The science behind Body Cardio

Body Cardio &
Pulse Wave Velocity

Heart Health &
Body Composition
Wi-Fi Smart Scale

withings

Pulse Wave Velocity in the medical community

Pulse Wave Velocity is an innovative metric used by the medical community to assess cardiovascular health. Despite its medical value, it is usually restricted to second-line medical examination.

Why it matters?

The impact of traditional cardiovascular indicators on health like blood pressure, diabetes, and cholesterol vary according to each person because they are influenced by factors such as age, personal history, and genetic predisposition. As a consequence, doctors need to analyze all these indicators to assess your cardiovascular health.

Pulse Wave Velocity takes many indicators into account — the impact of lifestyle, blood pressure, diabetes, and cholesterol — when assessing cardiovascular health. This is why Pulse Wave Velocity is the only stand-alone measurement that is able to give you the whole picture of your cardiovascular health and your potential risk of having or developing hypertension.

Definition of Pulse Wave Velocity & arterial stiffness

Pulse Wave Velocity is the propagation velocity of the pressure wave along the arterial tree. It is linked to the elasticity of the aorta arterial wall. The pressure wave along the arterial tree is due to heartbeats, which induce blood volume changes in the vessels that expand and contract in response to these blood pressure changes.

Increased stiffness of the aorta will increase the propagation velocity of the pressure wave traveling in the aorta. The consequence of reduced distensibility is increased propagation velocity of the pressure pulse along the arterial tree. It follows the physical principle that, the speed of travel of a pressure wave along an elastic tube is directly related to the stiffness of the tube, this relationship being described as the Moens–Korteweg equation[1].

Pulse Wave Velocity is used to measure the aortic stiffness and is considered to be the gold standard of arterial stiffness measurements[2]. Arterial stiffness describes the reduced capability of an artery to expand and contract in response to pressure changes. The consequence of this decreased capability is increased propagation velocity of the pressure pulse along the aorta.

Discover why Pulse Wave Velocity is a good indicator of your cardiovascular health

1) Pulse Wave Velocity as an independent indicator of your cardiovascular health

A recent expert consensus document on arterial stiffness[2] listed several longitudinal studies, demonstrating that a simple measure of Pulse Wave Velocity yielded prognostic values beyond and above traditional risk factors. The consensus report concluded that arterial stiffness measurements[2] are the only way to directly assess your cardiovascular health by measuring your arteries' health.

This is because Pulse Wave Velocity factors in the impact of blood pressure, atherosclerosis (plaques made up of fat on the arterial wall) and lifestyle when assessing the elasticity of the arterial wall.

2) Pulse Wave Velocity as an indicator of your potential risk for high blood pressure

Two different mechanisms induce an increase in Pulse Wave Velocity: high blood pressure by inducing a high load of the blood on the arterial wall[3][4] and arterial wall properties. A structural change of the arterial wall due to age, genetics, diabetes, atherosclerosis or sustained hypertension will increase the intrinsic stiffness of the arterial wall and impact its flexibility.

Because it is influenced by both properties of the arterial wall and blood pressure, a short-term increase in Pulse Wave Velocity can give you an indication of your blood pressure variations.

How is Pulse Wave Velocity usually measured?

Pulse Wave Velocity is usually measured between the carotid and the femoral artery using a sphygmometer and applanation tonometry. However, this device requires a well-trained operator and is only suitable in a medical setting.

What is a healthy Pulse Wave Velocity?

Pulse Wave Velocity values are used to calculate the age of your arteries. Each Pulse Wave Velocity value above the 75th percentile is a sign of an accelerated aging and each value above the 90th indicates damage in the arterial wall or elevated blood pressure. Pulse Wave Velocity increases with age by approximately 0.1m/s per year[5].

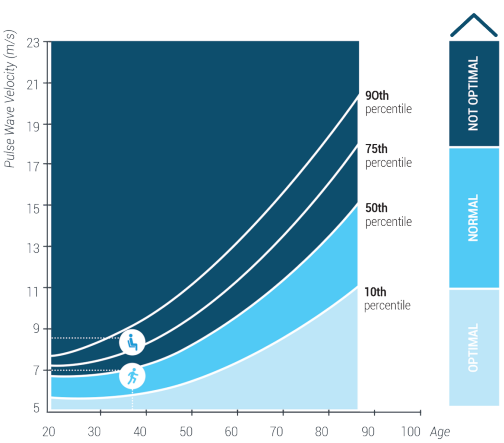


Figure 1: Relation between age, Pulse Wave Velocity and cardiovascular risk.

Pulse Wave Velocity on Body Cardio

An easy way to see an indication of your cardiovascular health

Pulse Wave Velocity is used by the medical community to help provide a cardiovascular health assessment, and it is usually restricted to a clinical setting. Body Cardio brings this unique measurement home so that everyone can have a better picture of their health just by stepping on the scale. Knowledge is power, and the scale and app have been designed to inform and inspire day-to-day behaviors that can add up to better long-term health.

How does Body Cardio measure Pulse Wave Velocity?

Body Cardio measures the time difference between blood ejection by the heart in the aorta and the arrival of the blood flow in the feet. The time it takes for the pressure wave to travel along the arterial tree is used by Body Cardio to compute Pulse Wave Velocity.

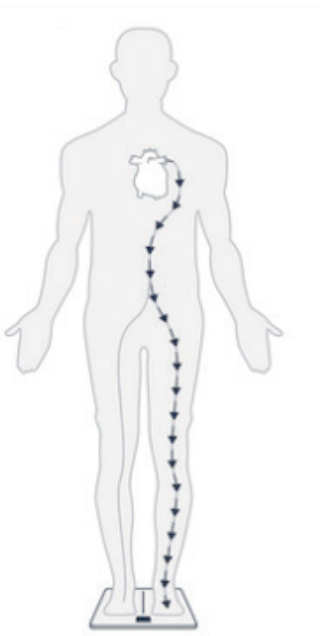


Figure 2: Measurement of PWV on Body Cardio.

Use of ballistocardiography and impedance plethysmography to measure Pulse Wave Velocity

When the heart beats, it ejects blood in the aorta and exerts a force that leads to weight variations on the scale. In the case of Body Cardio, ballistocardiography has been shown to be synchronized with the opening of the aortic valve and consecutive blood ejection. Impedance plethysmography in a single foot shows the arrival time of the pulse wave in the foot.

So the Pulse Transit Time measured on the scale is the interval between the onset of the systolic pressure wave at the base of the Pulse Wave Velocity derived from the Pulse Transit Time measured by Body Cardio and the height of the patient can be compared to the one measured with a Sphygmometer[6].

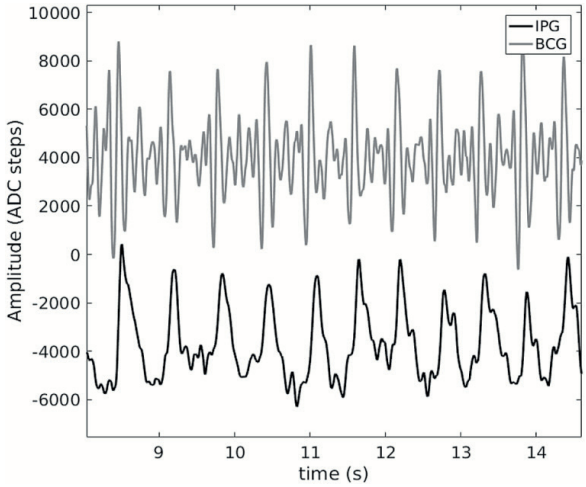


Figure 3: Ballistocardiography (BCG) and Impedance Plethysmography (IPG) signals on Body Cardio.

Scientific validation of Body Cardio

To assess the validity of the measurement of Body Cardio, Withings performed a study comparing the measurement of the aortic Pulse Wave Velocity in Body Cardio to a sphygmometer, following the recommended guidelines[1].

The sphygmometer uses applanation tonometry to measure the Pulse Wave Velocity in the aorta between the carotid and femoral arteries. This technique, called carotid–femoral pulse wave velocity, is a useful measure of central arterial, mainly aortic, stiffness and, by consensus, is generally accepted as the most simple, non-invasive, robust, and reproducible method to determine arterial stiffness[7].

The study was conducted on a group of 86 individuals in a clinical context by a medical team specializing in arterial stiffness (Pr. Pierre Boutouyrie, AP-HP, Hopital Europeen Georges Pompidou, Paris, France). Two parameters were considered: Pulse Transit Time and the Pulse Wave Velocity.

The results (figure 4) of this validation study show a good correlation between the Pulse Wave Velocity measurements using the Body Cardio and the measurements using the sphygmometer.

This study has been published in the American Journal of Hypertension[11].

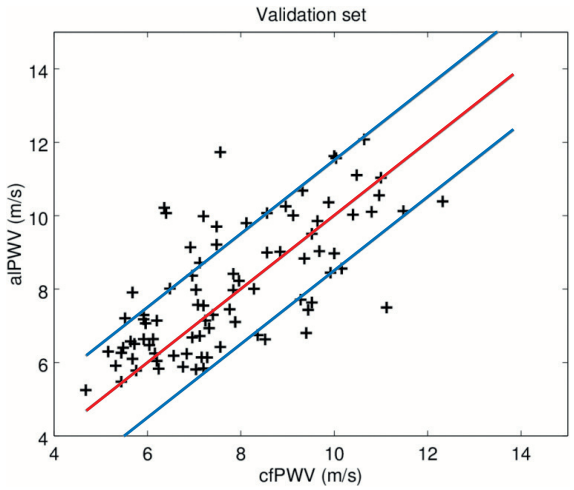
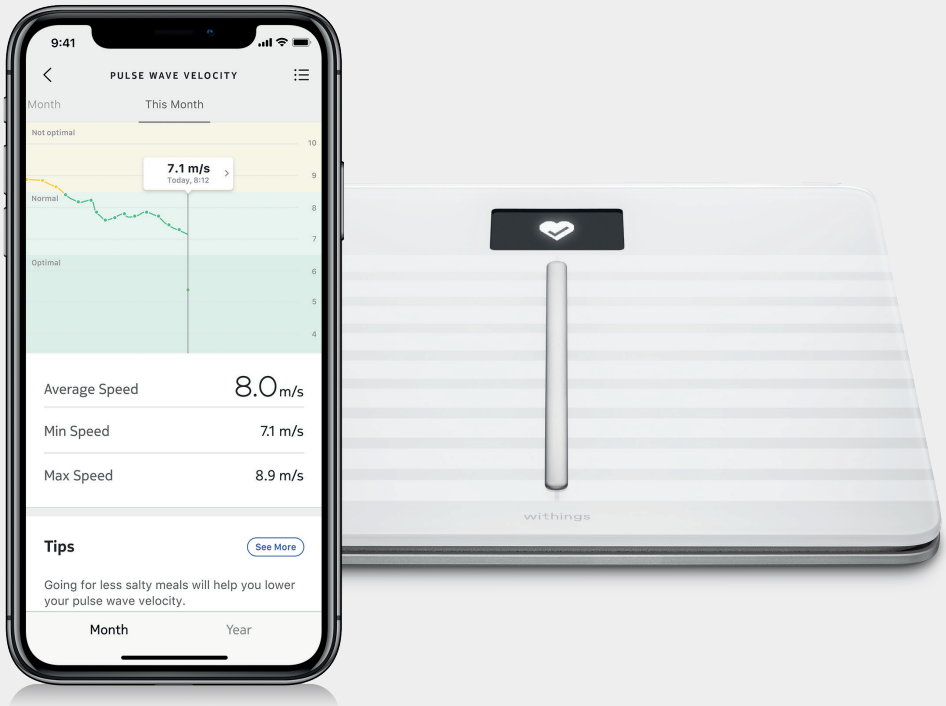


Figure 4: Estimated Body Cardio Body PWV against the reference values obtained with the Sphygmocor (correlation coefficient is r=0,72). Velocities on the red line are equal. Crosses within the blue lines are ≤ 1.5 m/s away from the reference value.



How can you improve your Pulse Wave Velocity?

- Increase physical exercise
- Decrease salt intake[8]
- Decrease alcohol consumption
- Lose weight[9]
- Decrease stress and anxiety
- Increase your intake of certain kinds of foods, such as dark chocolate, green tea, and food on the Mediterranean diet

How can you get a reliable measurement?

Changes in blood pressure are related to various factors: time of day, stress level, physical activity, diet, alcohol, coffee, and smoking. These factors will cause significant changes in Pulse Wave Velocity, so it is not unusual for one's person Pulse Wave Velocity to vary in a single day. The best way to use your Body Cardio is to follow your Pulse Wave Velocity trend over time. To improve reliability, take your measurements in the following conditions:

- Quiet room with stable temperature (the best is 22-23°C (71.6-73.4°F))[10]
- Same hour every day
- At least 3 hours after a meal, drinking coffee or smoking a cigarette
- No movement or speaking
- Feet at the center of the scale
- If you encounter several failures in your measurements, place your hands on the wall in front of you to ensure proper stability.

Bibliography

[1] P. Boutouyrie, D. Fliser, D. Goldsmith, A. Covic, A. Wiecek, A. Ortiz, A. Martinez-Castelao, B. Lindholm, Z. A. Massy, G. Suleymanlar, R. Sicari, L. Gargani, G. Parati, F. Mallamaci, C. Zoccali, and G. M. London, "Assessment of arterial stiffness for clinical and epidemiological studies: methodological considerations for validation and entry into the European Renal and Cardiovascular Medicine registry," Nephrol. Dial. Transplant., p. gft309, Sep. 2013.

[2] S. Laurent, J. Cockcroft, L. V. Bortel, P. Boutouyrie, C. Giannattasio, D. Hayoz, B. Pannier, C. Vlachopoulos, I. Wilkinson, and H. Struijker-Boudier, "Expert consensus document on arterial stiffness: methodological issues and clinical applications," Eur. Heart J., vol. 27, no. 21, pp. 2588–2605, Nov. 2006.

[3] A. D. Stewart, B. Jiang, S. C. Millasseau, J. M. Ritter, and P. J. Chowienczyk, "Acute Reduction of Blood Pressure by Nitroglycerin Does Not Normalize Large Artery Stiffness in Essential Hypertension," Hypertension, vol. 48, no. 3, pp. 404–410, Sep. 2006.

[4] A. D. Stewart, S. C. Millasseau, M. T. Kearney, J. M. Ritter, and P. J. Chowienczyk, "Effects of Inhibition of Basal Nitric Oxide Synthesis on Carotid-Femoral Pulse Wave Velocity and Augmentation Index in Humans," Hypertension, vol. 42, no. 5, pp. 915–918, Nov. 2003.

[5] A. P. Avolio, S. G. Chen, R. P. Wang, C. L. Zhang, M. F. Li, and M. F. O'Rourke, "Effects of aging on changing arterial compliance and left ventricular load in a northern Chinese urban community," Circulation, vol. 68, no. 1, pp. 50–58, Jul. 1983.

[6] Hakim Khettab, David Campo, Roger Yu, Nadine Buard, Pierre Boutouyrie, "First in man measurement of arterial stiffness using a connected bathroom scale: calibration against Sphygmocor," Eur. Soc. Hypertens. Congr. 2016.

[7] I. B. Wilkinson, C. M. McEniery, G. Schillaci, P. Boutouyrie, P. Segers, A. Donald, and P. J. Chowienczyk, "ARTERY Society guidelines for validation of non-invasive haemodynamic measurement devices: Part 1, arterial pulse wave velocity," Artery Res., vol. 4, no. 2, pp. 34–40, Jun. 2010.

[8] A. P. Avolio, K. M. Clyde, T. C. Beard, H. M. Cooke, K. K. Ho, and M. F. O'Rourke, "Improved arterial distensibility in normotensive subjects on a low salt diet," Arterioscler. Dallas Tex, vol. 6, no. 2, pp. 166–169, Apr. 1986.

[9] E. J. Balkestein, D. P. van Aggel-Leijssen, M. A. van Baak, H. A. Struijker-Boudier, and L. M. Van Bortel, "The effect of weight loss with or without exercise training on large artery compliance in healthy obese men," J. Hypertens., vol. 17, no. 12 Pt 2, pp. 1831–1835, Dec. 1999.

[10] "Fiche technique : Mesure de la rigidité artérielle." Société Française d'hy- pertension artérielle.

[11] D. Campo, H. Khettab, R. Yu, N. Genain, P. Edouard, N. Buard, and P. Boutouyrie, " Measurement of Aortic Pulse Wave Velocity With a Connected Bathroom Scale", American Journal of Hypertension, Sept. 2017.

withings