Technical Article

Emerging Medical Applications for Optical Heart Rate Sensor Technology in Wearables

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This is the third installment in a three-part series on optical heart rate sensors for biometric wearables. The first installment focused on how these sensor systems work and what you can measure with them. Part 2 shared the top 10 lessons learned from Valencell's completion of more than 50 biometric wearable product development cycles.

In an increasingly digital world, there are more and more uses for optical heart rate sensors in wearable devices. These devices have endless applications and provide insights on everything from personal activity and fitness levels to health status. Accurate biometric sensor data can lead to accurate fitness and health assessments, but what exactly can designers and engineers do with these assessments? Table 1 summarizes some of the common assessments used today in fitness applications, which also have validated health and medical implications.

Table 1. Key Fitness Assessments with Health and Medical Relevance

Assessment	Definition	What it means for fitness	What it means for health
VO_2 max	Aerobic capacity: the primary measure of chronic change to cardiovascular fitness	Higher VO_2 max correlates with better performance during aerobic activities	Higher VO_2 max correlates with lower mortality and improved recovery from a cardiac event
Resting heart rate	Heart rate during an awake period of no exertion	A decrease in resting heart rate correlates with an increase in fitness	A steadily increasing resting heart rate correlates with the progression of cardiovascular disease
Heart rate recovery	Change in heart rate over one minute after intense exercise	Higher heart rate recovery implies better exercise endurance	Higher heart rate recovery implies better cardiovascular health
Heart rate response	Change in heart rate over one minute at the start of exercise	Higher heart rate response can imply low cardiac readiness for exercise	Higher heart rate response paired with chronotropic incompetence, the inability of the heart to increase its rate commensurate with increased activity or demand, can predict carotid atherosclerosis
Cardiac efficiency	Average cadence divided by average heart rate at steady state	The higher cardiac efficiency, the fewer heart beats needed for all physical activities	Steadily declining cardiac efficiency correlates with the onset of hypertension
Heart rate variability (HRV)	The statistical variability of heart rate intervals	HRV can diagnose psychosocial stress and overtraining in exercise	HRV can predict atrial fibrillation and arrhythmia

(Info courtesy of the National Institutes of Health and Pacing and Clinical Electrophysiology)

Most wearables in the market today are targeted toward sports & fitness use cases, but you are beginning to see a shift toward wearables becoming personal health devices that can provide meaningful insights into a person's health. This is because the photoplethysmogram (PPG) sensors in these wearables devices have achieved a level of accuracy that is good enough for many of the health and medical use cases that have already been proven with electrocardiography technology.

Here are some examples of how these assessments are used today and how they could be used in health and medical wearables in the future.

VO_2 Max

Measurements of physical activity and the body's response to it are critical components in determining the improvement level. Some wearable devices today are starting to use VO_2 max (maximum oxygen consumption) to measure chronic changes to cardiovascular fitness. The higher the VO_2 max, the better the performance during aerobic activity. However, wearable devices measuring VO_2 max could also be used for health and medical purposes. For example, it has been shown that a higher VO_2 max is also associated with a lowered risk of mortality and an increased ability to recover from a cardiac event.

Resting Heart Rate

The term "rest" may not be the first thing that comes to mind when thinking about fitness, but resting measurements of heart rate can be great indicators of fitness levels. Decreased resting heart rate during periods of no exertion correlates to increased fitness. The more someone can lower their resting heart rate, the more likely they are to slow the progression of cardiovascular disease.

Heart Rate Recovery

Similarly, measuring heart rate recovery — the heart's ability to return to normal levels after physical activity — can also predict fitness levels and heart function. A healthy heart will recover at a quicker rate than a less healthy one. A higher heart rate recovery suggests increased endurance and better cardiovascular health. To evaluate heart rate recovery, you look at the difference between the heart rate during activity and the heart rate one to two minutes after stopping exercise.

Heart Rate Response

Another useful assessment from a heart rate sensor, taken about a minute into a workout, is heart rate response to exercise, which is physiological. Increased activity in working muscles causes an increase in sympathetic nervous system activity. The lower the fitness level, the stronger the heart rate response to exercise. With regular training, the body adapts. While heart rates will still increase with exercise, the body has to work harder to achieve the same rate increase. A higher heart rate response, paired with chronotropic incompetence, can also help predict carotid artery disease.

Cardiac Efficiency

Regular exercise also can lead to higher cardiac efficiency, which is the ratio of work done by the heart to the energy used to perform the work. The more efficient the heart becomes, the fewer beats it needs for physical activity. Cardiac efficiency can be a great heart-health indicator. A declining heart rate efficiency is correlated with many cardiovascular issues, including hypertension.

HRV

Physical activity, or stress on the body, can also be assessed using HRV – the variability of time between beats of the heart. This measurement indicates psychosocial or mental stress, as well as overtraining in exercise. HRV monitors the impact of stressors on the body, and it relates to fatigue (mental and work capacity) and readiness to perform mental and work tasks. HRV can also predict incidences of arrhythmia and atrial fibrillation. Professional athletes have used HRV for some time, but it's just now beginning to see traction in consumer devices.

There have been many recent announcements about wearable devices' new capabilities to detect atrial fibrillation, arrhythmia, core body temperature and more. These capabilities are being delivered by the same optical heart rate sensors using PPG already found in a great deal of wearable devices today.

Additional Resources

- View TI's photodiode sensing portfolio.
- Find TI resources and reference designs for wearables.

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