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APG

Acceleration Plethysmogram through Vyvo Technology Wearable Devices to Evaluate Cardiovascular Aging

Version 2.0 - 10.2024

Abstract

Cardiovascular disease is the leading cause of death worldwide, with atherosclerosis the primary underlying factor in CVD. Research has shown that acceleration plethysmogram (APG), otherwise known as the second derivative of photoplethysmogram (SDPTG), is a useful noninvasive tool to evaluate cardiovascular aging, given that it reveals more about the pulse wave than shown from photoplethysmography (PPG). Algorithmic interpretation of APG signals is essential for accurate understanding of APG readings. Equipped with a cutting-edge PPG function capable of APG measurements, Vyvo Technology wearable devices provide a highly useful method for assessing cardiovascular health and aging.

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Atherosclerosis and Cardiovascular Disease

Cardiovascular disease (CVD) is the leading cause of death worldwide. CVD is an umbrella term that includes numerous diseases of the heart or blood vessels, including heart attack, coronary artery disease, stroke, heart failure, and more. Given this prevalence, early detection of CVD and mitigation of risk factors could extend life and increase quality of life for millions around the world.

McGill et al claims “a convergence of evidence from diverse sources in the last two decades now indicates that the claim that we can prevent 90% of coronary heart disease should no longer be thought of as outrageous but as achievable.”[1]

Any effort to reduce CVD must start with reducing a primary contributor, atherosclerosis. This chronic inflammatory condition is identified by a buildup of plaques in arteries, which leads to a narrowing of the artery.[2] For many, a heart attack is the first sign of CVD.[3]

Atherosclerosis is recognized as a disease of aging, meaning “increasing age is an independent risk factor.”[4] But, “premature or accelerated … aging can be promoted by cardiovascular risk factors,”[5] meaning one of young chronological age could have an “old” cardiovascular system.

According to Qawqzeh et al, “Aging is accompanied by increased stiffness of large elastic arteries, leading to an increase in [pulse wave velocity] (PWV). Premature arterial aging, as determined by an elevated aortic PWV, is now recognized as a major risk factor for ischemic heart disease.”[6]

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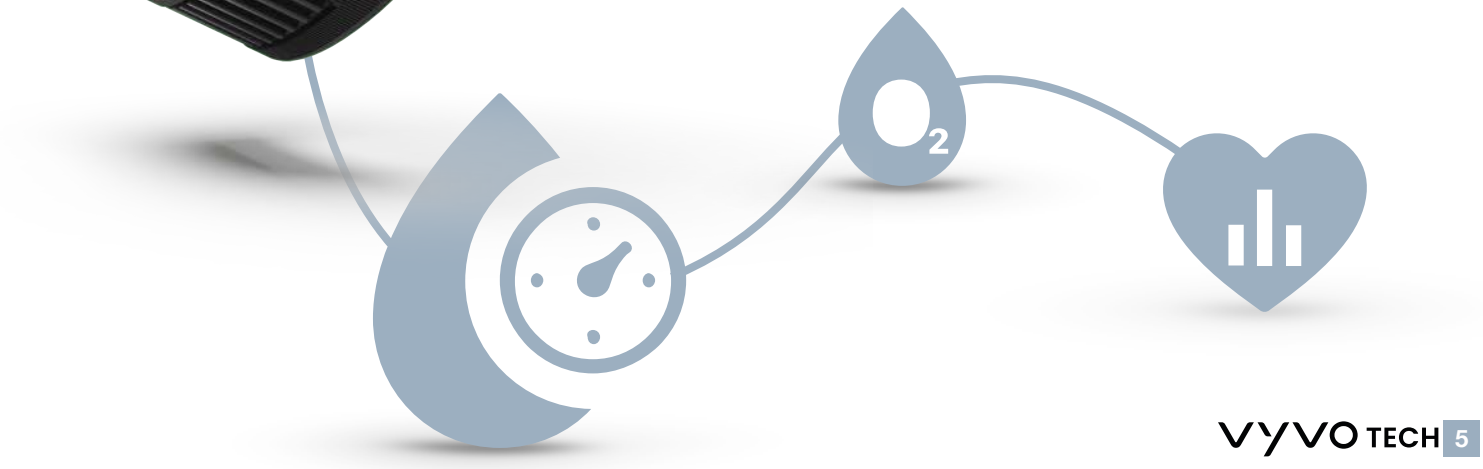
While most who die from CVD are 65 and older, “fatty streaks” that precede plaque begin to form in adolescence, meaning prevention must begin as early as possible. Based on studies they analyzed, McGill et al posit that “risk factor control in young people might retard the progression of atherosclerosis,” and that delaying intervention until adulthood is unwise because, “by early middle age, individuals who have been at high risk for several decades likely already have advanced lesions.”[7]

Given the high prevalence of atherosclerosis and CVD, and its usual “silent” nature - meaning most are unaware of the danger to their health until experiencing a serious incident - equipping people with a convenient way to understand their cardiovascular health will empower them to take appropriate action so they can protect their wellbeing.

Photoplethysmography and Acceleration Plethysmogram

Researchers are applying well-known techniques and analytical methods to noninvasively measure the health and “age” of cardiovascular systems. Photoplethysmography (PPG) is an optical method for measuring blood volume changes in a bed of tissue, such as a finger or earlobe, by illuminating the skin and measuring light absorption.

PPG waves “contain a wealth of cardiovascular circulatory information, and many studies have shown its effectiveness in measuring and evaluating heart rate, blood oxygen saturation, blood pressure, cardiac output, arteriosclerosis, and vascular aging.”[8] Additionally, PPG can be used to measure pulse wave velocity (PWV), which is “correlated to age, blood pressure (BP) and arteriosclerosis and has a better predictive value for cardiovascular disease than traditional risk markers.”[9]



But while PPG reveals much, it “allows analysis of the amplitude of the PW but not of the contour itself.”[10] In contrast, acceleration plethysmogram (APG) is more revealing. It “uses the second derivative of the waveform of the digital photoplethysmography to stabilize the baseline and to separate components of the waveform more clearly than the first derivative,”[11] which also explains why APG is sometimes referred to as the *second derivative of the digital photoplethysmogram* (SDPTG).

As explained by von Wowern et al, APG enables “detailed evaluations of the curvatures of the PPG waveform, i.e. the accelerative and decelerative phases of the curve contour, and a more accurate recognition of the inflection points on the original photoplethysmogram,”[12] as shown in Figure 1.

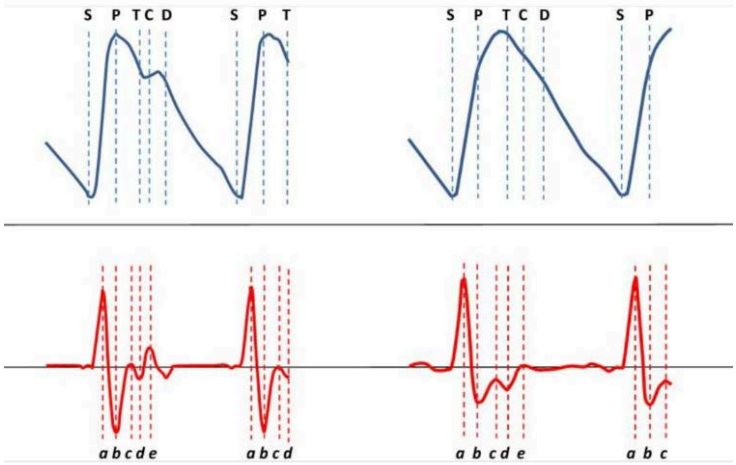


Fig. 1: *“Digital photoplethysmograms and acceleration photoplethysmograms. S = starting point of systole; P = peak of percussion wave; T = tidal wave; C = incisura wave; D = dicrotic wave.”*[13]

With this increased insight into the pulse waveform using APG, this method can be an effective way to evaluate cardiovascular aging.[14] In the words of Qawqzeh e t al, “since PPG and SDPTG [i.e., APG] reflect blood volume changes, much work has been done on its application as a diagnostic tool for screening arterial structure and its related diseases and disorders.”[15]

More specifically, “accurate a and b wave detection is an important first step for the assessment of arterial stiffness and other cardiovascular parameters,”[16] according to Elgendi et al.

Assessing Cardiovascular Aging with APG

As addressed above, vascular aging involves arterial stiffness, and this stiffness can be measured with PPG/APG. This ability enables the assessment of cardiovascular aging, as demonstrated by several studies.

Jae Mok Ahn of Hallym University, Korea, developed "a wave detection algorithm including a preamplifier based on a microcontroller," as shown in Figure 2. This approach was tested with 164 subjects, with the author concluding, "the wave indices of an APG in real-time are useful for evaluating vascular aging in the cardiovascular system in a simple healthcare device."[17]

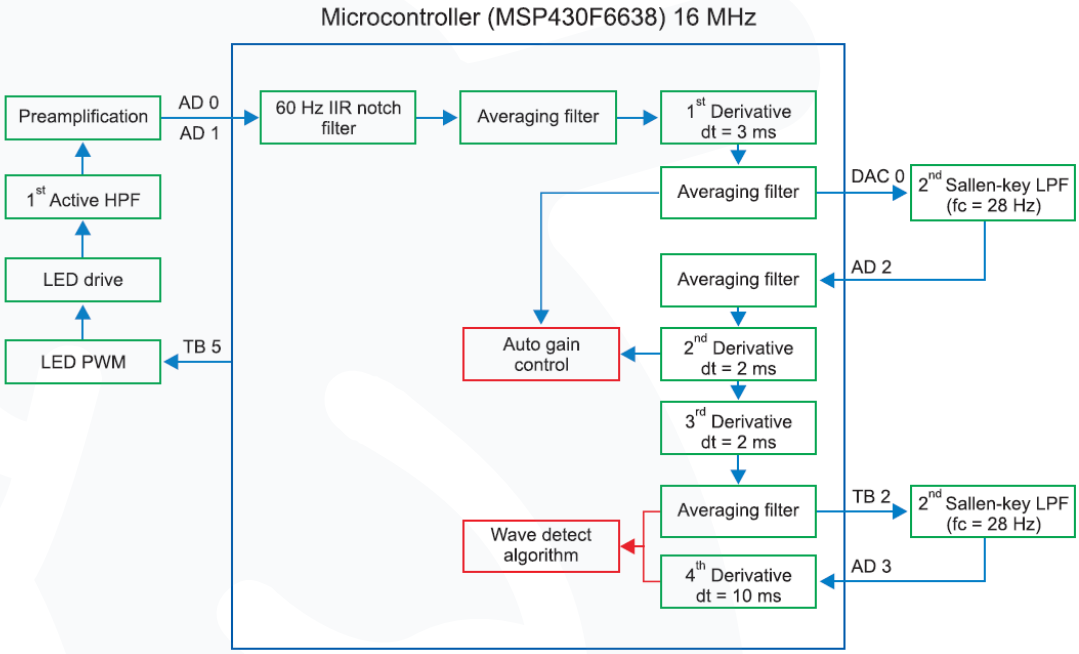


***Fig. 2**: "System configuration based on a microcontroller. An analog to digital converter, digital to analog converter, and pulse width modulation (PWM) timer provided by the microcontroller were used to generate the photoplethysmography and to develop a wave detection algorithm. LED: light emitting diode, HPF: high pass filter, LPF: low pass filter."[18]*

One approach, demonstrated by Takazawa et al, is to compare ratios of wave peaks, i.e., the points labeled a, b, c, d, and e in Figure 1. In a study involving 600 subjects, they found “the b/a ratio increased with age, and c/a, d/a, and e/a ratios decreased with age,” and concluded, “the b-cd-e/a ratio may be useful for evaluation of vascular aging and for screening of arteriosclerotic disease.”[19]

Imanaga et al investigated the correlation of pulse wave components and arterial distensibility — a measure of the artery’s ability to expand and contract with cardiac pulsation and relaxation. This study involved 82 subjects divided into three groups. One was non-atherosclerotic, the other two mild and severe atherosclerotic, as determined by ultrasonography of the carotid artery.[20]

The study showed a “significant negative correlation” of distensibility with age — meaning the arterial flexibility decreased as age increased — and this was seen with all subjects. Like Takazawa et al, the results also showed a “significantly positive” correlation of the b/a ratio and distensibility, leading the team to conclude, “the ratio of two wave components (magnitude of b/a constituting the second derivative of the plethysmogram (SDPTG)) was correlated with arterial distensibility.”[21]

In their study of 390 participants, Takada et al evaluated aging effects in cardiovascular systems. They concluded, “simply categorized wave patterns of APG could be a useful noninvasive tool to evaluate aging in cardiovascular system.”[22]

APG and Vyvo Technology Wearable Device

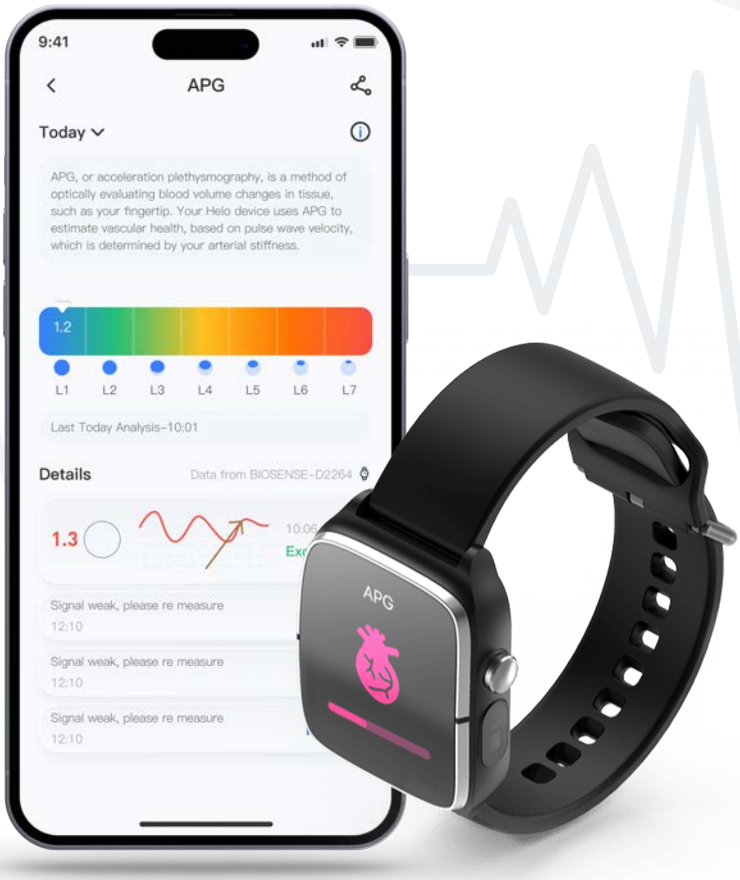
As amply demonstrated in the studies reviewed above, APG is an effective method for measuring cardiovascular health and aging.

In 2018, Eglendi et al stated,

> *"The study of PPG signal analysis is relatively new compared to research in electrocardiogram signals, for instance; however, we anticipate that in the near future blood pressure, cardiac output, and other clinical parameters will be measured from wearable devices that collect PPG signals, based on the signal's vast potential."*[23]

Wearable devices from Vyvo Technology are equipped with PPG functionality for measuring numerous parameters, and applying the second derivative of the plethysmogram (APG). With analysis through Vyvo's proprietary algorithm, the wearable device can accurately evaluate the pulse wave and assess cardiovascular health.

It represents a highly useful, highly convenient, and highly effective way to measure and report cardiovascular aging. This insight equips device users with the knowledge they need to protect and improve their health, with the involvement and advice of their doctor.



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Conclusion

Acceleration plethysmography is an accurate and effective way to analyze the pulse wave, which leads to improved understanding of several factors tied to heart health, including cardiovascular aging. Vyvo Technology wearable devices, which utilize proven AGP technology, provide users with actionable insights that enable them to proactively protect their health and make informed decisions with the guidance of a qualified physician.

Legal Disclaimer

Unless otherwise specified, Vyvo devices and related services are not medical devices and are not intended to diagnose, treat, cure, or prevent any disease. With regard to accuracy, Vyvo has developed products and services to track certain wellness information as accurately as reasonably possible. The accuracy of Vyvo's products and services is not intended to be equivalent to medical devices or scientific measurement devices.

Consult your doctor before use if you have any pre-existing conditions that might be affected by your use of any Vyvo product or service.

Useful Terms

Cardiovascular Disease (CVD) = An umbrella term involving diseases of the heart or blood vessels. It is the leading cause of death worldwide.
Atherosclerosis = A disease state characterized by lesions in artery walls, which can lead to narrowing of the artery due to accumulation of plaque.
Photoplethysmography (PPG) = An optical way to measure blood volume changes in a bed of tissue, such as a finger or earlobe. Obtained by illuminating the skin and measuring light absorption.
Acceleration Plethysmography (APG) = The second derivative of a photoplethysmography (PPG) signal. Also known as SDPTG.
Pulse wave velocity (PWV) = The measurable velocity of the pressure wave caused by the flow of blood through arteries.
Arterial distensibility = A measure of the arterial ability to expand and contract with cardiac pulsation and relaxation.

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