums.phoenixrising.me/threads/the-consult-part-ii-of-the-heart-rate-based-exercise-activity-management-video-series.59940/
- https://www.hrv4training.com/

Online resources – twitter, facebook

- Twitter

@PhysiosforME

@MEAssociation

@PTOT4MECFS

@4WorkWell

- Facebook

Physios for ME

ME/CFS Pacing with a HR monitor #2

Physical Therapist/Occupational Therapist Resources for Treating ME/CFS

References

Berne K, (2002) Chronic Fatigue Syndrome, Fibromyalgia and Other Invisible Illnesses. Hunter House Publishers pp. 54-5, 162-3.

Campbell, B. (2020) Pacing By Numbers: Using Your Heart Rate To Stay Inside the Energy Envelope. ME/CFS & Fibromyalgia Self-Help http://www.cfsselfhelp.org/library/pacing-numbers-using-your-heart-rate-to-stay-inside-energy-envelope (30 August 2020)

Carruthers, B. M. MD, CM, FRACP (C) & Van de Sande, M.I. B ed.(eds) (2012), International Consensus Primer For Medical Practitioners, International Consensus Panel, available from http://www.investinme.org/Documents/Guidelines/Myalgic%20Encephalomyelitis%20International%20Consensus%20Primer%20-2012-11-26.pdf (30 August 2020)

Chu, L, Valencia, IJ, Garvert, DW, Montoya, JG. (2018) Deconstructing post-exertional malaise in myalgic encephalomyelitis/ chronic fatigue syndrome: A patient-centered, cross-sectional survey. PLoS ONE 13(6): e0197811.

Davenport TE, Lehnen M, Stevens SR, VanNess JM, Stevens J and Snell CR (2019) Chronotropic Intolerance: An Overlooked Determinant of Symptoms and Activity Limitation in Myalgic Encephalomyelitis/Chronic Fatigue Syndrome? Front. Pediatr. 7, pp.82.

References

Davenport TE, Stevens SR, VanNess MJ, et al. (2010) Conceptual model for physical therapist management of chronic fatigue syndrome/myalgic encephalomyelitis. Phys Ther. 90,pp. 602–614

Jackson, S L. (2011) “Heart Rate and Post-Exertional Crashes in ME/CFS.” *Living with ME/CFS* blog (30 August 2020).

Johnson, Cort. “Heart Rate Monitor Based Exercise Program Improves Heart Functioning in Chronic Fatigue Syndrome (ME/CFS).” Health Rising website https://www.healthrising.org/blog/2013/08/13/heart-rate-monitor-program-improves-heart-functioning-in-chronic-fatigue-syndrome-mecfs/ (30 August 2020).

Holistic Myalgic Encephalomyelitis ~ POTS&CIRS https://holisticcfs.wordpress.com/dysautonomia-pots/ (30 August 2020)

Holtzman, C.S., Bahtia, S., Cotler, J, and Jason, L. (2019) Assessment of Post-Exertional Malaise (PEM) in Patients with Myalgic Encephalomyelitis (ME) and Chronic Fatigue Syndrome (CFS): A Patient-Driven Survey. *Diagnostics*, 9(1), p. 26.

Lien et al (2019) Abnormal blood lactate accumulation during repeated exercise testing in myalgic encephalomyelitis/chronic fatigue syndrome. Physiological reports. 7, 11, pp.1-14

Live with ME/CFS https://livewithcfs.blogspot.com/2011/02/heart-rate-and-post-exertional-crashes.html (30 August 2020)

References

Mead, G. and van Wijck, F. (2013) Exercise and Fitness Training after Stroke. A handbook for evidence-based practice. London: Churchill Livingstone, Elsevier.

National Institute of Clinical Excellence (2013) Stroke Rehabilitation. Long term rehabilitation after stroke. Department of Health.

Rowe PC, Calkins H.(1998) Neurally Mediated Hypotension and Chronic Fatigue Syndrome. *The American Journal of Medicine*, 105, 3,1, pp. 15S–21S.

Rowe PC, Bou-Holaigah I, Kan JS, Calkins H.(1995) Is Neurally Mediated Hypotension an Unrecognized Cause of Chronic Fatigue? *Lancet*, 345(8950), pp.623-4.

Snell, C.R., Stevens, S.R., Davenport, T.E., Van Ness, J.M. (2013) Discriminative Validity of Metabolic and Workload Measurements for Identifying People with Chronic Fatigue Syndrome. *Physical Therapy*, 93(11), pp. 1484-92.

Stewart JM, Gewitz MH, Weldon A, Arlievsky N, Li K, Munoz J. (1999) Orthostatic intolerance in adolescent chronic fatigue syndrome." *Pediatrics*, 103(1), pp.116–21. doi:10.1542/peds.103.1.116.

Stevens, S.R., Davenport, T.E.(2015) Functional Outcomes of Anaerobic Rehabilitation in a Patient with Chronic Fatigue Syndrome: Case Report with 1-Year Follow-up. *Bulletin of the IACFS/ME* .

Wasserman, K. (1986) The Anaerobic Threshold: Definition, Physiological Significance and Identification. *Advances in Cardiology*, 35, pp. 1-23.

Two podcasts

Podcast 1 – theory of HR monitoring

- Cardiorespiratory fitness
- Abnormalities with Cardiorespiratory fitness in people with ME
- Physiological principles for HR monitoring
- How to do HR monitoring
- Difficulties with HR monitoring
- HR variation

Podcast 2 – experiences of HR monitoring

- PwME experiences of HR monitoring