HELO GUIDES

SpO2

Estimating Oxygen Saturation by HELO Wearable Devices

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Abstract

Oxygen has an indispensable role in cellular function, and therefore in sustaining most forms of life. The gold standard for measuring blood oxygen saturation, SaO2, is through arterial blood gas test, which requires an invasive blood draw. Estimating saturation with high accuracy is possible via noninvasive pulse oximetry; this measurement is labeled SpO2. Because oxygenated and deoxygenated hemoglobin respond differently to light (specifically red and infrared wavelengths), pulse oximetry can estimate the oxygen of arterial blood. Wearable devices equipped with photoplethysmography hardware and, on the back end, analytical capabilities, can conveniently and continuously estimate SpO2. Helo wearable devices provide consumers with convenient and accurate blood saturation estimates.

Fundamentals of Oxygen

Oxygen is a chemical element identified with the symbol O and with atomic number 8. Oxygen is critical for the chemical reactions that most complex organisms require to maintain life.

In humans, blood oxygen saturation levels are typically 95 to 100 percent. A saturation below 90 percent is labeled hypoxemia, and saturation below 80 percent is life-threatening.[1] Given the critical importance of oxygen to maintaining life, a convenient and accurate method of measuring oxygen saturation is not only useful but also potentially lifesaving.

Estimating Blood Oxygen

A blood-oxygen saturation reading is the percentage of hemoglobin molecules in the arterial blood which are saturated with oxygen. The reading may be referred to as SaO_2, and the “gold standard” for this measurement is by “co-oximetry in extracted blood” in an arterial blood gas test. When measured by non-invasive pulse oximetry, the saturation metric is an estimate and is designated SpO_2.[2]

Compared to SaO_2, SpO_2 is accurate to a 2% error at hemoglobin saturations of 70–99%.[3] According to Nitzan et al, this 2% value is “the standard deviation (SD) of the differences between SpO_2 and SaO_2. A standard deviation of 2% is associated with an expected error of 4% (two SDs) or more among 5% of the examinations.”[4]

Confirming this finding, the U.S. Food and Drug Administration reports the accuracy of pulse oximeters it has cleared to be “within 2 to 3% of arterial blood gas values. This generally means that during testing, about 66% of SpO_2 values were within 2 or 3% of blood gas values and about 95% of SpO_2 values were within 4 to 6% of blood gas values, respectively.”[5]

Pulse Oximetry and Oxygen Saturation

A pulse oximetry device utilizes "two wavelengths of light,"[6] red and infrared, and a photodetector to estimate oxygen saturation, or more specifically "the percentage of hemoglobin binding sites in the bloodstream occupied by oxygen."[7] Deoxygenated hemoglobin absorbs red light and allows infrared to pass through it, while oxygenated does just the opposite.[8] This differing behavior enables the measurement.

Transmissive pulse oximetry transmits the light through a thin part of the body, such as an earlobe or fingertip. In contrast, reflectance pulse oximetry, as the name suggests, utilizes reflected or "back-scattered" light,[9] which makes it suitable for other parts of the body, including wrist, forehead, and feet. See Figure 1.

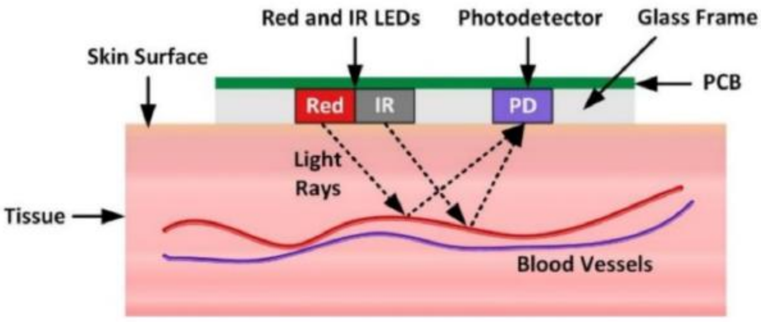

Fig. 1: Working principle of a reflection-type PPG sensor. "PCB" is printed circuit board.[10]

Regardless of method, pulse oximetry is convenient, quick, and accurate, and not prone to user error, making it highly suitable for clinical or consumer usage. According to Seok et al, "Unobtrusive, user-friendly, and long-term usable fully integrated wearable systems enable healthcare devices to monitor the human body condition continuously and to give feedback to users."[11]

Estimating SpO_2 with Wrist-Wearable Device

As Kumar et al report, "Wearable sensor devices have become a promising technology that enables applications such as continuous wireless monitoring of vital physiological parameters such as arterial oxygen saturation (SpO_2) and heart rate (HR)."[12]

Gruber et al compared the accuracy of a wrist-based pulse oximeter to a traditional fingertip device, finding "no significant differences … in all tested parameters." Plus, as a device for the wrist, it has "the advantage of extended use."[13]

Photoplethysmography (PPG) is the technology that enables Helo wearable devices to capture these metrics via reflectance oximetry. PPG "uses optical sensors for non-invasive monitoring of the volume changes in arterial blood. PPG is widely used in pulse oximetry for the measurement of various health parameters such as SpO_2, HR, blood pressure, anesthetic depth and respiration rate."[14]

In the Kumar study, researchers designed and tested a wearable device for the wrist which was "effectively implemented for SpO_2 and heart rate measurements of the patients in a clinical setting."[15]

Braun et al likewise developed a reflectance pulse oximetry device worn on the wrist, specifically to monitor oxygen saturation during sleep. Compared to "state-of-the-art fingertip SpO_2 measurements," their device "obtained an SpO_2 accuracy (average root mean square, or ARMS) of 3.4% when automatically rejecting 17.7% of signals due to low quality. When further excluding measurements suffering from insufficient contact of the watch with the skin an ARMS of 2.7% was obtained while rejecting a total of 23.2% measurements."[16]

Krizea et al recommend wearable devices for "pervasive monitoring of vital signs and the corresponding health status assessment of the rapidly growing elderly population in real time." To test this hypothesis, this team developed "a low-power wrist wearable device" with PPG functionality and "special extraction algorithms to estimate HR and SpO_2 parameters." After training, they found their Multiple Linear Regression model "performs considerable reduction of the imposed Motion Artifacts (Mas) thus enabling more accurate reading outputs."[17]

SpO2 Estimation with Helo Wearable Devices

As reviewed above, researchers have found PPG to be a convenient and effective method for estimating blood saturation levels. Helo wearable devices are equipped with PPG functionality that can estimate SpO_2, giving device users highly useful insights into their blood oxygen levels so they can take steps to address any concerns if necessary.

Conclusion

Seok et al emphasize that the COVID-19 pandemic "increases the global demand for in-home patient monitoring based on the temperature, respiration rate, and blood oxygen content" and that "many researchers are currently proposing wearable biosensors as a solution to an epidemic prevention system."[18] PPG is an effective, accurate method for in-home monitoring, including pulse oximetry. Estimating blood saturation is just one of many personal health metrics Helo wearable devices provide users.

Legal Disclaimer

Unless otherwise specified, Helo wearable devices and related services are not medical devices and are not intended to diagnose, treat, cure, or prevent any disease. With regard to accuracy, Helo has developed products and services to track certain wellness information as accurately as reasonably possible. The accuracy of Helo'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 Helo product or service.

Useful Terms

Hemoglobin: Oxygen-carrying protein of red blood cells.

SaO2: Arterial oxygen saturation; the percentage of hemoglobin molecules in the arterial blood which are saturated with oxygen.

SpO2: Arterial oxygen saturation as estimated by pulse oximetry.

Pulse Oximetry: A method of estimating oxygen saturation using two wavelengths of light, red and infrared, and a photodetector.

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.

References

(1) Nitzan M, Romem A, Koppel R. Pulse oximetry: fundamentals and technology update. Med Devices (Auckl). 2014 Jul 8;7:231-9. doi: 10.2147/MDER.S47319. PMID: 25031547; PMCID: PMC4099100.

(2) Hanning CD, Alexander-Williams JM. Pulse oximetry: a practical review. BMJ. 1995 Aug 5;311(7001):367-70. doi: 10.1136/bmj.311.7001.367. PMID: 7640545; PMCID: PMC2550433.

(3) Nitzan M, Romem A, Koppel R. Pulse oximetry: fundamentals and technology update. Med Devices (Auckl). 2014 Jul 8;7:231-9. doi: 10.2147/MDER.S47319. PMID: 25031547; PMCID: PMC4099100.

(4) Jubran A. Pulse oximetry. Crit Care. 2015 Jul 16;19(1):272. doi: 10.1186/s13054-015-0984-8. PMID: 26179876; PMCID: PMC4504215.

(5) Kumar S, Buckley JL, Barton J, Pigeon M, Newberry R, Rodencal M, Hajzeraj A, Hannon T, Rogers K, Casey D, O'Sullivan D, O'Flynn B. A Wristwatch-Based Wireless Sensor Platform for IoT Health Monitoring Applications. Sensors (Basel). 2020 Mar 17;20(6):1675. doi: 10.3390/s20061675. PMID: 32192204; PMCID: PMC7147171.

(6) D. Seok, S. Lee, M. Kim, J. Cho, C. Kim, "Motion Artifact Removal Techniques for Wearable EEG and PPG Sensor Systems," Frontiers in Electronics, 13 May 2021. Doi: 10.3389/felec. 2021.685513.

(7) Kumar S, Buckley JL, Barton J, Pigeon M, Newberry R, Rodencal M, Hajzeraj A, Hannon T, Rogers K, Casey D, O'Sullivan D, O'Flynn B. A Wristwatch-Based Wireless Sensor Platform for IoT Health Monitoring Applications. Sensors (Basel). 2020 Mar 17;20(6):1675. doi: 10.3390/s20061675. PMID: 32192204; PMCID: PMC7147171.

(8) Kumar S, Buckley JL, Barton J, Pigeon M, Newberry R, Rodencal M, Hajzeraj A, Hannon T, Rogers K, Casey D, O'Sullivan D, O'Flynn B. A Wristwatch-Based Wireless Sensor Platform for IoT Health Monitoring Applications. Sensors (Basel). 2020 Mar 17;20(6):1675. doi: 10.3390/s20061675. PMID: 32192204; PMCID: PMC7147171.

(9) Ibid. Braun F, Theurillat P, Proenca M, Lemkaddem A, Ferrario D, De Jaegere K, Horvath CM, Roth C, Brill AK, Lemay M, Ott SR. Pulse Oximetry at the Wrist During Sleep: Performance, Challenges and Perspectives. Annu Int Conf IEEE Eng Med Biol Soc. 2020 Jul;2020:5115-5118. doi: 10.1109 EMBC44109.2020.9176081. PMID: 33019137.

(10) M. Krizea, J. Gialelis, A. Kladas, G. Theodorou, G. Protopsaltis and S. Koubias, "Accurate Detection of Heart Rate and Blood Oxygen Saturation in Reflective Photoplethysmography," 2020 IEEE International Symposium on Signal Processing and Information Technology (ISSPIT), 2020, pp. 1-4, doi: 10.1109/ ISSPIT51521.2020.9408845.

(11) D. Seok, S. Lee, M. Kim, J. Cho, C. Kim, "Motion Artifact Removal Techniques for Wearable EEG and PPG Sensor Systems," Frontiers in Electronics, 13 May 2021. Doi: 10.3389/felec.2021.685513.

(12) Wikipedia article, "Oxygen saturation," https://en.wikipedia.org/wiki/Oxygen_saturation_(medicine), accessed 12-3-2021.

(13) U.S. FDA article, "Pulse Oximeter Accuracy and Limitations: FDA Safety Communication," https:www.fda.gov/medical-devices/safety-communications/pulse-oximeter-accuracy-and-limitations-fda-safety-communication, accessed 12-8-2021.

(14) Wikipedia article, "Pulse oximetry," https://en.wikipedia.org/wiki/Pulse_oximetry, accessed 12-3-2021.

(15) University of Iowa Health Care website, "Pulse Oximetry Basic Principles and Interpretation," https://medicine.uiowa.edu/iowaprotocols/pulse-oximetry-basic-principles-and-interpretation, accessed 11-30-21

(16) Guber, A., Epstein Shochet, G., Kohn, S. et al. Wrist-Sensor Pulse Oximeter Enables Prolonged Patient Monitoring in Chronic Lung Diseases. J Med Syst 43, 230 (2019). https://doi.org/10.1007 s10916-019-1317-2.

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