COHERENT BREATHING®
VOLUME 2, ISSUE 9 - JUNE, 2023

Hello all,

Welcome to Coherent Breathing®, Volume 2, Issue 9, June 5th, 2023, ***A Comprehensive Exploration Of Resonance***. I'd like to acknowledge that friend and breathing colleague Tom Granger proposed this quest over tea while he was visiting the office in 2022. The question he posed: *Is resonant behavior at .1 Hz. due to resonant circulatory physiology or is it due to Mayer Wave activity?* A very compelling question...

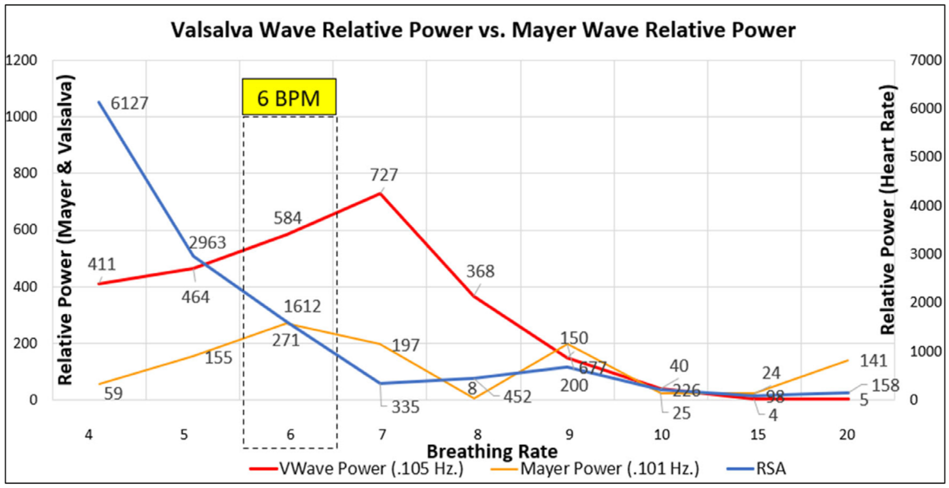

Figure 1: Valsalva Wave & Mayer Wave Frequency Components

The "Mayer Wave" is an oscillation in the arterial blood pressure that occurs at .1 Hertz. The phenomenon is named after German physiologist Sigmund Mayer who was the first to describe it in 1876. It is generally understood to be the result of efferent sympathetic nervous system activity, closely coupled to baroreception (blood pressure sensing). From the National Library of Medicine, *The enigma of Mayer waves: Facts and models:* "Mayer waves are oscillations of arterial pressure occurring spontaneously in conscious subjects at a frequency lower than respiration." (1) .1 Hz. has a period of 10 seconds, 1/.1 = 10, and carries on at .1 Hertz (here at .101 Hz.) regardless of breathing rate, i.e., there is always a .1 Hz. component in the frequency spectrum, Mayer Wave activity going on 100% of the time like a ticking clock. *As a point of interest, while the Mayer wave is enigmatic, the understanding of its frequency relative to that of breathing is fundamentally wrong.* While its frequency is lower than that of typical respiration, it shouldn't be. But it isn't the Mayer wave that is wrong, it is the breathing rate of the typical adult that is wrong. This is a primary thesis of Coherent Breathing Science — we should be breathing at a resonant rate. Coherent Breathing is nominally 5 breaths per minute vs. 6 breaths per minute.

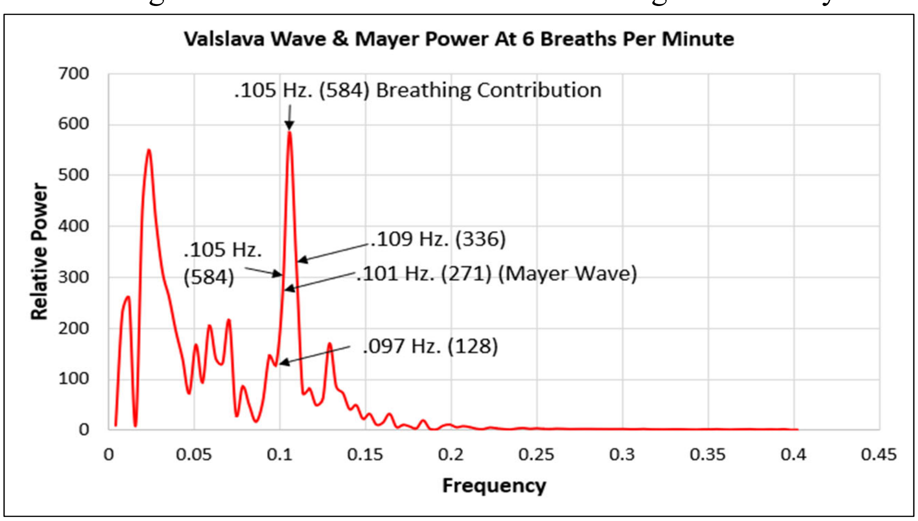

Figure 2: Valsalva Wave & Mayer Wave Frequency Components @ 6 BPM

The significance of resonant breathing is that it is "the moment" when the cardio-pulmonary-circulatory-system is working at peak efficiency and effectiveness, i.e., the optimal outcome with the least effort, where we are talking about the circulatory system serving the needs of the 100 trillion cells of the body. This author likes to refer to this as "blood flowing *freely* in a circle." The circulatory significance of the Mayer Wave is that it moves blood completely autonomically, i.e., the arterial tree is pulsing every 10 seconds regardless of breathing rate or state. We know of the "resonant breathing" phenomenon that occurs at 6 breaths per minute, this being where spectral power of both Valsalva Wave and its outcome, respiratory sinus arrhythmia, RSA, a.k.a. breathing induced Heart Rate Variability, peak. The interesting question posed by Tom: *Is this resonant behavior at .1 Hz. due to resonant circulatory physiology or is it due to Mayer Wave amplification at this breathing rate?* To understand this requires us to discriminate the spectral contribution of the Mayer Wave component vs. the breathing component. Figure 1 is derived by breathing at 9 different frequencies and assessing the spectral powers of the Valsalva Wave, the Mayer Wave, and Heart Rate at each. The spectral analysis at each breathing rate is presented in Figures 4 thru 21. Looking at 6 breaths per minute, we can see that of the 3 signals being assessed, the Mayer Wave is the only one that is peaking at 6 breaths per minute at power = 271. The Valsalva Wave power = 584, but it does not peak until 7 breaths per minute, an interesting finding.

Referring to Figure 2, the interpretation of this is that the left edge of the Mayer "signal" is visible at .101 Hz., but the spire is being dominated by the Valsalva Wave at .105 Hz. and power of 584. Yet, the Mayer Wave does have a .1 Hz. peak at essentially the same frequency, such that they appear to overlap at this resolution (sampling rate). 271 is 46% of 584, approximately half the height of the spire. Here we might guesstimate that Mayer Wave and breathing contributions are almost equal when breathing at 6 breaths per minute, a rate of .1 Hertz, the *absolute* frequency of the Mayer Wave. If either signal were absent, the spire would be about half the height at a power of ~300 vs. 600. The Heart Rate spire of Figure 3 has the identical .101 Hz./.105 Hz. proportions. (Note: Referring back to Figure 1, different Y axes are required for Valsalva Wave and Heart Rate due to the natural outcome of Fourier transformation of integers vs. fractions.)

Another interesting finding is that Heart Rate power is not maximal at 6 breaths per minute. Heart Rate power is maximal at 4 breaths per minute power equaling 6127, then falls to 2963 at 5 breaths per minute, and lands at power of 1612 at 6 breaths per minute. There is a great deal of conjecture and belief that "the resonant frequency of the heart" is .1 Hertz. Here we don't find that to be true, in that there are no significant peaks in the Heart Rate spectrum other than its high at 4 breaths per minute. This appears to mean that the Mayer Wave is the guiding light regarding the phenomenon of resonance at 6 cycles per minute. Breathing at the same frequency as the Mayer Wave adds to the height of both Valsalva Wave and Heart Rate spires, where both Mayer Wave and Heart Rate phase-lock with breathing, all three phenomena falling into synchrony (?)

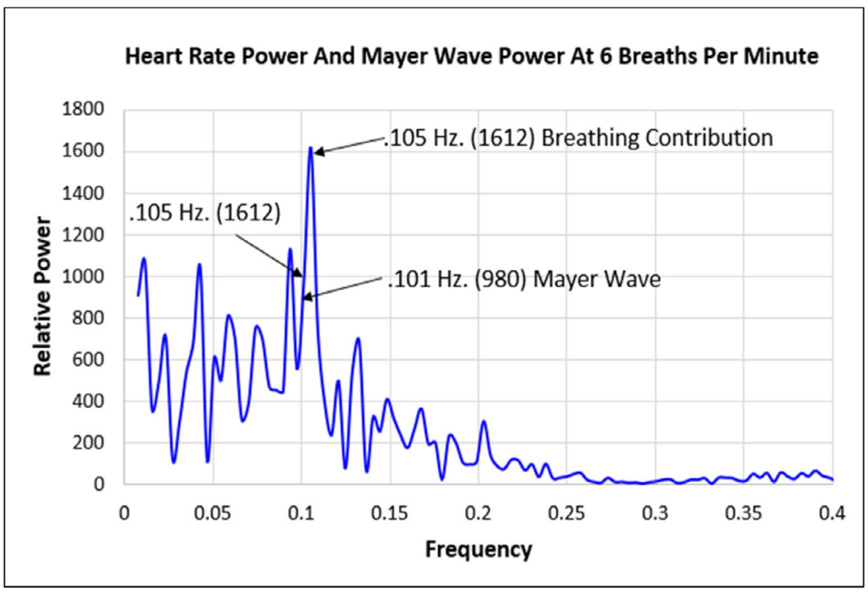

Figure 3: Heart Rate & Mayer Wave Frequency Components @ 6 BPM

Here, there exists "a forest for the trees moment"...The scientific efforts regarding the Mayer Wave (of which I am aware), are highly focused on "the origin of the signal". Is it centralized or distributed? Is it sensory or motor? Is it sympathetic or parasympathetic? Here, I overdo it to make a point.

It is interesting to point out that the Mayer phenomenon exists across the mammalian class and maybe across the vertebrate class, although there is not much evidence outside of the study of humans with the exception of cats and rats, where cats share the frequency of ~.1 Hz. and rats at ~.4 Hertz, the faster Rattus rate is inevitably due to their much faster metabolic rate.

The further we go back in terms of its shared presence across phylum, the more primordial it becomes. The Mayer Wave exists for a reason. Charles Darwin would say that reason is "selective pressure". This must lead us to ask, "What is the function and purpose of the Mayer Wave, anyway?" There may be more than one answer to this question, but there is certainly one, and that answer is that it prevents the circulatory system from crossing a threshold into dysfunction, specifically dysfunction that places cells at risk. In other words, it keeps blood and fluids in the body flowing, even though *breathing* may not be playing its humble role, i.e., that of generating the Valsalva Wave. The Valsalva Wave and Mayer Wave share the purpose of facilitating circulation; the Valsalva Wave performs this function when the diaphragm is active and breathing is productive in terms of fluid flow. The Mayer Wave performs this function 100% of the time but at varying signal strength. With a final referral to Figure 1, there is a quiet period between 10 and <20 breaths per minute where the amplitudes of all 3 signals are relatively low. This relative "quiet" period may serve the purpose of sleep, where the body is horizontal and the metabolic rate is relatively low. "Whoop", a respiratory monitoring app reports that the breathing rate while sleeping is between 13 and 18 breaths per minute.

Stephen Elliott, President, COHERENCE LLC. Special thanks to Tom Granger for articulating the quest.

Spectral Analyses:

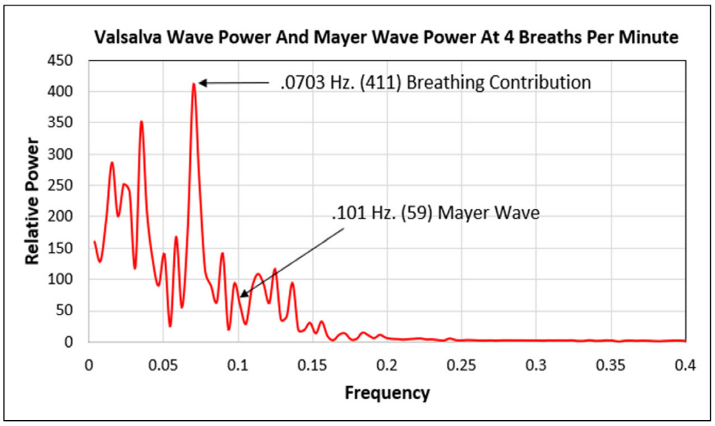

Figure 4: Valsalva Wave & Mayer Wave Frequency Components @ 4 BPM = .067 Hertz Target

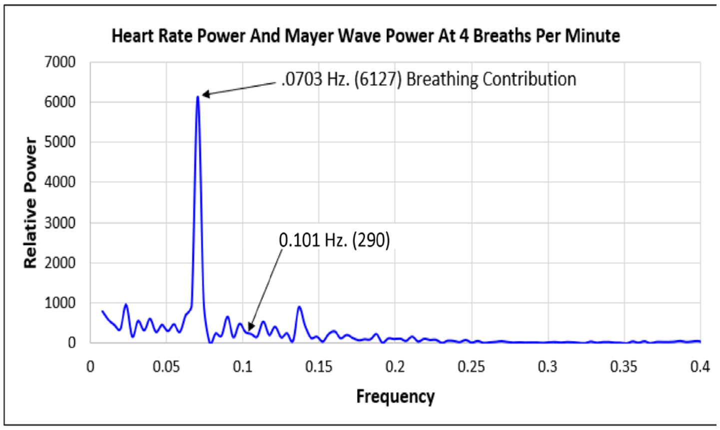

Figure 5: Heart Rate & Mayer Wave Frequency Components @ 4 BPM = .067 Hertz Target

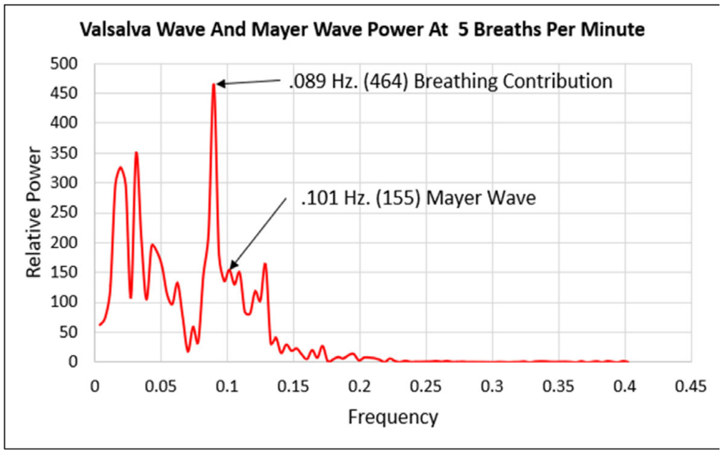

Figure 6: Valsalva Wave & Mayer Wave Frequency Components @ 5 BPM = .083 Hertz Target

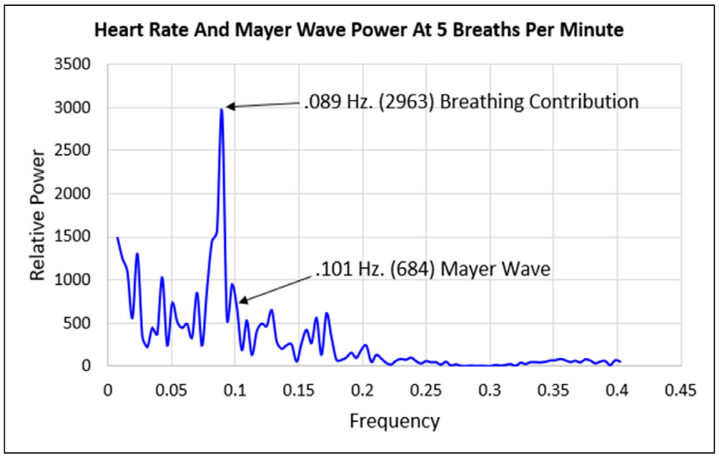

Figure 7: Heart Rate & Mayer Wave Frequency Components @ 5 BPM = .083 Hertz Target

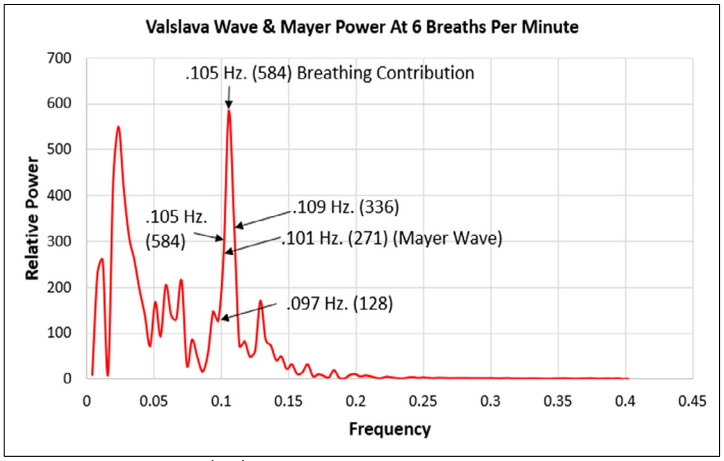

Figure 8: Valslava Wave & Mayer Wave Frequency Components @ 6 BPM = .100 Hertz Target

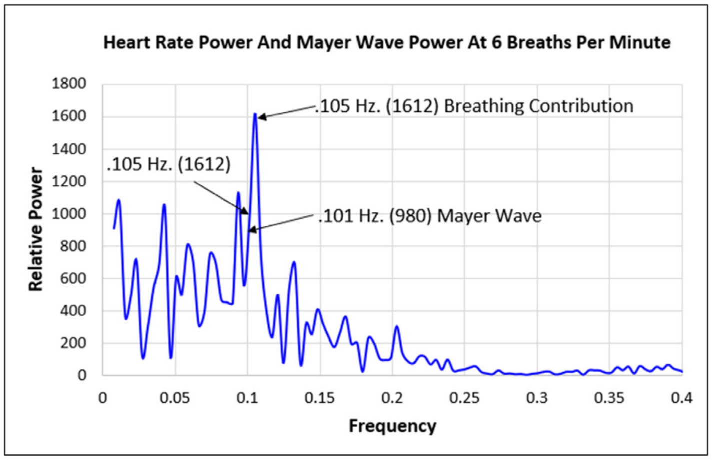

Figure 9: Heart Rate & Mayer Wave Frequency Components @ 6 BPM = .100 Hertz Target

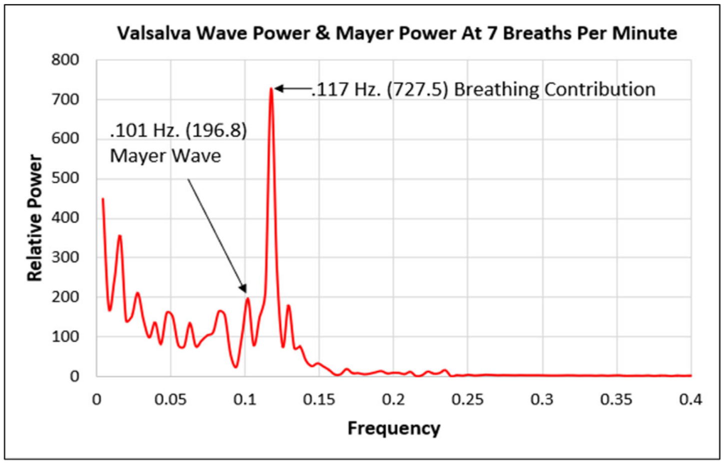

Figure 10: Valsalva Wave & Mayer Wave Frequency Components @ 7 BPM = .117 Hertz Target

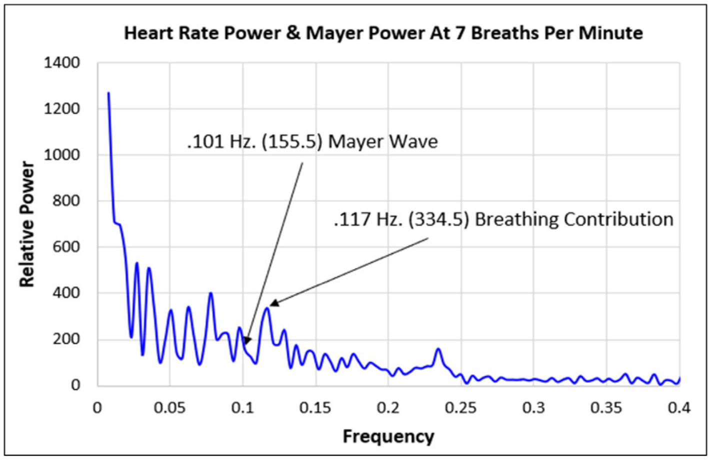

Figure 11: Heart Rate & Mayer Wave Frequency Components @ 7 BPM = .117 Hertz Target

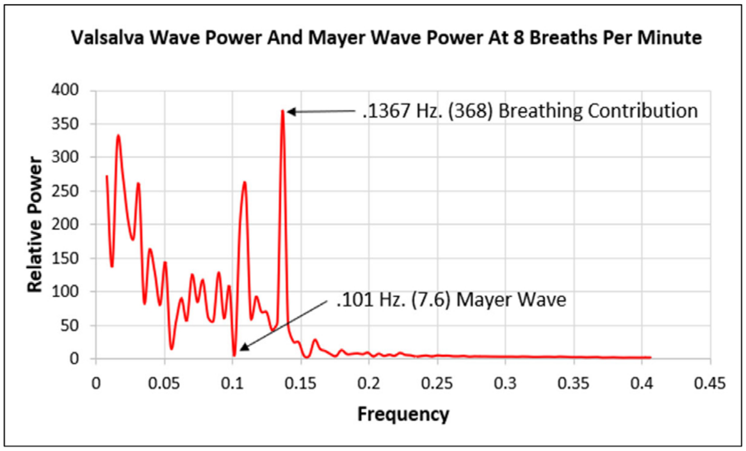

Figure 12: Valsalva Wave & Mayer Wave Frequency Components @ 8 BPM = .133 Hertz Target

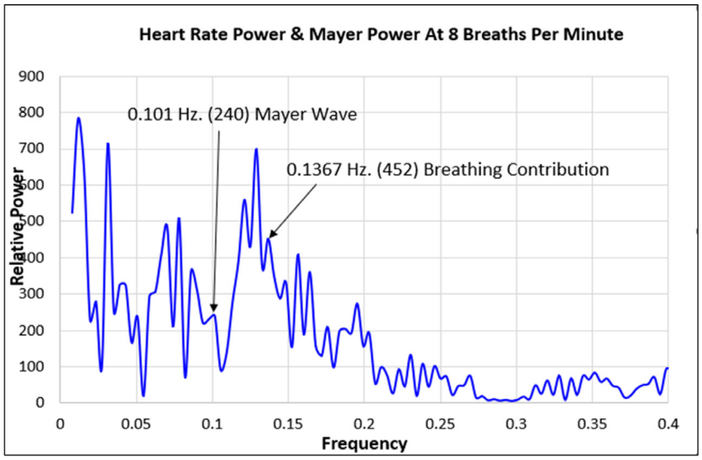

Figure 13: Heart Rate & Mayer Wave Frequency Components @ 8 BPM = .133 Hertz Target

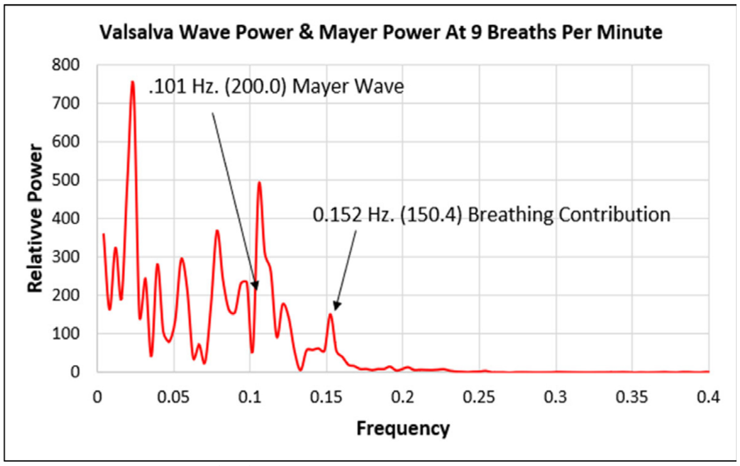

Figure 14: Valsalva Wave & Mayer Wave Frequency Components @ 9 BPM = .150 Hertz Target

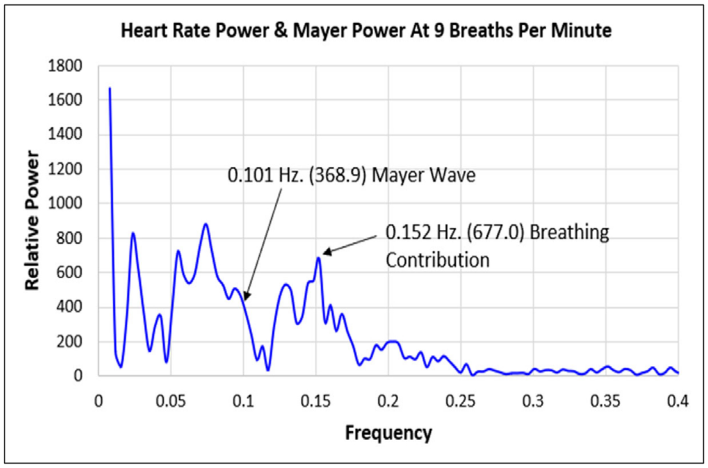

Figure 15: Heart Rate & Mayer Wave Frequency Components @ 9 BPM = .150 Hertz Target

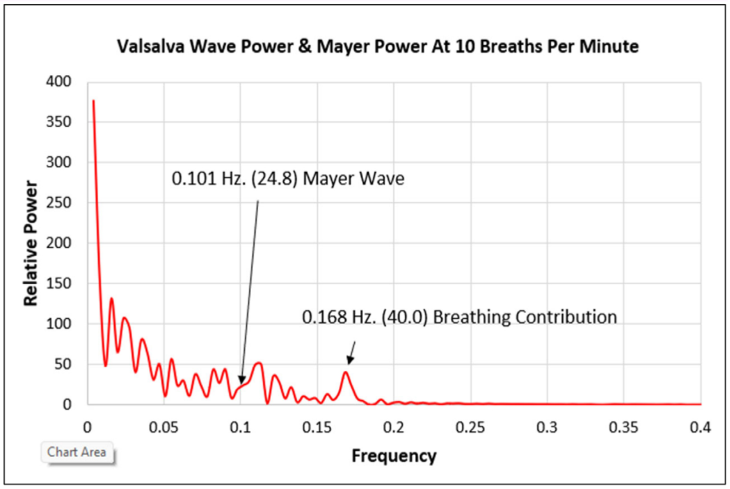

Figure 16: Valsalva Wave & Mayer Wave Frequency Components @ 10 BPM = .167 Hertz Target

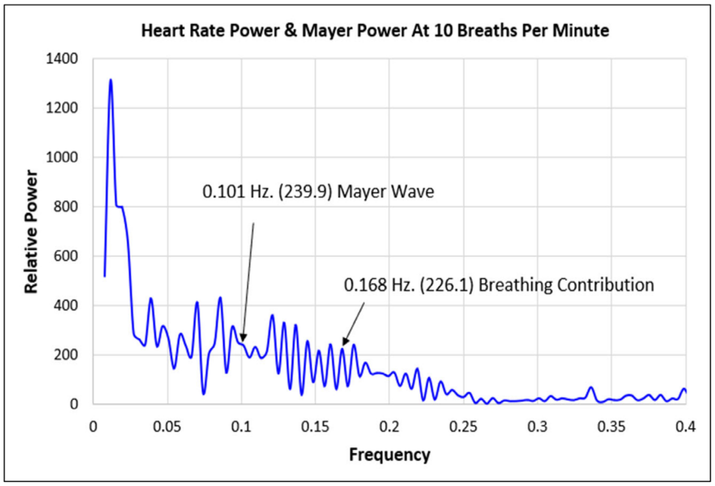

Figure 17: Heart Rate & Mayer Wave Frequency Components @ 10 BPM = .167 Hertz Target

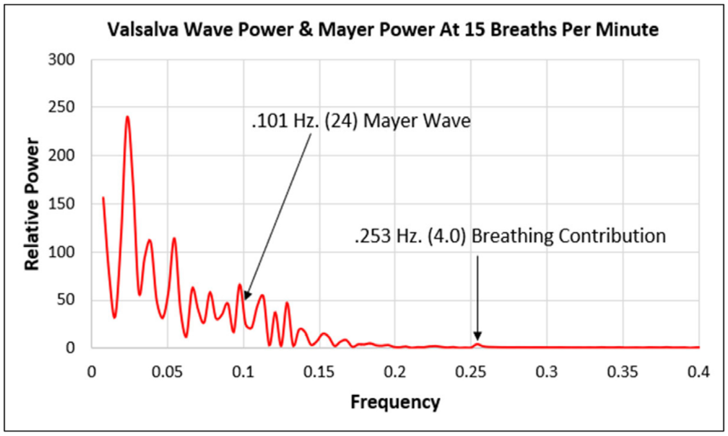

Figure 18: Valsalva Wave & Mayer Wave Frequency Components @ 15 BPM = .250 Hertz Target

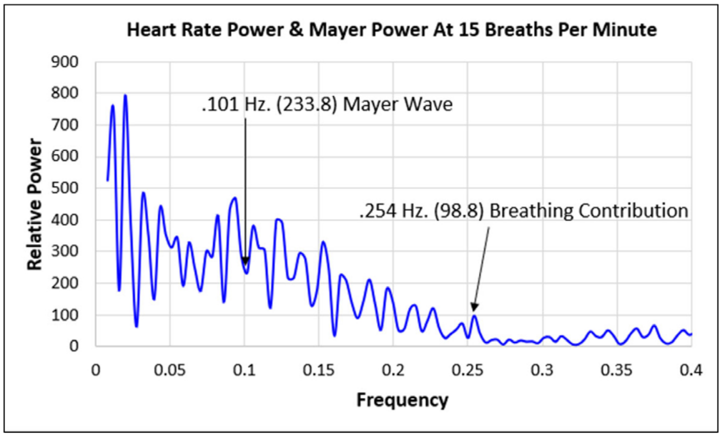

Figure 19: Heart Rate & Mayer Wave Frequency Components @ 15 BPM = .250 Hertz Target

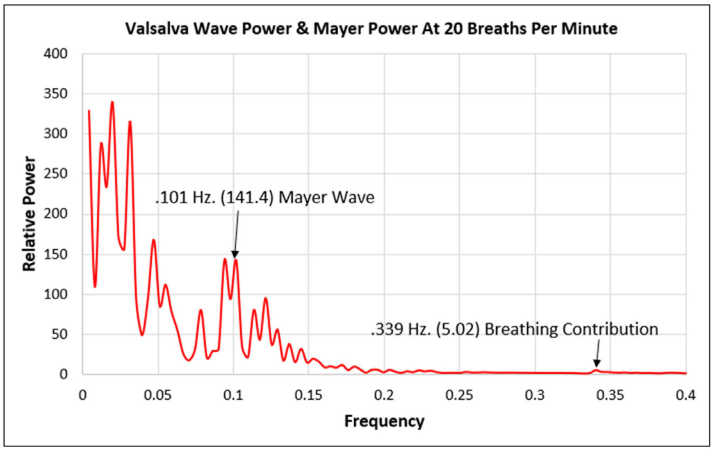

Figure 20: Valsalva Wave & Mayer Wave Frequency Components @ 20 BPM = .333 Hertz Target

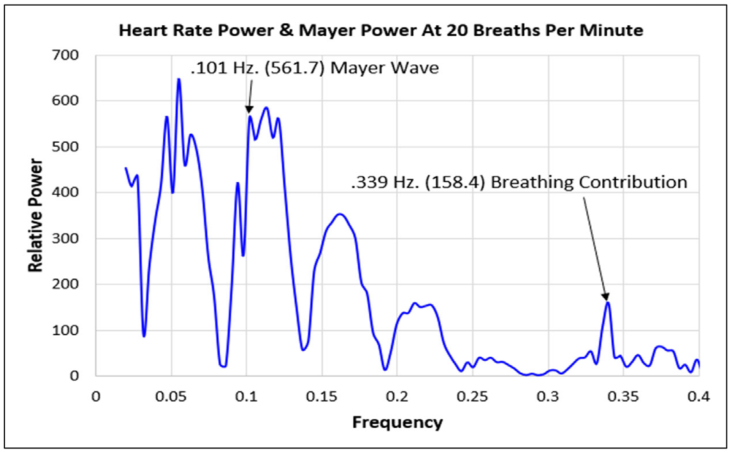

Figure 21: Heart Rate & Mayer Wave Frequency Components @ 20 BPM = .333 Hertz Target

BPM	Period	Hertz
4	15	0.067
5	12	0.083
6	10	0.100
7	8.6	0.117
8	7.5	0.133
9	6.7	0.150
10	6	0.167
15	4	0.250
20	3	0.333

Figure 22: Breathing Rates, Periods, & Frequencies

Notes:

1) Julien C. The enigma of Mayer waves: Facts and models. Cardiovasc Res. 2006 Apr 1;70(1):12-21. doi: 10.1016/j.cardiores.2005.11.008. Epub 2005 Dec 19. PMID: 16360130.

References:

1) Julien C. The enigma of Mayer waves: Facts and models. Cardiovasc Res. 2006 Apr 1;70(1):12-21. doi: 10.1016/j.cardiores.2005.11.008. Epub 2005 Dec 19. PMID: 16360130.

2) Medical Physiology, Tenth Edition, Guyton & Hall, 2000, pg. 193.

3) On the Origins of Mayer Waves, M. Ghali, G. Ghali, Kindle Edition, March, 2020.

4) Whoop.com: https://www.whoop.com/thelocker/what-is-respiratory-rate-normal/

About the study:

Instrument: COHERENCE Valsalva Wave Pro

Pacing audio: Slow Down! by COHERENCE

Breathing occurred in nine 5-minute periods, each period being paced by audio, and recorded by Valsalva Wave Pro, generating 9 time domain records of both Valsalva Wave and Heart Rate. Fourier transform then applied to time domain records to realize frequency analyses.