Oura and Cardiovascular Health:
Product, Scientific, and Clinical Insights

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Foreword

Cardiovascular disease remains the leading cause of death worldwide, yet much of its progression occurs silently, shaped by everyday behaviors and physiologic patterns long before clinical symptoms emerge. In practice, cardiovascular health is rarely defined by a single measurement or isolated encounter. Instead, it reflects trajectories that unfold over time across sleep, physical activity, stress, metabolic health, and recovery.

Traditional cardiovascular care has relied largely on episodic assessment like blood pressure readings, laboratory values, and imaging obtained at discrete points in time. While foundational, these snapshots incompletely capture the continuous and adaptive nature of cardiovascular physiology. As our understanding of risk evolution has matured, so too has the recognition that prevention requires tools capable of observing patterns, trends, and early deviations as they occur in daily life.

In this context, advances in validated wearable sensing technologies have created new opportunities to complement conventional cardiovascular assessment. When rigorously studied and appropriately interpreted, such tools can enable longitudinal observation of physiologic signals, including resting heart rate, heart rate variability, sleep architecture, activity patterns, and recovery. Sleep in particular represents a physiologic state of relative stability, offering a valuable window into autonomic and cardiovascular regulation that is difficult to capture during waking clinical encounters.

This white paper explores cardiovascular health as a dynamic, multidimensional system rather than a static diagnosis. Concepts such as Cardiovascular Age may offer one perspective on vascular health, but they are most meaningful when considered alongside broader measures of resilience, recovery, and lifestyle context. Importantly, many of these domains are modifiable. Evidence-based behaviors, including regular physical activity, restorative sleep, and effective stress management, remain central to prevention, regardless of the tools used to measure them.

Digital health technologies, including consumer wearables such as Oura Ring, should be viewed as adjunctive instruments rather than replacements for clinical judgment or established diagnostic pathways. Their value lies not in isolated metrics, but in the longitudinal patterns they reveal and in their potential to support earlier awareness, more personalized prevention strategies, and informed conversations between patients and clinicians. As a practicing cardiologist, I believe the responsible integration of continuously collected physiologic data when grounded in validation, transparency, and clinical context represents a meaningful evolution in preventive cardiovascular care. Used thoughtfully, these approaches may help bridge the gap between how cardiovascular disease develops in real life and how we currently detect it.

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Member, Oura Medical Advisory Board

Executive summary

Supporting cardiovascular health is at the heart of our product, scientific, and clinical offerings. And for good reason – cardiovascular disease (CVD) remains the leading cause of death globally, contributing to nearly one-third of all deaths and accounting for approximately 437 million disability-adjusted life years (DALYs) in 2023. We need to bend the curve of this public health crisis. We know that 79.6% of these DALYs and deaths are linked to modifiable risk factors, such as poor sleep, unhealthy diets, sedentary behavior, and stress. These risks often develop silently over time, and deviations from baseline are difficult to detect before a serious acute health event.

Oura Ring can contribute to transforming cardiovascular care from episodic, reactive sick care towards longitudinal, personalized, behavior-led prevention and awareness. From supporting daily actions that promote wellbeing, to providing a snapshot of heart health with our Cardiovascular Age feature, and conducting an innovative Blood Pressure Profile Study examining changes in pulse wave velocity, Oura is leading the future of heart health.

The report provides a technical overview of Oura's validated Heart Health features, summaries of our latest scientific contributions to advance understanding of cardiovascular health and disease through wearable technology, and practical clinical use cases for patients and healthcare providers to use Oura Ring.

Highlights:

Vascular aging and Cardiovascular Age (CVA): Dive into the science behind the CVA feature and its clinical utility.

Cardiovascular health features: Learn about the validation studies supporting core Oura metrics, including resting heart rate (RHR) and heart rate variability (HRV), as well as the development of proprietary Oura metrics like Cumulative Stress.

New scientific research: Examine three abstracts presented at the American Heart Association Scientific Sessions in 2025, details about Singapore's flagship heart health research initiative, as well as our first randomized, controlled clinical trial, GONDOR-AS, which will evaluate if Oura Advisor, our AI-driven, personalized wellness coach, can provide individualized, sustainable exercise guidance that leads to meaningful improvements in cardiorespiratory fitness (CRF, measured directly with VO2max testing) and arterial stiffness.

Women's cardiovascular health: Oura places sex differences at the center of its cardiovascular research, utilizing large-scale, anonymized, aggregated datasets to bridge historical gaps in clinical understanding. This research investigates how lifestyle factors and metabolic conditions intersect to influence cardiovascular risk, empowering women and their care teams with actionable, data-driven insights for long-term prevention.

Clinical integration: Discover practical frameworks for utilizing Oura data in clinical settings, ranging from remote risk tracking for hypertension to supporting recovery in cardiac rehabilitation.

We are optimistic that the future of heart health won't be defined by once-a-year exams or costly emergency responses, but by continuous, meaningful engagement with data that is useful to patients and their healthcare providers alike. Oura brings together proactive, individualized behavior change and passive monitoring to support better cardiovascular health at scale.

Key terms

Arterial stiffness: Rigidity of the arterial wall.

Carotid-femoral pulse wave velocity (cfPWV): Measure of arterial stiffness and an established measure of vascular aging. cfPWV is calculated from the time it takes for the arterial pressure pulse to travel from the carotid artery to the femoral artery.

Diastolic blood pressure: Lowest arterial blood pressure of a cardiac cycle occurring during diastole (relaxation and dilation) of the ventricles.

Systolic blood pressure: Systolic pressure is the pressure of blood against the artery walls when the heart has just finished contracting or pumping out blood.

Reading blood pressure

If a person's systolic pressure is 120 millimeters of mercury (mm Hg) and the diastolic pressure is 80 mm Hg, blood pressure is recorded as 120/80 and read as "120 over 80."

Photoplethysmography (PPG): Optical technique that can be used to detect blood volume changes in the vascular bed. PPG measures the arterial pulse wave. During ventricular systole, the wave is generated as blood is ejected from the heart, which temporarily increases arterial pressure and causes vessel expansion and contraction. Devices that use PPG work by shining light (Oura Ring green LED) on part of the body (e.g., the finger), and a photodetector measures the reflected light from the tissue. The reflected light is proportional to blood volume variations.

What Is PPG?

Photoplethysmography (PPG) measures the volumetric changes in the arteries using light reflection.

The PPG signal is an optical measurement of the arterial pulse wave — i.e. the wave generated when blood is ejected from the heart during systole, temporarily increasing arterial pressure and causing vessel expansion and contraction. PPG works by shining a light on the finger and capturing the changes in light reflected back from the vascular bed or capillaries.

Research has shown that this signal contains a wealth of information on the heart, blood vessels, breathing, and autonomic nervous system. It provides the basis for our Cardiovascular Age estimate.

Introduction

Cardiovascular disease (CVD) is the leading cause of death globally, contributing to nearly one-third of all deaths worldwide. A primary driver of CVD is hypertension, yet it is often undetected or undertreated. Studies show that many individuals with elevated blood pressure and related vascular changes remain asymptomatic yet experience progressive arterial stiffness — an established marker of vascular aging that precedes overt CVD and end-organ morbidity. Increased arterial stiffness with age and elevated blood pressure promotes microvascular dysfunction and end-organ damage even before clinical symptoms emerge.

According to the American Heart Association, annual healthcare costs for cardiovascular conditions are expected to increase from $393 billion in 2020 to $1,490 billion in 2050. Outside of these direct costs, we know that poor cardiovascular health reduces overall quality of living and productivity in multiple, substantial ways. Cardiovascular disease manifestations, including heart attacks, strokes, and chronic heart conditions, are also major drivers of disability. Globally, CVD accounted for approximately 437 million disability-adjusted life years (DALYs) in 2023.

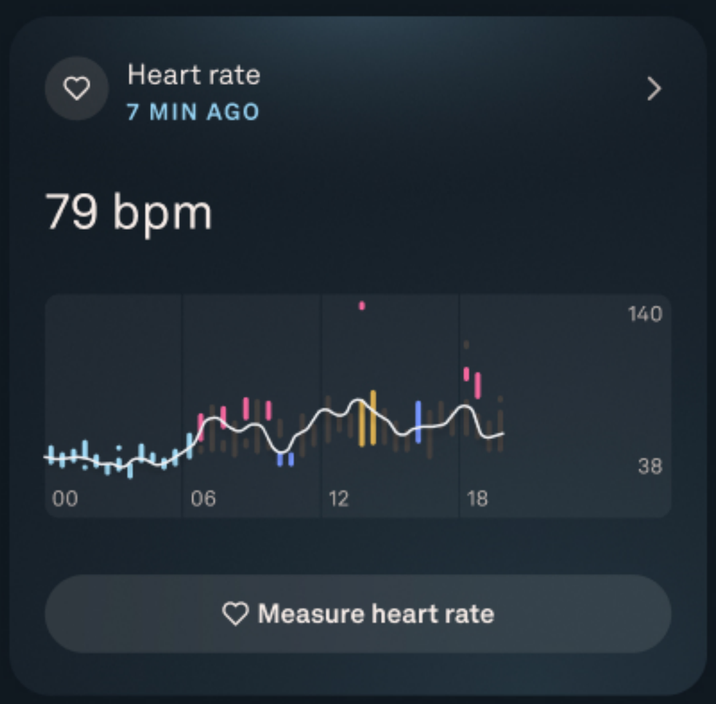
However, 79.6% of global CVD DALYs are linked to modifiable risk factors, including high body mass index, smoking and tobacco use, sedentary behavior, unhealthy diet, poor sleep, and stress that also contribute to hypertension. This preventable disease burden signals a significant opportunity for approaches that can monitor an individual's health continuously, support healthy behavior, and screen for signs of hypertension.

To meaningfully change the course of CVD at both an individual and population level, we need to pair evidence-based lifestyle practices with proactive, data-informed care. Oura Ring enables earlier awareness of potential cardiovascular risk through metrics that give members visibility into resting heart rate (RHR), heart rate variability (HRV), sleep quality, and activity. Tracking cardiovascular health trends over time — both improvements and warning signals — can help individuals and their healthcare providers better understand risk and identify opportunities for behavior change that may reduce long-term disease burden and improve health outcomes.

Cardiovascular health features

Oura Ring provides several heart-health measures based on continuous PPG measurement, collected mainly during sleep when movement is minimal, and signal quality is highest. Using these data, Oura reports nightly resting heart rate, heart-rate variability, and other indicators of autonomic activity. These metrics are shown as both daily values and trends over time, allowing members, clinicians, and researchers to establish a baseline and monitor positive and negative deviations.

Heart-related data are further combined with Sleep and Activity information to produce broader Readiness or recovery indicators that reflect overall physiological load. Although not intended as clinical diagnostic tools, these features can help members notice changes from their usual patterns and support research efforts that rely on continuous, passive cardiovascular monitoring.



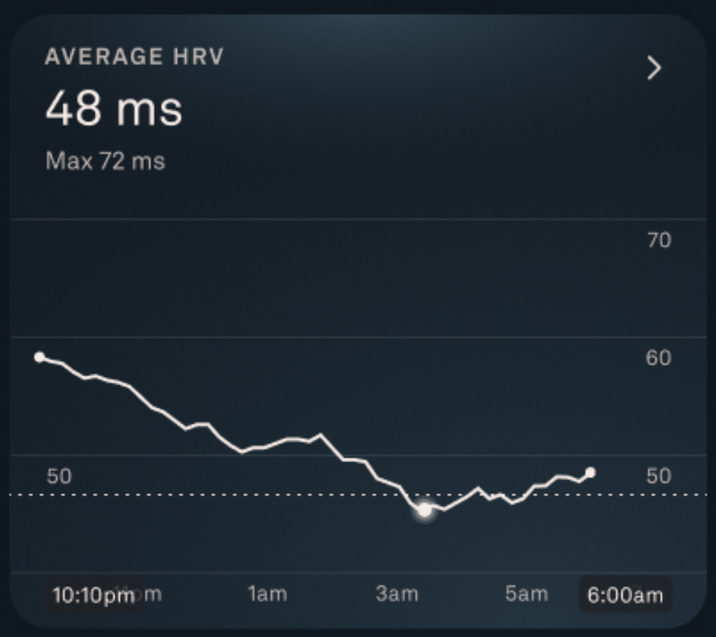
Heart Rate

Oura Ring has optical sensors that measure resting heart rate (RHR) every five minutes during the day, with a higher sampling frequency at night.

The Heart Rate feature can be used to monitor RHR and restorative time, as well as heart rate during exercise. The Oura App shows beats per minute ranges during sleep and activity, as well as the daytime lowest average. Members can also measure heart rate on demand with Oura Ring sensors and a single tap in the app.

In a study of 49 healthy subjects, Oura Ring performed near-perfect for resting heart rate ($r^2 = 0.996$) and extremely high for heart rate variability ($r^2 = 0.980$) when compared to an ECG device. The results of this 2020 study conducted by Kinnunen, et al. are published in Physiological Measurement.

Learn about How sleeping heart rate varies by age



Heart Rate Variability (HRV)

HRV is the measurement of variation in time between heartbeats, reflecting the balance and responsiveness of the autonomic nervous system. HRV is used to assess stress, recovery, cardiovascular health, and autonomic function, and it is increasingly applied in areas like mental health, chronic disease management, and early illness detection.

HRV* performance of Oura Ring in multiple, real-world, peer-reviewed evaluations has a consistent correlation with ECG, at above 90%, with mean absolute error below 6ms.

*HRV is measured as rMSSD (Root Mean Square of the Successive Differences).

Read more: What is the average HRV?

Cardiovascular Age (CVA)

Cardiovascular Age is an estimate of the health of an individual's cardiovascular system in relation to their actual age. Oura gauges CVA by analyzing age-related observations within the photoplethysmography (PPG) signal, which carries information about estimated arterial stiffness and pulse wave velocity (PWV). Carotid-femoral pulse-wave velocity (cfPWV) is also estimated by analyzing the PPG signal collected by Oura Ring during sleep and is a metric for measuring arterial stiffness and vascular aging.

Younger arteries are more elastic, expanding and contracting in response to changes in blood flow. As vessels age, arteries tend to stiffen and lose some of their elasticity, and with this stiffening, the energy of the heartbeat can become a strain on the internal organs. Faster pulse waves are associated with less flexible arteries and a higher CVA.

Learn more about developing our CVA feature

An Oura member's estimated CVA is shown relative to their chronological age. The comparison results in the categorization into one of three levels: **Above, Aligned, and Below:**

NEEDS CARE

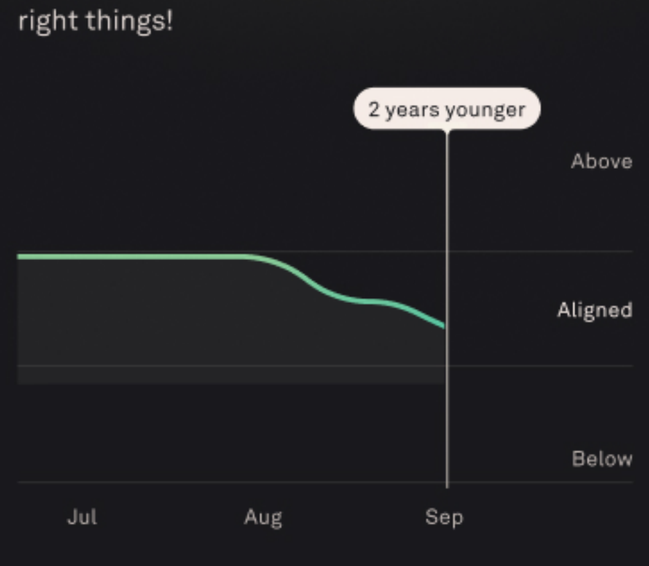
Your cardiovascular age is still above your actual age.

Your high activity levels are a big boost to your cardiovascular health. You are doing all the right things!

ROOM TO GROW

Your cardiovascular age is aligned with your actual age.

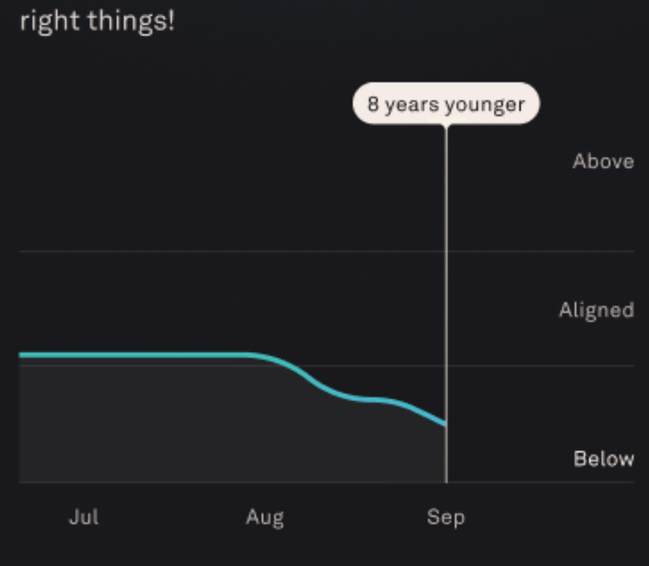
Your high activity levels are a big boost to your cardiovascular health. You are doing all the right things!



THRIVING

Your cardiovascular age is below your actual age.

Your high activity levels are a big boost to your cardiovascular health. You are doing all the right things!



Above: When a member's estimated Cardiovascular Age exceeds the chronological age by six years or more, it is categorized as 'Above.' This difference indicates that various factors have potentially accelerated the cardiovascular aging process.

Aligned: Members whose estimated Cardiovascular Age falls within a five-year range above or below their actual age are considered 'Aligned.' This category follows a normal pace of cardiovascular aging.

Below: The 'Below' category includes those whose estimated Cardiovascular Age is at least six years younger than their chronological age. Achieving this level typically reflects the positive impact of long-term healthy lifestyle choices and/or an advantageous genetic background.

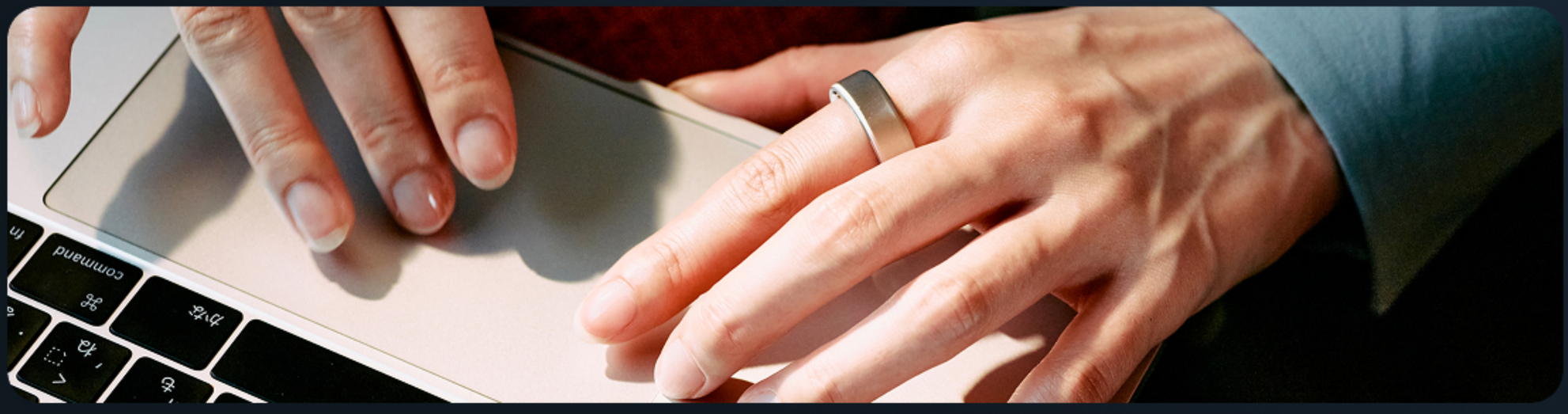
VO_2 Max

This feature provides an estimate of an individual's VO_2max, or how efficiently the body supplies oxygen to muscles during exercise, often considered a benchmark for cardiovascular and respiratory system health. Higher cardio capacity has been associated with a reduction in heart failure, delayed onset of chronic diseases, and better long-term health.

Cumulative Stress

The Cumulative Stress feature is the latest addition to Oura's suite of stress-tracking tools:

- Daytime Stress monitors stress throughout daily activities
- Resilience tracks the ability to recover from stress
- Cumulative Stress helps members understand the impact of chronic stress on health and prevent burnout



Cumulative Stress is designed to help members understand how their body accumulates and responds to sustained physiological stress over time. Leveraging 31 days of Oura data, it evaluates the effects of accumulated stress on an individual's sleep metrics, stress baseline, and activity levels.

This measure gives an objective, physiological signal of long-term strain. It was trained and validated using two standardized stress and burnout questionnaires: the Copenhagen Burnout Inventory (CBI) and the Perceived Stress Scale (PSS). This insight is drawn from five key contributors that reveal how well the body is managing and recovering from constant strain:

- **Sleep Continuity:** measures how frequently someone is awakening or tossing and turning
- **Heart Stress-Response:** a measure of HRV and resting heart rate
- **Sleep Micromotions:** measures involuntary movements or muscle twitches during sleep
- **Temperature Regulation:** measures shifts in overnight skin temperature
- **Activity Impact:** measures how physical exertion affects recovery from stress

Cumulatives Stress is intended to reflect chronic physiological strain rather than momentary fluctuations, enabling clinicians to evaluate whether an individual's risk of burnout is increasing due to sustained activation of stress pathways. Chronic stress has been linked epidemiologically and biologically to increased risk for cardiovascular disease as well as endocrine and metabolic dysregulation (e.g., increased risk for type 2 diabetes) and compromised immune function.

Recognizing sustained elevations in Cumulative Stress provides clinicians with actionable insights into an individual's physiological state of stress burden, highlights potential risk for downstream morbidity, and supports the clinical rationale for recommending interventions that enhance recovery, resilience, and regulation.

Spotlight on Cardiovascular Age

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Understanding Cardiovascular Age

Cardiovascular Age (CVA) is an estimate of an individual's vascular health, representing the biological aging of the cardiovascular system rather than just chronological years. Oura estimates CVA by analyzing age-related observations within the photoplethysmograph (PPG) signal, which contains information about arterial stiffness and pulse wave velocity (PWV). While aging is a non-modifiable cause of large artery stiffening (LAS), this process can be exacerbated by lifestyle factors like obesity, smoking, and insulin resistance. By turning nighttime physiology into a composite metric, CVA helps people make use of biometric data to inform long-term cardiovascular wellbeing.

The scientific foundation for CVA is rooted in the established link between arterial stiffness and cardiovascular outcomes. The gold standard measure for arterial stiffness is carotid-femoral PWV, (cfPWV). Research indicates that arterial stiffness is a strong predictor of total and cardiovascular mortality, even after adjusting for traditional risk factors. High PWV is associated with increased relative risks for all cardiovascular events, cardiovascular mortality, and all-cause mortality. Specifically, each 1 m/s increase in PWV is linked to a 14% higher relative risk of any cardiovascular event and a 15% higher relative risk of death.

Arterial stiffness and end-organ damage

Arterial stiffness affects the entire arterial system and all of the organs connected to it. The primary organs impacted by increased pulsatile stress are the heart itself, the brain, and the kidneys. In a normal physiologic state, most coronary blood flow occurs during diastole, when the heart muscle (myocardium) relaxes and aortic diastolic pressure provides the driving pressure for coronary perfusion. As the heart contracts (systole), a pulse wave is ejected into the peripheral system. When arteries are elastic (with low stiffness), the main pressure wave travels relatively slowly and reflected waves tend to return later; central systolic pressure is lower and diastolic pressure is preserved. This helps keep left-ventricular afterload lower while maintaining the diastolic perfusion pressure that supports coronary flow. With advanced arterial stiffness, the pulse wave travels faster, and the reflected waves return earlier, augmenting pressure in mid-to-late systole. This increases left-ventricular afterload and myocardial oxygen demand, and it can also reduce diastolic aortic pressure, which reduces pressure for coronary perfusion during diastole. This means the heart has to do more work with less oxygen, which also explains why arterial stiffness is a predictor of heart failure.

One of the central hemodynamic properties of the large, central arteries is to act as a "shock-absorber" that dampens the pulsatile forces generated by the heart. With LAS, this ability progressively weakens, and sensitive organs like the brain and kidneys become exposed to stronger pulsatile stress, over time contributing to microvascular and organ-level damage.

Building CVA

The CVA algorithm utilizes high-resolution PPG signal data. It assesses age-related changes in the shape of the PPG pulse wave to estimate both CVA and PWV. The algorithm takes into account the impact of individual demographics and shows personalized estimates of an individual's CVA. It has been validated against cfPWV in an internal study, achieving a strong correlation between cfPWV and CVA, and acceptable accuracy for PWV estimate based on the recent clinical guidelines.

The algorithm gives a continuous estimate of CVA and how much it deviates from chronological age. Members can see their CVA categorized into one of three levels: **Above** (CVA exceeds chronological age by 6 or more years), **Aligned** (CVA is + or -5 years of chronological age), or **Below** (CVA is at least 6 years lower than chronological age).

Figure 5. Correlation of Oura's estimated PWV with carotid-femoral PWV in healthy individuals (r=0.83).

Item	Mean ± SD
Age (year)	46.60 ± 16.58
BMI (kg/m2)	26.29 ± 4.83
cfPWV (m/s)	7.77 ± 1.49

Subjects N=99 (36 males and 63 females)

Implementation and clinical limitations of CVA

Generating a CVA estimate requires Oura Ring to collect at least 14 days and nights of data within a 30-day window. Measurements are exclusively initiated during sleep when physical motion is minimal to ensure accuracy. Individual member demographic information is used to provide an accurate estimate of CVA; if the provided demographics are incorrect, estimation accuracy may be affected. Cardiovascular Age results may not be valid for users with certain medical conditions, including heart diseases, neurodegenerative diseases, or pacemakers.

Clinical use cases for CVA

CVA offers an innovative approach to personalized health by transforming healthcare from reactive to proactive. It shows weekly updates reflecting vascular health, enabling clinicians and individuals to identify and contextualize changes in aging trends that traditional snapshot metrics might miss. Because arterial stiffness can be slowed or even reversed through aerobic exercise, weight loss, and dietary sodium restriction, CVA serves as a powerful tool for monitoring the efficacy of lifestyle interventions.

Featured research

Oura is committed to advancing cardiovascular health through rigorous, transparent research and continuous validation. Our cardiovascular health studies are designed to deepen scientific understanding of how everyday behaviors, physiology, and long-term trends influence heart health, while ensuring that insights derived from Oura data are grounded in robust evidence. Through carefully designed studies, clinical collaborations, and ongoing validation of our algorithms against gold-standard measures, we prioritize scientific integrity and reproducibility at every stage. By openly sharing methodologies, publishing findings, and continuously refining our models as new data emerge, Oura aims to build trust, support the broader research community, and deliver meaningful, evidence-based insights that empower individuals to better understand and manage their cardiovascular health.

AHA Scientific Sessions presentations 2025: accepted abstracts

American Heart Association.
Scientific Sessions

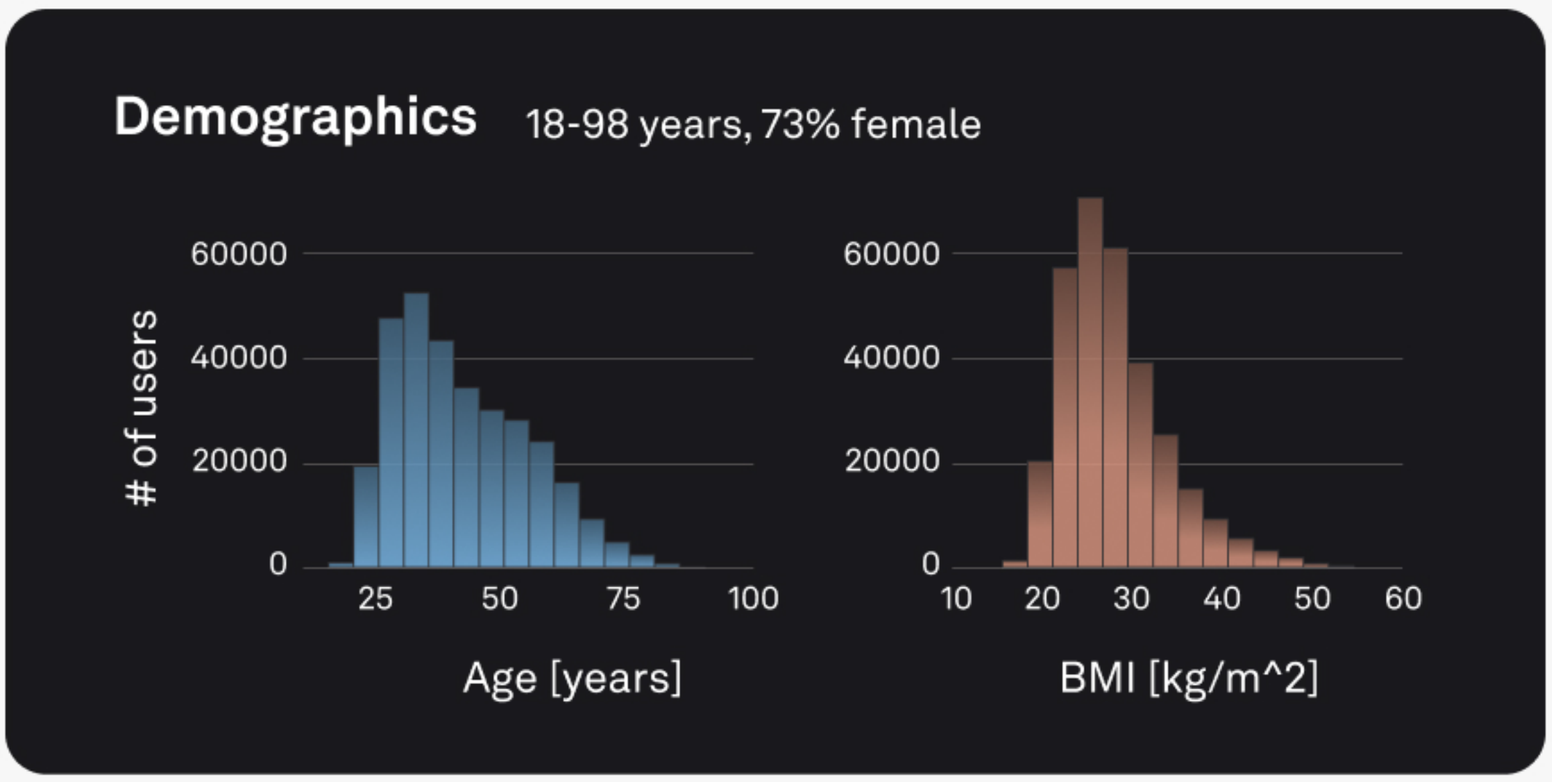
Cardiovascular disease detection with a large-scale foundation model

Authors: Venla Lymysalo, Xi Zhang, PhD, Raphael Vallat, PhD

Background: Wearable photoplethysmography (PPG) offers a noninvasive means to continuously monitor cardiovascular signals and holds potential for the early identification of cardiovascular diseases.

Objectives:
This study investigated:

- whether Oura Ring PPG embeddings from a self-supervised model can detect self-reported hypertension, coronary/peripheral artery disease, and type 2 diabetes
- whether disease predictions are sensitive to longitudinal physiological changes after blood-pressure-lowering treatment initiation.



Methods: A neural network encoder was trained via self-supervised contrastive learning on more than two million 30-second PPG segments collected during sleep from ~230,000 Oura Ring Members. Logistic regression models were then trained on top of the embeddings generated by the foundation model for downstream classification of cardiovascular diseases. The final classification dataset included self-reported disease status from ~320,000 de-identified Oura Ring Members. A third of participants were held out for testing, and PPG embeddings from seven nights were aggregated at the participant-level and used as inputs to the classifier. For each target condition, the area under the receiver operating characteristic curve (AUC) was computed on the test set, and compared to the AUC of a baseline classifier using age, sex, and BMI. Longitudinal changes in estimated probabilities of hypertension were analyzed for 605 people with self-reported hypertension over a period of 22 weeks around the self-reported onset of blood-pressure-lowering treatment.

Results: On the test set, embedding-based classifiers achieved ROC–AUCs of 0.842 for hypertension, 0.887 for coronary artery disease (CAD), 0.889 for peripheral artery disease (PAD), and 0.886 for type 2 diabetes. Compared to the baseline model (using age, sex, and BMI), this corresponds to statistically significant improvements in the model's ability to label self reporting for hypertension (+0.038; 95% CI [−0.041, −0.036]) and type 2 diabetes (+0.078; 95% CI [−0.084, −0.071]). In contrast, improvements for CAD (+0.005; 95% CI [−0.011, 0.002]) and PAD (+0.001; 95% CI [−0.015, 0.011]) were not statistically significant at $\alpha = 0.05$.

In the longitudinal analysis, initiating blood-pressure-lowering medication was associated with a statistically significant decrease in hypertension predictions.

Self-report disease status

Prevalence	
Hypertension	13.6%
Type 2 diabetes	2.4%
Peripheral artery disease	1.0%
Coronary heart disease or angina pectoris	0.2%
Other	16.5%

Note: True disease prevalences are expected to be higher.

Conclusion: Large-scale self-supervised models trained on wearable PPG data encode relevant features of cardiovascular health. When paired with simple classifiers, these embeddings facilitate preliminary detection of cardiovascular and metabolic conditions. The decrease in PPG-based estimates of self-reported hypertension following initiation of BP medication is consistent with the model capturing correlates of the underlying disease rather than physiological signatures of the medication itself. Our findings support the utility of wearables as scalable digital biomarkers for early disease detection and monitoring.

Wearable-PPG-based multi-task neural network for robust cardiorespiratory monitoring

Authors: Venla Lymysalo, Xi Zhang (PhD), Raphael Vallat (PhD)

Background: Continuous monitoring of heart rate (HR), heart rate variability (HRV), and respiratory rate (RR) provides valuable insight into autonomic and cardiovascular function. Photoplethysmography (PPG), widely available in wearables, enables large-scale, continuous tracking of these biomarkers in free-living conditions.

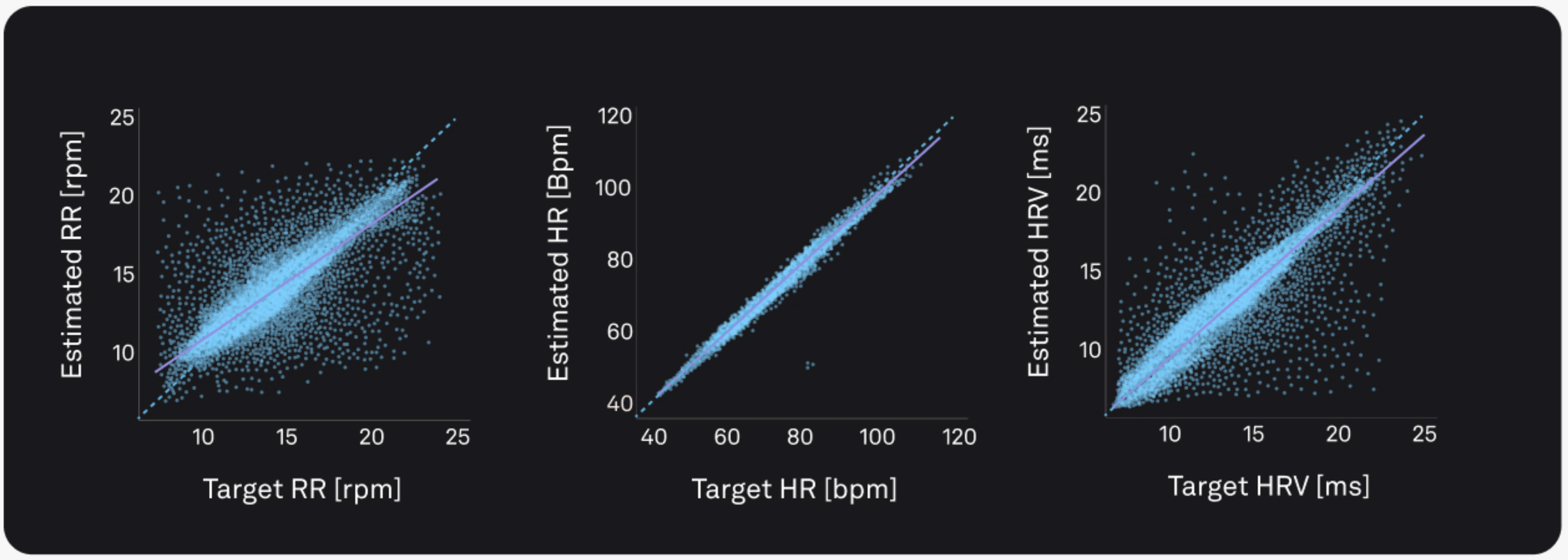
Objectives:
This study aimed to:

- develop and validate a lightweight, multi-task neural network for simultaneous estimation of HR, HRV (as measured by Root Mean Square of Successive Differences), and RR from wearable PPG.
- apply the model to a large wearable cohort to investigate associations between estimated physiological metrics and self-reported cardiovascular disease (CVD) status.

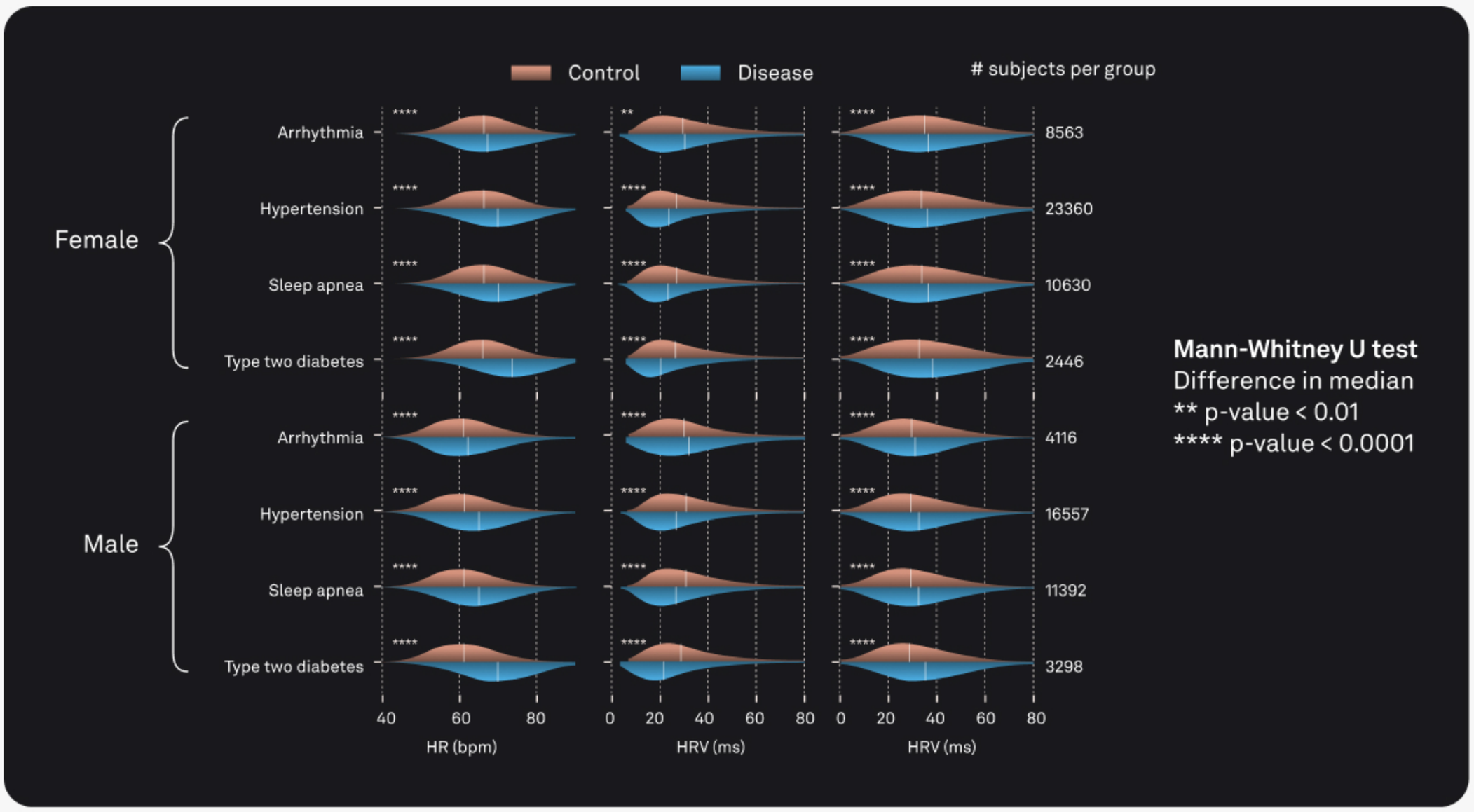
Methods: A lightweight multi-task neural network combining convolutional and recurrent layers was trained to simultaneously estimate HR, HRV, and RR from 30-second PPG segments collected with Oura Ring. Training data consisted of simultaneous ring PPG and polysomnography (PSG) data from 617 participants enrolled in a PSG sleep study. Ground-truth labels were derived from ECG (for HR, HRV) and respiratory inductance plethysmography (for RR). To assess clinical relevance, the model was applied to ~320,000 de-identified Oura Ring Members with self-reported CVD status. Resting HR, HRV, and RR were compared between individuals with CVD and age- and sex-matched controls.

Results: On the independent test set (97,147 segments), the 76k-parameter multi-task model achieved coefficients of determination (R^2) of 0.990, 0.890, and 0.672 with mean absolute errors (MAE) of 0.46 bpm, 4.06 ms, and 0.94 breaths per minute for HR, HRV, and RR, respectively. Aggregation over 5-minute epochs improved R^2 to 0.995 (HR), 0.950 (HRV), and 0.793 (RR) with respect to PSG reference devices. Application of the model to PPG recordings from the cohort with known (self-report) CVD status revealed higher resting HR and RR, and lower HRV in individuals with CVD compared with controls, with variable effects depending on the type of CVD (e.g., participants with arrhythmia showed higher HRV than controls).

Agreement between multi-task neural network estimates and PSG reference for heart rate (HR), heart rate variability (HRV), and respiratory rate (RR)



Distributions of PPG-derived HR, HRV, and RR for individuals with cardiovascular disease and age-matched controls



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Non-invasive estimation of pulse wave velocity in pregnant women using a wearable smart ring

Authors: Aleksi Rantanen, Miska Valkonen, Pauli Ohukainen, PhD

Background: Pulse wave velocity (PWV) is an indicator of arterial stiffness and cardiovascular health. Traditionally, PWV is assessed using clinical-grade systems such as tonometry or oscillometric devices. Recent research has shown that photoplethysmography (PPG) signals, measured by devices such as wearables and pulse oximeters, can be used to extract features associated with PWV.

Pregnancy is associated with cardiovascular adaptations, including changes in vascular tone and compliance. These adaptations typically follow a U-shaped pattern that can be observed in PWV, with increased vascular compliance during early and mid-pregnancy followed by a return toward pre-pregnancy levels near term. These maternal adaptations provide a natural context for evaluating whether PPG-based PWV estimates reflect known vascular trends.

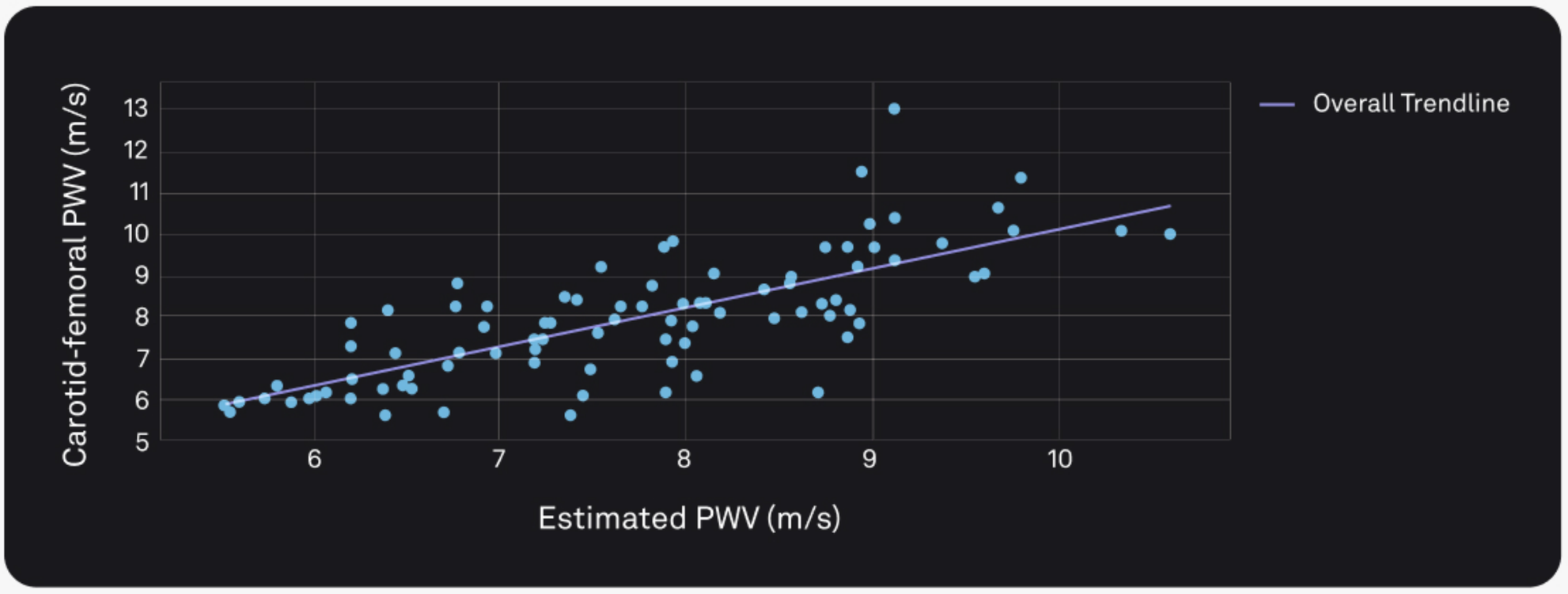
This study evaluates how pulse wave velocity estimates derived from smart ring photoplethysmography signals (ePWV) compare with reference PWV measurements and whether longitudinal ePWV trends during pregnancy reflect known cardiovascular adaptations.

Methods: Carotid–femoral PWV (cfPWV) was measured using the SphygmoCor XCEL system alongside PPG signals collected with Oura Ring in a cohort of 300 healthy adults. A machine learning model was trained using wearable PPG-derived features from 200 participants and evaluated in the remaining 100 participants.

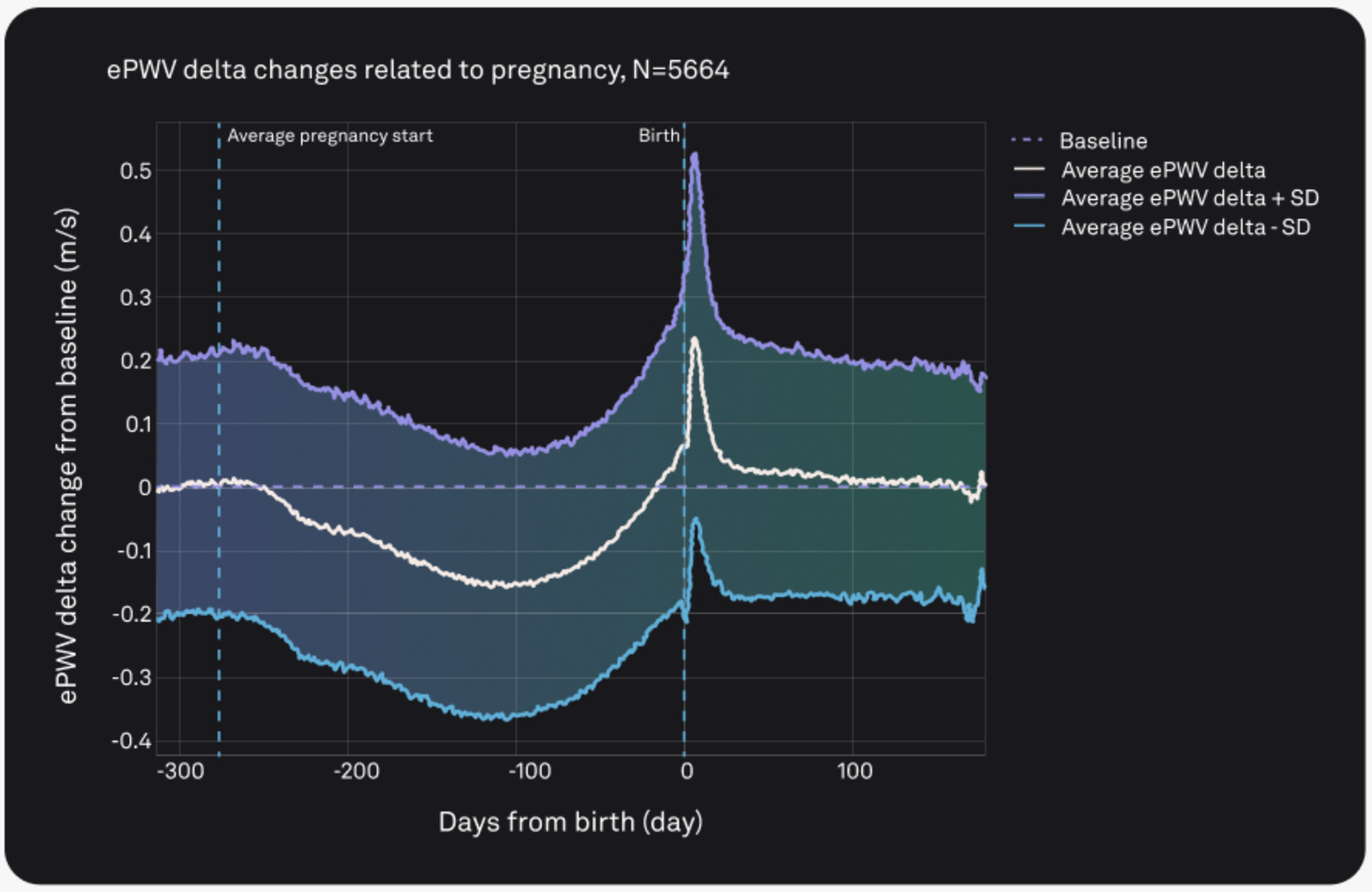
The machine learning model was applied to an anonymized dataset from 5,664 Oura Ring Members who self-reported pregnancy. Night-time PPG signals collected during sleep were analyzed from one month prior to conception through six months postpartum. For each individual, changes in estimated PWV were evaluated relative to a personal pre-pregnancy baseline (ePWV delta), and values were aligned by gestational timing to assess population-level trends.

Results: Evaluation of ePWV against cfPWV showed a strong correlation ($r = 0.76$), with a mean difference of 0.210 m/s and a standard deviation of 0.999 m/s, meeting acceptable validation criteria defined in recommended validation guidelines.

Correlation between estimated PWV and carotid–femoral PWV



Across the pregnancy cohort, ePWV exhibited a characteristic U-shaped trajectory. ePWV values declined during the first two trimesters, reaching a nadir near the end of the second trimester, and then increased through the third trimester. A transient increase was observed shortly after delivery, followed by a gradual return toward pre-pregnancy levels over the six-month postpartum period.



Conclusion:

PWV estimates derived from smart ring PPG data showed strong agreement with reference cfPWV measurements. During pregnancy, ePWV values reproduced the U-shaped trajectory described in prior studies, demonstrating the ability to capture pregnancy-related vascular adaptations. These findings highlight the potential of wearable devices to support large-scale, non-invasive monitoring of cardiovascular dynamics over time in real-world settings.

Project RESET

Oura is a key partner in Project RESET, Singapore's flagship heart health research initiative. This five-year, $25 million program aims to gain a deeper understanding of metabolic, cardiovascular, and liver health, as well as lifestyle behaviors across Singapore's population, to help prevent heart disease and associated complications like heart attack and stroke. The goal is to map heart disease progression, develop predictive models for early identification of cardiovascular risk, and empower individuals to take proactive steps in their heart health journey. The study of 3,000 participants between the ages of 40-70 will examine how sleep duration, regularity, efficiency, and continuity affect cardiovascular health markers, as well as how everyday behaviors influence long-term cardiovascular outcomes. Participants will wear Oura Ring, enabling continuous, high-resolution data collection on Sleep, heart rate variability, temperature, respiratory rate, Activity, and stress.

Learn more: RESET collaborates with ŌURA to transform preventive cardiovascular health through AI-powered wearable insights

GONDOR-AS clinical trial: AI advisor for cardiovascular health

The GONDOR-AS Trial (NCT06644014): Our first randomized, controlled clinical trial will evaluate if Oura Advisor, our AI-driven, personalized wellness coach, can provide personalized, sustainable exercise guidance that leads to meaningful improvements in cardiorespiratory fitness (CRF, measured directly with VO2max testing) and arterial stiffness. Conducted in partnership with the Kuopio Research Institute of Exercise Medicine (KuLTu), the trial will randomly assign participants to one of three arms:

- **Oura Ring only (control):** Usual low activity; no structured exercise prescription or AI coaching.
- **Oura Ring + supervised HIIT:** Twice-weekly, supervised high-intensity interval cycling sessions.
- **Oura Ring + AI-based coaching:** Oura Advisor focusing on ~2–3 hours/week of moderate "zone 2" steady-state aerobic exercise personalized to the participant's preferences and circumstances.

The study population of 165 participants, with 55 people per group, includes sedentary adults, aged 30-65 years, primarily from the Kuopio area of Finland. Inclusion criteria include being below standard aerobic physical activity guidelines (≤150 min/week moderate or ≤75 min/week vigorous), with exclusions for major cardiovascular and metabolic diseases and unsafe hypertension.

The trial includes a comprehensive behavioral process evaluation, using qualitative interviews and narrative analysis to examine how participants experience the intervention, what contextual factors shape engagement, and which behavioral mechanisms may drive changes in activity and cardiovascular outcomes.

GONDOR-AS is powered around physiological endpoints — cfPWV and VO_2max — while also capturing wearable-derived vascular aging metrics, activity behavior, and behavioral/experiential data to explain how an AI coach plus a wearable like Oura Ring might change cardiovascular risk profiles in a real-world, sedentary adult population.

Behind the science:

"As a post-doctoral researcher, I studied lipid-related cardiovascular risk as well as lipoprotein metabolism, and grew accustomed to keeping an eye on my cholesterol levels. While I primarily focus on strength training, I've also incorporated other exercises to improve my cardiorespiratory fitness (CRF). I want to make heart health features that are scientifically sound — that I would trust as both a cardiovascular health researcher and member. When we were setting up the GONDOR-AS clinical trial, I wanted us to use the most robust testing for assessing CRF, but I also knew from experience that being pushed to your physical max is not exactly a pleasant experience. Prior to launching the trial, our team wanted to thoroughly test and streamline all of the test and measurement procedures to make sure they would run smoothly, including the VO_2max test. As the Principal Investigator of the study, I felt I wouldn't be comfortable having our participants go through anything I wouldn't do myself, so I volunteered to be the first test subject for the cycle ergometer test. It was a grueling, sweaty experience, but worth it to understand what we were asking of participants. (FYI, I scored above the 93rd percentile of my age group)."

Pauli Ohukainen, PhD, Staff Research Scientist

Research collaborators

NUS National University of Singapore

KuLTu

Blood Pressure Profile Study

An estimated 44% of adults around the world have undiagnosed hypertension and of those diagnosed, only 23% have it under control.

The Blood Pressure Profile Study, available in Oura Labs, allows eligible* members to participate in research that will support the development of a software feature that is intended to help identify hidden hypertension risks.

By consenting to participate in the Blood Pressure Profile Study, participants can provide direct feedback and contribute valuable data that may help researchers at Oura understand new ways wearable technology could support future heart health research.

**Eligibility: Oura Members must meet the following eligibility criteria in order to participate in the Blood Pressure Profile Study: must be based in the United States and use the English version of the Oura App, must be 22 years or older, must use Oura Ring Gen3 or newer, and must provide informed consent. Members who are currently pregnant or within 12 weeks postpartum are not eligible to participate.*

Women’s cardiovascular health

Cardiovascular disease (CVD) is the leading cause of death for women in the United States and remains understudied, under-recognized, underdiagnosed, and undertreated across the care continuum. CVD is responsible for nearly one in five female deaths, and women have worse health outcomes from acute coronary syndrome than men.

Yet women are often underrepresented in the evidence base that guides cardiovascular care. One study reviewed data from 1,079 cardiovascular clinical trials registered on ClinicalTrials.gov from 2017 to 2023 and found that women accounted for 41% of the study participants. In some areas, such as studies of hypertension, 50.3% of participants were women. However, women are not represented equally across morbidities. Women represented 22.1% of participants in acute coronary syndrome studies and 27.7% in pulmonary hypertension studies.

Women’s cardiovascular disease often presents differently than in men, which contributes to frequent misdiagnosis and higher rates of being discharged during an active myocardial infarction. Instead of chest pain, women may experience symptoms such as discomfort in the neck, jaw, shoulder, back, or epigastric region, pain in one or both arms, nausea or vomiting, lightheadedness, unusual fatigue, or heartburn-like sensations.

These risks shift across the lifespan. Pregnancy acts as a cardiometabolic stress test, where complications such as preeclampsia and gestational diabetes predict elevated future cardiovascular risk. Early menopause, before the age of 40, is linked to a 40% increased risk of developing coronary heart disease over a woman’s lifetime compared to those who did not go through early menopause. Declining estrogen levels as a result of menopause lead to adverse effects such as endothelial dysfunction, increased arterial stiffness, and lipid profile deterioration.

At Oura, we take a broad view towards women’s health and do not limit our research, feature development, or science to reproductive physiology and conditions. We recognize that there are some conditions that are specific to females, such as hypertensive disorders of pregnancy (e.g. preeclampsia) and menopause, while there are others where female physiology or presentation differs from men and disease burdens may be higher. This recognition of sex differences is at the forefront of our approach to understanding and improving cardiovascular health. With aggregated data from millions of women across the lifespan, we are evaluating not only individual diseases like hypertension, but also associations with modifiable risk factors, like activity and sleep, as well as medical conditions such as diabetes, and how Oura can support members in reducing risk.

Read more:

Oura’s Commitment to Women’s Health

7 Must-Know Facts About Heart Disease in Women

Oura’s Ongoing Commitment to Health Data Privacy and Security

Using Oura in clinical care

The use of Oura Ring in cardiovascular care marks a shift from episodic encounters to a continuous view of heart health that bridges daily life with the clinic. Rather than relying solely on snapshots taken in the exam room or lab, Oura provides longitudinal data on resting heart rate (RHR), heart rate variability (HRV), sleep, activity, and newer metrics like Cardiovascular Age, giving both patients and clinicians a clearer sense of what is "normal" for each member and when there are signals of change that may point to underlying risk and health conditions.

While Oura Ring is not a diagnostic device, it can act as an objective, behaviorally grounded contextual companion across the continuum of cardiovascular care — from prevention and lifestyle modification, to remote risk tracking, cardiac rehabilitation, and long-term disease management. For patients, it translates recommendations into everyday habits and feedback; for clinicians, it supports shared decision-making by focusing conversations on data trends, care plan adherence, and early deviations from baseline.

Prevention and lifestyle modification: Patients who require behavior change support can use Oura to track their exercise progress and subsequent metrics, as well as chat with Advisor for coaching and additional support.

Remote cardiovascular risk tracking: For patients with known risk factors, such as hypertension, diabetes, obesity, or a family history of cardiovascular disease, Oura provides continuous monitoring of RHR and HRV alongside Cardiovascular Age and VO_2 Max.

Heart disease management: For heart disease patients, knowing when to rest vs. be active is critical, and the Readiness Score can help avoid overexertion. Tracking changes in trends like increased RHR, reduced HRV, or disturbed sleep could prompt patients or providers to take preventative action before a hospitalization is needed.

Monitoring cardiovascular recovery and function: Oura can be a powerful tool in cardiac rehabilitation by providing continuous, personalized monitoring that supports recovery and guides future healthy behavior. Wearable personal activity monitoring devices have been proven to increase activity among patients in the maintenance phase of cardiac rehabilitation and are associated with increases in physical activity and aerobic capacity compared with cardiac rehabilitation alone. By tracking daily Activity levels and Readiness scores, Oura can help patients gradually increase physical activity within safe limits set by their care team.

Leveraging real world data in personalized cardiovascular healthcare: Oura's longitudinal, high-frequency Sleep, recovery, and Activity signals, organized in ontology-driven data models- that align lifestyle patterns, medical history, symptoms, and therapies, can give trend views that complement episodic encounters for individual patients. Organized, diverse data processed by big data analytics are already demonstrating value in population health management, drug safety monitoring, personalized treatment, and predictive modeling. With thoughtful, clinical, and scientific frameworks, combined cardiovascular data sets could also ground potential future development like multimodal data-informed risk scores, early decompensation flags, and treatment-response tracking. Each member's ring is not just a wellness device, but a continuously-learning sensor that helps move cardiovascular care from retrospective, visit-based snapshots toward proactive, prospective, data-informed management.

A look to the future from Ricky Bloomfield, MD, Chief Medical Officer, Oura

I have spoken to clinicians, research scientists, regulatory professionals at the FDA, insurance providers, and others in the healthcare community. The most common questions I receive are related to how accurate Oura Ring is compared to gold-standard clinical tools and how Oura actually works in members' lives. I am always proud to share the peer-reviewed studies conducted by independent organizations that validate Oura as one of the most accurate consumer health devices on the market for measuring heart rate, heart rate variability, and sleep. These studies, with findings included in this report, demonstrate not only scientific credibility but also trust. When I practiced medicine as a hospitalist, I would trust a patient coming to me with wearable data demonstrating a rapid uptick in heart rate, like Ted N. or Jim H. Hospital or clinic data is episodic, so it's not possible to capture a truly individual baseline to understand when something else might already be going on, like an infection. Passive data collection during sleep gives clinicians a new set of tools in their toolbox for both acute and longitudinal patient data.

While I am proud of how far Oura has come, we have much more to do, and our robust cardiovascular health roadmap is a testament to that. You can expect us to further refine our core metrics with advances in machine learning, sensors, and research. We are also exploring the development of a new suite of health features that serve as a 'check engine light' for Oura Members, much like our Symptom Radar that was developed alongside researchers at UCSF, which alerts people when a combination of their biometrics are indicating that their body is showing signs of strain and potential illness.

At Oura, we are dedicated to the pursuit of excellence across science, patient education, and data privacy. The launch of our Blood Pressure Profile Study is an example of Oura starting with an IRB-approved research study to learn about changes in PPG waveform with the goal of learning how to detect signs of hypertension with Oura Ring. Also, as Oura has become a popular health companion tool for women, we can advance our understanding of female cardiovascular health at the population level, while continuing to respect health data privacy and security.

We are moving toward a future where cardiovascular health is no longer defined by once-a-year physicals or responses to an acute event, but by a continuous, meaningful dialogue between individuals, their data, and their care team. By providing clinicians and members with a shared data set, we aren't just monitoring the heart, but are empowering people to protect it. I am incredibly optimistic that we can turn the tide on cardiovascular disease through the power of proactive, personalized insights.

In health,

Ricky Bloomfield, MD
Chief Medical Officer, Oura

Meet our scientists and clinicians

Emmi Antikainen, PhD, is a Senior Data Scientist at Oura, developing new algorithms for wellbeing. Her expertise is in signal processing and machine learning in the health domain. Throughout her career, her work has focused on health-related quality of life and solutions for preventative care.

Ricky Bloomfield, MD, is Chief Medical Officer at Oura. Dr. Bloomfield's expertise spans clinical care in internal medicine and pediatrics, digital health, informatics, and health data interoperability. Throughout his career, his work has focused on empowering patients and clinicians with actionable health data and advancing technology-enabled, preventative care.

Tanvi Jayaraman, MD, is the Clinical Lead of Health AI at Oura, where she bridges medicine and product strategy to advance responsible, trustworthy tools. She ensures that Oura's guidance meets rigorous clinical standards.

Heli Koskimäki, PhD, is the Senior Director, Future Physiology at Oura. Since joining the Oura Science Team in 2016, she has contributed to several core feature development projects, from nocturnal heart rate and heart rate variability (HRV) studies to sleep staging, chronotype detection, and period prediction. Currently, she is responsible for Oura's long-term roadmap planning from a physiological features perspective.

Venla Lymysalo, MSc, is a Machine Learning Scientist at Oura, specializing in deep learning approaches for cardiovascular health assessment from wearable sensor data. She contributed to the Blood Pressure Profile Study and related cardiovascular initiatives, helping bridge research advances and scalable consumer health features.

Kerry Martin, PhD, is a Senior Data Scientist at Oura, working on blood biometric integration. His background is in cellular and computational physiology, including oxidative stress and cardiopulmonary modeling.

Joseph Munaretto, PhD, is a Staff Data Scientist at Oura, with a background in signal processing and modeling of physiological signals, with work in developing advanced metrics for evaluating cardiovascular fitness.

Meet our scientists and clinicians

Pauli Ohukainen, PhD, is a Staff Research Scientist at Oura, where he leads cardiometabolic research and supports feature development. He holds an MSc in biochemistry and earned a PhD at the University of Oulu, investigating the molecular mechanisms of human aortic valve calcification. As a post-doctoral researcher, he focused on systems epidemiology of cardiometabolic risk prediction and human lipoprotein metabolism.

Aleksi Rantanen, MHSc and PhD candidate, is a Staff Biomedical Engineer at Oura, where he leads physiology-driven algorithm development for cardiovascular health using wearable photoplethysmography. His work includes algorithms for pulse wave velocity, Cardiovascular Age, heart rate, and HRV, as well as large-scale data analyses to gain insight into underlying cardiovascular health and physiology.

Annie Tilton, MD, is the Director of Clinical Outcomes Research at Oura, where she leads research strategy and execution with academic medical centers and other Oura partners to determine how Oura use affects patient health and economic outcomes.

Raphael Vallet, PhD, is a Staff Machine-Learning Data Scientist at Oura, where he leverages his deep expertise in algorithm development and physiological data analysis to pioneer new health-tracking technologies. A neuroscientist by training, Dr. Vallat's research has led to numerous publications in top-tier scientific journals, contributing significant advancements to the field of sleep neuroscience and wearable technology.

Massimiliano de Zambotti, PhD, is the Director of Health Science at Oura, where he leads health science initiatives. His research focuses on leveraging high-resolution wearable data to advance scientific understanding at the intersections of sleep, women's health, and cardiovascular health. Dr. de Zambotti has authored over 140 scientific publications.

Chris Curry, MD, PhD, is the Clinical Director of Women's Health at Oura, where she works across all aspects of women's health, including research, product, design, and clinical partnerships. She is the Principal Investigator for Oura's Blood Pressure Profile Study.

Dedication to data privacy and security

At Oura, we know that your health data is deeply personal. Our commitment to protecting your privacy and data security is fundamental to our company and built into our privacy-first business model.

Oura uses advanced technology and organizational safeguards to keep your data safe and secure. Where appropriate, these safeguards include measures such as anonymization or pseudonymization of personal data, strict access control, and the use of encryption to protect the data we process.

Oura adheres to some of the most stringent global privacy standards. For us, protecting our customers' personal data is non-negotiable. Oura stands firmly against unauthorized data sharing. We will never sell your personal data or share your personal data with third parties without your consent or authorization.

Protected Health Information (PHI) maintained by Oura is processed in accordance with HIPAA privacy and security standards. In addition, Oura complies with General Data Protection Regulation (GDPR), one of the world's most comprehensive data protection laws.

The full Oura Health Privacy Policy can be found on our website and you can learn more about Oura's commitment to privacy and security here.

Authored by Katie McMillan, MPH, Pauli Ohukainen, PhD, and Chris Curry, MD, PhD with special contributions from Oura Science, Clinical, and Product teams.

Oura Ring is not a medical device and is not intended to diagnose, treat, cure, monitor, or prevent medical conditions or illnesses. Please do not make any changes to your medication, nutrition, or workouts without first consulting your doctor or another medical professional.

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