International Journal of Chronic Obstructive Pulmonary Disease

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Are Smart Watches Really Smart? Comparison of Blood Oxygen Saturation Values Measured by Smart Watch, Pulse Oximetry and Arterial Blood Gases in Patients with Chronic Obstructive Pulmonary Diseases

Ümran Toru Erbay[1], Şebnem Emine Parspur[1], İnci Arikan[2], Zeynep Yaren Yılmaz[1], Havva Koçak[3], Feride Marim[1], İlknur Kaya[1], Mehmet Doğan[1]

[1]Department of Chest Diseases, Kütahya Health Sciences University Faculty of Medicine, Kütahya, Turkey; [2]Department of Public Health, Kütahya Health Sciences University Faculty of Medicine, Kütahya, Turkey; [3]Department of Biochemistry, Kütahya Health Sciences University Evliya Çelebi Training and Research Hospital, Kütahya, Turkey

Correspondence: Ümran Toru Erbay, Kütahya Health Sciences University Faculty of Medicine, Department of Chest Diseases, Kütahya, 43100, Turkey, Tel +90 543 216 16 98, Email umran.erbay@ksbu.edu.tr

Objective: Oxygen saturation is an important parameter for the follow-up of Chronic Obstructive Pulmonary Disease (COPD) patients. Pulse oximeters are the most common non-invasive way to assess peripheral blood saturation. Invasive way for this is blood gas analyses. Smart watches are actually developed as sports and physical activity watches in order to be used in daily routine by assessing vital parameters such as heart rate, blood pressure and oxygen saturation. In this sense, they can help better monitoring for patients with COPD on the other hand accuracy of these devices is the major concern.

Background: This study aims to evaluate the correlation of oxygen saturation assessed by smart watch, pulse oximetry and blood gas analyses in COPD patients.

Methods: This is a cross-sectional study evaluating the pulse oximetry technology of smart watch by comparing it real time oxygen saturation measurements of conventional pulse device and arterial blood gas (ABG) analysis in 100 patients with COPD.

Results: A moderate correlation was found between oxygen saturation levels obtained by smart watch, pulse oximetry and ABG.

Conclusion: Smart watches are really smart. Thus, COPD patients can use smart watches to measure oxygen saturation levels in their daily lives. However, SpO2 measurements should be tested in other patient groups and also different degrees of COPD.

Keywords: smart watch, arterial blood gas, COPD, oxygen saturation, pulse oximetry

Introduction

Smart watches, which aim to provide a better assessment and information about people's general physical health, are actually developed as sports and physical activity watches. However, vital parameters such as heart rate, blood pressure, oxygen saturation (SpO_2) can also be used as parameters for monitoring some diseases.[1–4] Daily or continuous measurements would be a simple way for long-term monitoring of patients with chronic diseases and increasing their awareness of their disease status.[2–4] However, the accuracy and reliability of the measurement results of these frequently used devices is an important problem. It is stated in the user manual of smart watches that blood oxygen measurements are designed to monitor general fitness and healthy life.[1–3] However, SpO_2 is an important parameter for controlling respiratory and circulatory function and is particularly important for Chronic Obstructive Pulmonary Diseases (COPD) patients who may derive health benefits from daily measurements.

Received: 12 October 2024
Accepted: 22 March 2025
Published: 13 May 2025

By 2030, the third leading cause of death worldwide is known to be COPD and patients with COPD may suffer from low blood oxygen concentrations and hypoxaemia may worsen with increasing disease severity.[1,2,4] Pulse oximetry which is used to assess peripheral blood SpO_2 is a non-invasive method. Spot control SaO2 measurements with 88–92% thresholds are recommended for detection of hypoxaemia.[2,4] Additionally, despite the great accuracy of pulse oximetry in measuring oxygen saturation when SpO2 > 90%, studies have shown that ABG, although an invasive method, is the gold standard for evaluating clinical parameters in all circumstances.[5,6]

Smart watches can help better monitoring for patients with COPD and provide valuable informations to treating doctors. Furthermore, treatment adjustments can be initiated quickly without delaying oxygen needs until the next visit. Low SpO_2 throughout the day during the periods of physical activity, stress and sleep can be monitored with smart watch tracking. It provides the possibility to collect SpO_2 data at higher time frequencies and over longer time periods. This makes it possible to assess and account for SpO_2 fluctuations in patients with COPD.[2,5–12] In this sense, they can help better monitoring of patients with COPD on the other hand accuracy of these devices is another concern. It is an important step to evaluate the agreement between oxygen saturation measured by a smart watch, pulse oximeter, and blood gas analysis in COPD patients, and thus to assess whether the data obtained from the smart watch is reliable for daily clinical applications. Up to our knowledge, there are studies showing the compatibility between smart watches and pulse oximeter O2 saturation,[2–4,9] however studies comparing the gold standard ABG are very recent and few.[5,6,11]

The aim of this study was to compare the agreement of SpO_2 measured using the smart watch with blood gas and pulse oximetry SpO_2 measurements obtained simultaneously from patients with COPD.

Materials and Methods

Study Design

The study was a cross-sectional study conducted between 01.01.2023–30.06.2023 in Kütahya Health Sciences University Evliya Çelebi Training and Research Hospital Department of Chest Diseases. Blood SpO_2 values of the patients measured by different methods (smart watch, pulse oximetry, ABG) were compared.

Study Sample

A total of 100 COPD patients hospitalised in the Chest Diseases Clinic of Kütahya Health Sciences University Evliya Çelebi Training and Research Hospital were included. Intensive care patients, severely hypoxic patients (SpO_2<70%), patients whose wrist could not be used, and patients who could not be adapt with a smart watch were excluded from the study.

SpO_2 Measurement

Routine SpO_2 measurement was performed with a finger pulse oximeter with the left arm on the table while the patients were resting and sitting, blood SpO_2 measurement was performed simultaneously with a smart watch placed on the wrist of the same arm of the patient, and arterial blood gas was taken simultaneously from the same wrist by an experienced pulmonologist.

"Beurer PO 30 brand pulse oximeter" was used in the measurements and the measurement range of this device, which is manual, mobile and sensorised, is 0–100%. At the same time, Huawei Band 7 smart watch was used. Four LED clusters emitting green, red and infrared light were placed on the back of the smart watch. The smart watch calculates SpO_2 based on the measured ratio of light reflected at different wavelengths. Blood gas measurements were taken in arterial blood gas injectors containing lithium heparin and the samples were measured in the Biochemistry laboratory using a Radiometer cassette-based ABL90 Flex analyser and the results were given as %.

Statistical Analysis

A sample volume of at least 100 was calculated with a 95% confidence interval, effect size: of 0.5, and power of the study: 0.80.[6,7]

The Statistical Package for Social Sciences version 20 (IBM, Armonk, NY, USA) was employed to statistically analyze the results. Categorical variables were expressed as number and percentage, and measurable variables were expressed as mean, minimum, maximum and standard deviation. The conformity of the measured variables to normal distribution was tested by Kolmogorov–Smirnov test.

Two-way randomised intraclass correlation coefficients (ICC) with absolute agreement were used to summarise the relationship between SpO_2 levels measured by fingertip pulsoximetry, ABG and smart watch. By taking the gold standard ABG SpO_2 measurement results, The Bland-Altman method was performed to assess the agreement between the methods used in the study. Linear regression analysis was used to test whether there was a statistically significant bias among the measurements. All p values less than 0.05 at 95% confidence interval were considered to indicate statistical significance.

Results

The mean age of 100 COPD patients was 70.7 ± 8.5 years (min: 47–max: 91) and 85% were male. Congestive heart failure was present in 10%, diabetes mellitus in 30%, hypertension in 43%, hyperlipidaemia in 7% and cerebrovascular events in 2%. According to COPD severity, 33.0% is group A, 11.0% is group B, 56.0% is group E, and 41% had a CAT score of 10 or higher. Mean SpO_2 values were 91.9±5.2 (min: 72–max: 99.3) for ABG measurements, 92.4±3.8 (min: 80–max: 98) for pulse oximetry and 93.7±3.8 (min: 83–max: 99) for smart watch (Table 1).

A moderate correlation was found between smart watch and blood gas SpO_2 measurements (ICC: 0.502, p: 0.004). Bland-Altman analysis revealed a mean error of −1.79% between the watch and blood gas, with limits of agreement ranging from −7.43% to 4.87% (SD: 5.54). Blood gas tends to measure lower SpO_2 levels than the smart watch (Figure 1). According to the

Table 1 Sociodemographic and Clinical Characteristics of the Patient Group

	n (%)	Mean±SD (min–max)
Gender		
Female	85 (85.0)	
Male	15 (15.0)	
Chronic Diseases		
Congestive heart failure	10 (10.0)	
Diabetes mellitus	30 (30.0)	
Hypertension	43 (43.0)	
Hyperlipidaemia	7 (7.0)	
Cerebrovascular events	2 (2.0)	
COPD groups		
A	33 (33.0)	
B	11 (11.0)	
E	56 (56.0)	
Smoking Status		
Never-smoker	22 (22.0)	
Active-smoker	78 (78.0)	
Age		70.7 ± 8.5 (min:47–max:91)
BMI		25.53±5.21 (min:15.7–max:46.9)
CAT score		8.75 ± 2.4 (min:4–max:14)
Mean SpO_2		
ABG		91.9±5.2 (min:72–max:99.3)
Pulse oximetry		92.4±3.8 (min:80–max:98)
Smartwatch		93.7±3.8 (min:83–max:99)

https://doi.org/10.2147/COPD.S500643

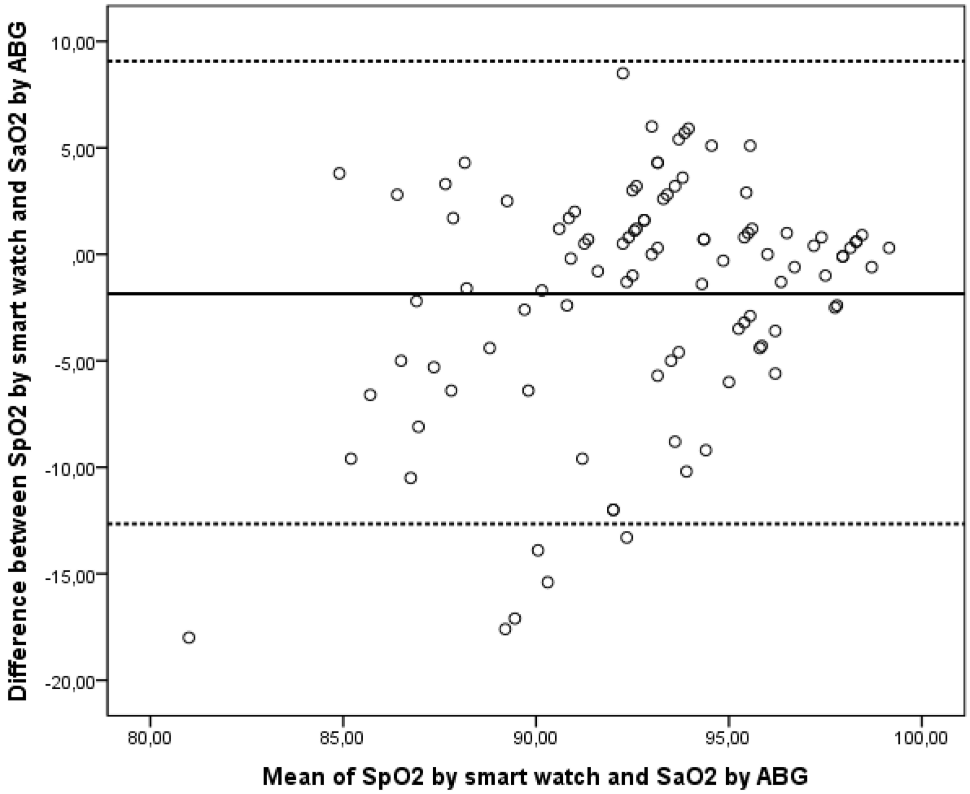

Figure 1 Bland-Altman plot for deviation and limits of agreement between smart watch and blood gas measured SpO_2.

linear regression analysis, it was determined that there was no statistically significant bias between blood gas and smart watch measurements and that two methods provided compatible measurements (R^2: 0.102, p: 0.067).

Bland-Altman analysis showed that the absolute mean difference in SpO_2 between the blood gas and pulse oximetry was 0.52%, with limits of agreement ranging from −8.54% to 9.58% (SD: 4.62). Fingertip pulse oximetry tends to measure lower SpO2 levels than smart watch pulse oximetry (Figure 2). A moderate correlation was found between blood gas and pulse oximetry SpO_2 measurements (ICC: 0.659, p: 0.001). According to the linear regression analysis, it was determined that there was no statistically significant bias between blood gas and pulse oximetry measurements and that two methods provided compatible measurements (R^2: 0.123, p: 0.059).

Discussion

COPD is a chronic respiratory disease causing major morbidity and also mortality as the third leading cause of death worldwide.[13] Respiratory failure is one of the most serious complications of COPD that may cause mortality and hypoxemia is a reliable parameter that indicates respiratory failure in patients with COPD.[10,14] Additionally, the quality of life of hypoxemic patients is seriously impaired. Since symptom variability is seen at a rate as high as 50%, monitorization of SpO2 is vital which is a significant and convenient parameter for the assessment of clinical status of patients.[11,12,15]

In clinical practice, the presence of hypoxemia can be assessed by various methods however the most commonly used non-invasive and practical way to assess SpO_2 is pulse oximetry.[16] Pulse oximetry-based SpO_2 measurement is an effective method that can be used both in hospitalized and ambulatory patients with lung disease.[15,16]

Conventional pulse oximetry technology is a non-invasive, reliable and cost-effective alternative to arterial blood gas analysis which is an invasive way.[11] Additionally, smart watches use the standard pulse oximetry technology to assess peripheral oxygen saturation.

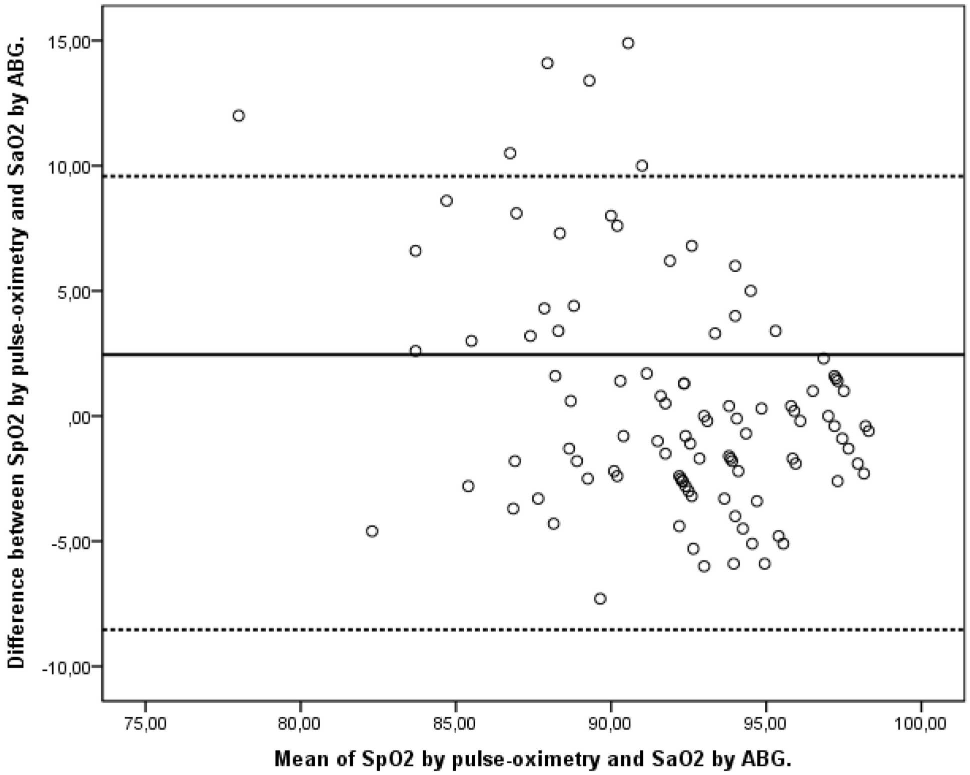

Figure 2 Bland-Altman plot for deviation and limits of agreement between pulse oximetry and blood gas measured SpO_2.

It is a known fact that smart watches are not produced as medical devices. But today they became very popular in digital health field because smart watch pulse oximetry applications are easy to use in daily routine. Healthy individuals and most importantly patients especially with chronic pulmonary diseases who use household oxygen can monitor their SpO_2 using smart watches both at home and outside also may find it more convenient than the commercial pulse oximeters.[17] Additionally, continuous monitoring of blood oxygen saturation can be of great benefit for patients using oxygen therapy.[7]

In literature, there are several studies showing that smart watch pulse oximeters were accurate in comparison with pulse oximetry devices[5,11,17] Although their widespread use for digital health information and despite the existence of studies supporting their reliability, accuracy of the data is still the major concern for smart watches.

In our study, a moderate correlation was found between saturation values of arterial blood gas and pulse oximetry when compared to fingertip pulse oximetry and blood gas also there was a moderate correlation between smart watch and blood gas saturation measurements. Similarly, it was determined that there was no statistically significant difference between the three methods applied simultaneously and that measurements were consistent with arterial blood gas which is the gold standard.

According to our knowledge, there are currently a few studies showing the validation of SpO_2 function of smart watch with arterial blood gas analysis.[5,6,11] In this meaning, our study is one of the rare studies simultaneously comparing the accuracy of SpO_2 measured by using the smart watch with blood gas measurements in patients with COPD.

On the other hand, most of our study population was consisted of COPD patients with low symptom score and severely hypoxemic patients are excluded from the study. So there may be a tendency to present higher values of SpO_2 average which was more than 90% and this may have affected the results. Since our study group has had high SpO_2 values, a statistically significant bias may not have emerged between the measurements. SpO_2 measurements should be tested in other patient groups and at different levels of COPD.

In conclusion, it seems that smart watches are really smart and therefore COPD patients can use smart watches to measure SpO2 levels in their daily lives by consulting their doctors. However, it should not be forgotten that smart watches may not be applicable in outpatient settings until these devices are approved for medical use by FDA. Thus, the results of future studies with different brands and larger study populations are important in this respect.

Limitations

There are some limitations of our study. For instance, our study population was small, a single brand smart watch was used and of course smart watch technology continues to improve day by day. In addition, our study group has had high SpO_2 averages which may have made it easier to obtain measurements and this may be a limitation of the study in terms of generalisation.

Data Sharing Statement

All data used in this study were incorporated into the manuscript, tables, and figures.

Ethical Statement

All procedures of this study were performed in accordance with the guidelines outlined in the Declaration of Helsinki. The study received approval from the Noninvasive Ethics.

Department of the Kütahya Health Sciences University (Decision Number: 2022/11-16).

Informed Consent

Informed consent forms were obtained from all patients.

Funding

The authors declared no financial support.

Disclosure

The authors declare that they have no conflicts of interest in this work.

References

1. GBD Chronic Respiratory Disease Collaborators. Prevalence and attributable health burden of chronic respiratory diseases, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet Respir Med*. 2020;8(6):585–596. doi:10.1016/S2213-2600(20)30105-3
2. Buekers J, Theunis J, De Boever P, et al. Wearable finger pulse oximetry for continuous oxygen saturation measurements during daily home routines of patients with chronic obstructive pulmonary disease (COPD) over one week: observational study. *JMIR mHealth uHealth*. 2019;7(6): e12866. doi:10.2196/12866
3. Kirszenblat R, Edouard P. Validation of the Withings ScanWatch as a wrist-worn reflective pulse oximeter: prospective interventional clinical study. *J Med Internet Res*. 2021;23(4):e27503. doi:10.2196/27503
4. Dalbak LG, Straand J, Melbye H. Should pulse oximetry be included in GPs assessment of patients with obstructive lung disease? *Scand J Prim Health Care*. 2015;33:305–310. doi:10.3109/02813432.2015.1117283
5. Arslan B, Sener K, Guven R, et al. Accuracy of the Apple Watch in measuring oxygen saturation: comparison with pulse oximetry and ABG. *Ir J Med Sci*. 2024;193(1):477–483. doi:10.1007/s11845-023-03456-w
6. Abraham EA, Verma G, Arafat Y, Acharya S, Kumar S, Pantbalekundri N. Comparative analysis of oxygen saturation by pulse oximetry and arterial blood gas in hypoxemic patients in a tertiary care hospital. *Cureus*. 2023;15(7):e42447. doi:10.7759/cureus.42447
7. Pipek LZ, Nascimento RFV, Acencio MMP, Teixeira LR. Comparison of SpO_2 and heart rate values on Apple Watch and conventional commercial oximeters devices in patients with lung disease. *Sci Rep*. 2021;11(1):18901. doi:10.1038/s41598-021-98453-3
8. Behzadi A, Sepehri Shamloo A, Mouratis K, Hindricks G, Arya A, Bollmann A. Feasibility and reliability of smart watch to Obtain 3-Lead Electrocardiogram recordings. *Sensors*. 2020;20(18):5074. doi:10.3390/s20185074
9. Patz C, Michaelis A, Markel F, et al. Accuracy of the apple watch oxygen saturation measurement in adults and children with congenital heart disease. *Pediatr Cardiol*. 2023;44(2):333–343. doi:10.1007/s00246-022-02987-w
10. Lopez-Campos JL, Calero C, Quintana-Gallego E. Symptom variability in COPD: a narrative review. *COPD*. 2013;8:231–238. PMID: 23687444. doi:10.2147/COPD.S42866
11. Jiang Y, Spies C, Magin J, Bhosai SJ, Snyder L, Dunn J. Investigating the accuracy of blood oxygen saturation measurements in common consumer smart watches. *PLOS Digit Health*. 2023;2(7):e0000296. doi:10.1371/journal.pdig.0000296
12. Plüddemann A, Thompson M, Heneghan C, Price C. Pulse oximetry in primary care: primary care diagnostic technology update. *Br J Gen Pract*. 2011;61(586):358–359. doi:10.3399/bjgp11X572553
13. Holtjer JCS, Bloemsma LD, Beijers RJHCG, et al. Identifying risk factors for COPD and adult-onset asthma: an umbrella review. *Eur Respir Rev*. 2023;32(168):230009. doi:10.1183/16000617.0009-2023
14. Korzh N, Ostrovskyy M. Diagnostic value of leptin in chronic obstructive pulmonary disease of the III degree in patients with excessive body weight. *Galician Med j*. 2019;26(4). doi:10.21802/gmj.2019.4.14
15. Singhal A, Prafull K, Daulatabad VS, John NA, John J. arterial oxygen saturation: a vital sign? *Niger J Clin Pract*. 2023;26(11):1591–1594. doi:10.4103/njcp.njcp_2026_21
16. Jubran A. Pulse oximetry. *Crit Care*. 2015;19(1):272. doi:10.1186/s13054-015-0984-8
17. Rafl J, Bachman TE, Rafl-Huttova V, Walzel S, Rozanek M. Commercial smart watch with pulse oximeter detects short-time hypoxemia as well as standard medical-grade device: validation study. *Digit Health*. 2022;11(8):20552076221132127. doi:10.1177/20552076221132127