HEART RATE *VARIABILITY*

What it is. How to measure it. What helps. And what it means to steward it.

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Women : The Portal

A NOTE FROM DR. SARA

MAKING THE INVISIBLE VISIBLE

There is a word I have come to prefer over self-care: self-stewardship.

Of all the tools available to me as a physician, HRV has become one of the most revealing. I use it as part of a clinical dashboard, alongside hormone panels, sleep data, and metabolic markers, to understand where a patient sits on the spectrum between resilience and depletion. It tells me things that a conversation sometimes cannot: whether the nervous system is genuinely recovering between stressors, or whether someone is running on reserves they may not know are emptying.

What I find most compelling is not any single reading, but the pattern — the trajectory over weeks and months, and how that trajectory responds to changes in sleep, hormones, movement, and the subtler inner work of nervous system regulation. When a patient's HRV trend begins to rise, I notice it before they do. When it begins to quietly fall despite everything looking *fine* on the surface, that data gives us a place to look deeper.

I use HRV data not to alarm or overwhelm, but to illuminate. To make the invisible visible. The numbers in this guide are not prescriptions — they are invitations to understand your own biology more intimately. That is what this work has always been about.

Self-care has been sold back to us as a candle and a bath. Self-stewardship is something else. For a woman, it is not indulgence and it is not maintenance. It is governance: becoming the first and most reliable authority over your own nervous system, after years of being trained to read everyone else's. Most women I treat were taught early to monitor a room before they learned to monitor their own breath. Self-stewardship is the work of reversing that order — without guilt, and without waiting for permission.

> *HRV is one of the few measures I trust to tell a woman the truth about whether that reversal is taking hold — not whether she feels calm, but whether her body has stopped bracing.*[21]

The number does not care how composed you look at pickup or in the boardroom. It cares whether your system believes it is finally safe enough to come off duty. Stewardship of your own biology is not a metaphor in this work. It is a daily practice with a number attached to it, and that number is HRV.

PART ONE

WHAT IS HEART RATE VARIABILITY?

A heart that beats with rigid, metronomic precision is a warning sign. A heart whose rhythm breathes is in conversation with a healthy nervous system.

Heart rate variability (HRV) is the beat-to-beat variation in the time intervals between consecutive heartbeats, measured in milliseconds as R-R intervals. It reflects the dynamic interplay between the sympathetic (fight-or-flight) and parasympathetic (rest-and-digest) branches of the autonomic nervous system.[1,2] Contrary to common belief, a higher HRV is a sign of better nervous system health, not cardiac instability.

As we age, HRV typically declines — an indicator of reduced physiological flexibility and resilience. Men often experience a slow, steady decrease, while women tend to see a sharper drop during perimenopause and beyond, likely linked to declining estrogen and its effect on vagal tone.[1,2,4] Even consistent sleep, exercise, and nutrition may not fully offset this decline, because autonomic regulation and hormone signaling change intrinsically over time.[4]

KEY HRV METRICS: WHAT THE NUMBERS MEAN

Time-domain metrics measure statistical variation between successive heartbeat intervals:

- **RMSSD** (root mean square of successive differences) — the most commonly reported metric on consumer devices, primarily reflecting parasympathetic (vagal) activity. Most reliably captured by optical sensors.[1,2]
- **SDNN** (standard deviation of NN intervals) — reflects overall autonomic variability across all frequency bands.
- **pNN50** — percentage of successive intervals differing by more than 50 ms. Another vagal marker.

Frequency-domain metrics decompose the heart rate signal into bands using spectral analysis:[1,2]

- **HF** (High Frequency, 0.15–0.40 Hz) — reflects parasympathetic activity and respiratory sinus arrhythmia; the most direct vagal marker.
- **LF** (Low Frequency, 0.04–0.15 Hz) — reflects a mix of sympathetic and parasympathetic modulation, commonly misread as purely sympathetic. It is not.
- **VLF** (Very Low Frequency, 0.003–0.04 Hz) — speculatively linked to the renin-angiotensin-aldosterone system and thermoregulation. Physiological basis remains poorly defined.[2]
- **LF/HF ratio** — a rough index of sympathovagal balance. Useful directionally; should not be over-interpreted.

Because HRV is a variance metric, it must be derived over a defined time window — ultra-short (under 1 min), short-term (under 5 min), or long-term (over 24 hours) — and measurements from different durations are not directly comparable.[1] This is why your ring's overnight average differs from a two-minute morning reading.

PART TWO

HOW TO MEASURE YOUR HRV

Measurement conditions matter more than device brand.

All major consumer wearables measure HRV using photoplethysmography (PPG) — optical sensors that shine light into the skin and detect blood volume changes to estimate interbeat intervals. The key limitation: PPG measures pulse rate variability (PRV), a proxy for true ECG-based HRV. This proxy is most accurate at rest and during sleep, and degrades significantly during movement.[1,3] The gold standard is the electrocardiogram (ECG), which captures the electrical signal of the heart directly.

Chest Strap (Polar H10, Garmin HRM-Pro)

The closest consumer tool to a clinical ECG. Uses electrical sensing rather than optical light, capturing true R-R intervals with high fidelity. In a 2025 study of athletes, the Polar H10 achieved a mean error of 2.16% for RMSSD versus ECG, far outperforming PPG-based devices (17.49% for smartphone PPG).[10] Excellent reliability supine; accuracy degrades seated and in older participants.[11]

Best for: frequency-domain analysis, HRV biofeedback training, morning resting readings, and research-grade applications.

Oura Ring (Generations 3 and 4)

Captures HRV primarily during sleep using infrared PPG sensors on the inner finger surface. High correlation with ECG for nocturnal RMSSD ($r = 0.980$, mean bias −1.2 ms in manufacturer data[6]), but more than half of participants over age 45 exceeded 10% error for HRV in an independent study.[5] Frequency-domain metrics are not displayed.

Best for: longitudinal overnight trend tracking. Not appropriate for real-time biofeedback or frequency-domain analysis.

Ultrahuman Ring Air

Uses PPG-based optical sensing with identical fundamental limitations to Oura, and does not display frequency-domain components. Published ECG validation data are more limited than for Oura. Both rings are best treated as trend devices — valuable for tracking personal RMSSD trajectories over weeks and months, not for clinical-grade single readings.

DEVICE COMPARISON AT A GLANCE

DEVICE	FORM	RMSSD ACCURACY VS. ECG	FREQ-DOMAIN	BEST USE
Polar H10	Chest strap	~2% error[10]; ECG-based, excellent	Yes, reliable	Biofeedback, frequency analysis, research
Oura Ring Gen 3/4	Finger ring	r = 0.980, bias −1.2 ms[6]; >50% of adults 45+ exceed 10% error[5]	No, not displayed	Overnight trend tracking
Ultrahuman Ring Air	Finger ring	Limited published ECG data; PPG-based	No, not available	Overnight trend tracking
Apple Watch S9 / Ultra 2	Wrist	~29% error; underestimates ~8 ms; fails equivalence[7]	Not validated	Convenient; least accurate for HRV
Garmin Forerunner / Vivosmart	Wrist	Limited HRV-specific ECG data[8,9]	Not validated	HR tracking; HRV trends less reliable
WHOOP 3.0 / 4.0	Wrist	Good correlation in sleep lab[8]	Not validated	Recovery tracking; trend use

RMSSD is the most reliable metric from PPG devices; frequency-domain metrics are unreliable from wrist or ring sensors. Nocturnal measurements outperform daytime across all devices. HRV is a personal metric — track your trend, not someone else's number.[1,4,13]

PART THREE

WHAT CONFOUNDS YOUR HRV READING?

Your HRV number is shaped primarily by biology, and only secondarily by anything you do on a given day.

Understanding HRV well means understanding how many forces can shift the number on any given morning, independently of your actual health or recovery state. Confounders fall into two categories: factors that change your actual autonomic tone, and factors that introduce measurement error in the device itself.

A large population study of 149,205 individuals found that age and sex together explained 17.4% of the variance in RMSSD, dwarfing all other factors combined. Lifestyle, stress, neuroticism, and social well-being together explained less than 0.5% of additional variance.[C2]

PHYSIOLOGICAL & BEHAVIORAL CONFOUNDERS

Non-modifiable. Age is the single strongest determinant of HRV, declining most rapidly through the 50s.[C2,C3] Sex matters — the menstrual cycle alone produces a 3.2% change in HRV between follicular and luteal phases.[C2,C4] Ethnicity is identified as a confounder, though less well quantified.[C5]

Modifiable lifestyle factors. High alcohol intake produces a 12% reduction in HRV and a 6% increase in resting heart rate, with effects persisting 10+ hours — one of the most potent acute confounders.[C4] Caffeine and nicotine both shift balance toward sympathetic dominance.[C1,C5] Exercise is bidirectional: vagal RMSSD drops in the days after high-intensity effort but rises over weeks of training.[C1,C4] Poor sleep reduces nocturnal HRV directly,[C1] as does dehydration,[C1] and higher BMI is weakly associated with lower HRV.[C4]

Acute physiological stressors. Infection produces a ~10% reduction in HRV, often detectable by wearables before symptoms are consciously recognized.[C4] Circadian timing and body position also matter — supine yields higher HRV than seated or standing.[C1,C5,C6]

MEDICATIONS

A clinically significant area often overlooked. Tricyclic antidepressants consistently lower HRV.[C7] SSRIs show mixed but generally weaker effects.[C7,C8] Beta-blockers, certain calcium channel blockers, digoxin, antiarrhythmics, opioids, and lithium can all induce bradycardia and alter HRV.[C9,C10] Higher anticholinergic burden is independently associated with lower HRV.[C11]

TECHNICAL & DEVICE-RELATED CONFOUNDERS

TECHNICAL FACTOR	MECHANISM OF ERROR	CLINICAL IMPACT
Motion artifact	Movement disrupts the PPG signal; HRV error rises 14–51% during activity vs. rest	The most significant error source — why most devices report HRV only during sleep
Darker skin tone	Increased melanin absorbs green LED light; up to 61% signal loss in simulation	50–85% of missing data from dark-skinned participants; may worsen health disparities
Tattoos	Ink absorbs and scatters light, reducing PPG amplitude	Known confounder; limited quantitative data
Obesity	Subcutaneous tissue attenuates light penetration	Up to 61% signal loss in Monte Carlo simulations
Device fit	Too loose causes motion artifact; too tight impairs blood flow	Affects all PPG metrics; especially problematic for wrist-worn devices
Cold / low perfusion	Peripheral vasoconstriction reduces pulsatile blood volume	Reduces signal-to-noise ratio
Ectopic beats	Premature beats alter interbeat intervals, artificially inflating HRV	Cannot be filtered by PPG-only devices without simultaneous ECG

A meta-analysis of 23 studies (301 effect sizes) confirmed that the HRV metric chosen, body position, and biological sex — but not the specific device — were the significant moderators of measurement error.[C19] *Standardizing your conditions matters more than choosing a brand.*

PART FOUR

HOW HRV CHANGES WITH AGE AND SEX

Women tend toward stronger vagal tone in midlife – until perimenopause changes the equation.

Time- and frequency-domain HRV metrics — SDNN, RMSSD, LF, and HF — all show a downward trend with age, reflecting reduced cardiac autonomic modulation. This pattern holds even after adjusting for lifestyle factors like activity level, body composition, or resting heart rate.[1,2,3,4]

SEX DIFFERENCES IN HRV

Women tend to have higher resting heart rates and higher normalized high-frequency power, reflecting stronger vagal tone, along with lower LF/HF ratios.[5,6,9,10] Men generally show lower resting heart rates, higher absolute HRV, and greater sympathetic modulation.[5,6,9,10] These patterns are most apparent in midlife: women aged 35–54 show greater vagal dominance, while men show higher overall variability.[3] After about age 60–65, sex differences narrow as hormonal leveling occurs.[2,3] Even under laboratory-induced stress, women tend to display lower HRV than men despite comparable resting baselines.[11]

HRV AND RESTING HEART RATE

HRV and resting heart rate move in opposite directions: as resting heart rate decreases, HRV tends to increase. A lower heart rate allows more time between beats, creating space for greater variability — reflecting stronger parasympathetic modulation and autonomic flexibility.[1,2,3,4,7,8]

PERIMENOPAUSE AND HRV

Perimenopause has measurable cardiovascular impact. As estrogen falls, vagal tone weakens, reducing both HRV and overall stress resilience. Oura data suggest a 20–30% drop in HRV during perimenopause and post-menopause, often accompanied by sleep disruption and increased sympathetic activation. Adequate sleep appears to blunt HRV decline in middle-aged women, but not men — highlighting the unique interplay between sex, hormones, and autonomic health.[6]

> *Average HRV in Oura population data: women ~41.5 ms (median ~35); men ~40.3 ms (median ~34.2). The sex gap narrows sharply after menopause.*

WHAT SUPPRESSES HRV, EVEN ON 'GOOD' DAYS

A disconnect between how relaxed you feel and what the device reads is not a malfunction. It is data literacy.

Several lifestyle factors cause physiological HRV suppression even when a person feels subjectively relaxed. Understanding these separates data literacy from data confusion.

- **Alcohol.** Even moderate evening consumption suppresses nocturnal HRV, reduces baroreflex sensitivity, and increases sympathetic activity throughout the night, with effects persisting 10+ hours. High intake causes a 12% reduction in HRV and 6% increase in heart rate.[A3,A4]
- **Sleep quality, not just duration.** Fragmented sleep suppresses HRV even when total hours are adequate. Low sleep efficiency is associated with significantly lower HF-HRV independent of duration.[A5,A6]
- **Exercise carryover.** Moderate-to-vigorous exercise can suppress HRV for 5+ hours afterward — a morning session can still register in evening readings.[A1]
- **Menstrual cycle phase.** HRV is highest at cycle start and lowest premenstrually. Progesterone — not estradiol — drives this within-person effect.[A8,A9]
- **Caffeine timing.** Caffeine can delay parasympathetic recovery after exercise, suppressing post-workout RMSSD restoration.[A10]
- **Subclinical inflammation or illness.** HRV can drop before any subjective awareness of illness — a 10% reduction seen in large longitudinal data.[C4]

A systematic review of 36 studies found that only 35% of analyses showed a significant association in the expected direction between perceived stress and physiological measures.[A11] HRV is sensitive but non-specific: it responds to many physiological inputs simultaneously, making it an unreliable indicator of any single factor, including psychological stress.

PART SIX

WHAT HELPS TO RAISE HRV

Research-backed strategies, in rough order of evidence strength.

- **Get restorative sleep.** A 2025 meta-analysis of 11 RCTs found sleep deprivation significantly decreased RMSSD and increased LF and LF/HF ratio.[A5]
- **Stay active, especially zone 2.** Consistent aerobic and endurance training has the most robust evidence for increasing HRV.[12,13,14,15,16,17]
- **Practice resonance-frequency breathing.** Slow rhythmic breathing (~4.5–6 breaths per minute) activates the baroreflex and directly increases HRV. Effects are enhanced when combined with contemplative training.[18]
- **Attend to micro-transitions.** The capacity to flexibly shift between high and low physiological activation — not just the presence of rest — distinguishes adaptive from maladaptive autonomic regulation. The quality of the spaces between moments matters.[A13,A14]
- **Wear blue-light-blocking glasses after sunset.** Supports circadian alignment, sleep quality, and HRV.
- **Proactively address perimenopause.** Declining estrogen reduces parasympathetic tone and HRV; managing hormonal transitions directly supports autonomic health.
- **Magnesium at night.** Some evidence supports parasympathetic activity and improved sleep-related HRV.
- **Progressive muscle relaxation (PMR).** Improves parasympathetic tone with regular practice.[19]
- **Rhythmic skeletal muscle tension (RSMT).** An emerging method for stimulating vagal activity when breath-focused methods are not feasible.[20]

PART SEVEN

HRV AS A PRACTICE OF SELF-STEWARDSHIP

A wearable can tell you that your number is low. It cannot tell you why you keep saying yes.

Most of the women in my practice are not collapsing. They are fawning. Pete Walker named the fawn response in 2013 as a fourth survival strategy alongside fight, flight, and freeze: a nervous system that has learned to keep itself safe by tending to everyone else's needs first.[22] In wearable data, the fawner's autonomic signature tends to look like sustained sympathetic activation paired with chronic parasympathetic suppression — a flat, low HRV that does not lift in response to the usual interventions, because the usual interventions never address the load.[23]

This is where self-stewardship and HRV meet. Closing the gap between the data and the decision is the practice itself. Three places it shows up most often:

- **The digital bleed.** Smartphone use elevates sympathetic tone, reduces HRV, and disrupts the sleep architecture that does your overnight autonomic repair.[24] A boundary around your phone is a stewardship decision about who gets access to your nervous system, and when.
- **Telepressure.** The felt urgency to respond immediately disrupts sleep and reduces HRV recovery independent of your actual workload.[25] An out-of-office reply tells your system it is allowed to stop running the background process of being reachable.
- **The unsat meal.** Eating standing up, scrolling, or mid-task drives a measurable sympathetic shift and a lower postprandial HRV response.[27] Sitting down for a meal is a small, repeatable act of telling your body it is safe enough to digest.

None of these are about discipline. They are about reducing what is being asked of a system that has been asked for too much for too long — the same insight that makes structural de-loading more effective than another layer of stress management.[26] You cannot meditate your way out of a load problem. You can only put some of the load down.

> *Self-stewardship looks less like a single intervention and more like an ongoing relationship: noticing what costs you, noticing what restores you, and trusting the number enough to keep adjusting the load rather than your story about why the load is fine.*

SUMMARY

- HRV declines with age for both sexes; women experience a sharper midlife drop.
- HRV is a personal metric — track your own trend, not someone else's number.
- Consumer rings (Oura, Ultrahuman) reliably track RMSSD overnight; they do not provide frequency-domain analysis.
- The Polar H10 chest strap is the most accurate consumer-accessible option, approaching ECG-level RMSSD precision.
- Confounders — from medications to skin tone to device fit — matter as much as which device you choose.

- Measurement conditions (supine, consistent timing, whole-night averaging) matter more than device brand.
- The quality of transitions between states matters as much as the presence of rest.

COMMUNITY QUESTIONS & EVIDENCE-BASED ANSWERS

> **COMMUNITY QUESTION**
>
> *Which device gives the most reliable HRV reading — the Oura Ring, Garmin, or a chest strap, head to head?*

All major consumer wearables use PPG, which measures pulse rate variability as a proxy for true ECG-based HRV — most accurate at rest and during sleep, degrading during movement.[1,3] The **Polar H10 chest strap** is the reference standard, with ~2.16% RMSSD error versus ECG.[10] The **Oura Ring** has the most extensive validation among ring devices (nocturnal RMSSD r = 0.980), though over half of participants over 45 exceeded 10% error.[5,6] **Ultrahuman** shares the same constraints. The **Apple Watch** is the most widely used and least accurate for HRV — underestimating by ~8.31 ms and failing equivalence testing.[7] The bottom line: measurement conditions, body position, metric type, and biological sex matter more than the device brand.[13]

> **AMY ASKS**
>
> *I've used my Oura for two weeks. My HRV varies between the low 20s and 40. On low-stress days — yoga, a beach walk, no work — the ring still says I'm 'engaged' or 'stressed.' I think it has more to do with how I move from one moment to the next.*

Context matters enormously. Population studies show average daytime RMSSD around 42 ms in healthy adults; values in the 30s–40s are likely normal depending on age, while values consistently in the low 20s may warrant closer attention.[Q2-1,Q2-2] Your ring derives its stress score from HRV and heart rate patterns — it does not directly measure psychological stress.[Q2-3,Q2-4] A morning yoga session can suppress HRV for five or more hours, still showing autonomic carryover into your afternoon walk.[Q2-6] Your instinct about transitions is supported by the evidence: the capacity to flexibly shift between high and low activation — not absolute HRV level — may be what distinguishes adaptive from maladaptive regulation.[Q2-9,Q2-10] Four years of sobriety has already removed one of the major HRV suppressants. The next layer may be exactly what you named: the quality of the spaces between.

> **COMMUNITY QUESTION**
>
> *Does the Ultrahuman show the heart spectrum in the frequency domain? I understand the fawn response can only be identified by viewing LF, HF, and VLF components — and that high VLF signals unresolved trauma.*

Your technical read is accurate: neither Oura nor Ultrahuman displays LF, HF, or VLF spectral components, and consumer wearables show high error rates for frequency-domain metrics in short recordings.[Q3-1,Q3-2,Q3-3] For frequency-domain analysis, a chest strap is required. The core premise that trauma and PTSD are associated with reduced parasympathetic activity and a higher LF/HF ratio is well-supported.[Q3-5,Q3-6] But precision matters:

the *fawn* response is a concept from popular trauma psychology and does not have a validated, distinct HRV frequency-domain signature in the peer-reviewed literature.[Q3-8,Q3-9,Q3-10] VLF's physiological origins remain poorly understood, and claiming that elevated VLF specifically signals unresolved trauma goes beyond what current evidence supports.[Q3-5,Q3-6,Q3-7]

> *Autonomic dysregulation is real, measurable, and responsive to intervention. Science doesn't yet have the tools to fully capture what happens at that threshold. That doesn't mean the threshold isn't real.*

A CLOSING NOTE ON SELF-STEWARDSHIP

The data in this guide will not tell you what to release first: sleep, alcohol, an obligation, a relationship that has been quietly costing you for years. Only you know that — and likely you already do.

What the data can do is confirm what your body has been reporting, sometimes for years, before anyone gave it a name. Self-stewardship is not the absence of strain. It is the practice of staying in relationship with your own nervous system closely enough to know the difference between strain that is building you and strain that is depleting you — and the willingness to act on what you find.

HRV will not do that work for you. It will simply keep the record, faithfully, for as long as you are willing to read it.

— DR. SARA SZAL, MD

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