



DERLEME/REVIEW

Exhaled Carbon Monoxide Measurement Errors: A Systematic Review of Causes and Solutions

Ekshale Edilen Karbon Monoksitin Ölçüm Hataları: Nedenler ve Çözümlerin Sistematik Bir Derlemesi

İzzet Fidancı¹ , Özlem Kızıldaş² 

¹Hacettepe University, Faculty of Medicine, Department of Family Medicine, Ankara, Türkiye

²Seyhan Health Directorate, Adana, Türkiye

ABSTRACT

The review will discuss the various etiologies that lead to a faulty measurement using exhaled carbon monoxide devices, widely utilized in clinical settings, especially with smoking-cessation programs and the assessment of exposure to carbon monoxide (CO). These devices, though of paramount importance in monitoring CO levels, bear errors in measurement that may be immense in significance to clinical decisions and patient outcomes. Some of the other common reasons for faulty readings include calibration errors, different sensor technologies, humidity and temperature, poor breath sampling on the part of the users, and the ageing of devices. Even with an increase in the sensitivity of sensors, their performance can be influenced by both external and internal factors. Periodic recalibration of the devices, their proper use, and updating with advanced technologies are stressed in the review for error-free results. This would aid in overcoming most the problems with exhaled CO measurement devices and enhance their reliability, since continuous and accurate data would be provided for both clinical and emergency use.

Keywords: Carbon monoxide, breath tests, smoking, bias, outcome measurement errors

ÖZET

Klinik ortamlarda, özellikle sigarayı bırakma programları ve karbon monoksit (CO) maruziyetinin değerlendirilmesinde yaygın olarak kullanılan ekshale edilen karbon monoksit cihazları kullanılarak yapılan hatalı ölçümlere yol açan çeşitli etiyolojiler bu derlemede ele alınacaktır. Bu cihazlarda, CO seviyelerinin izlenmesinde büyük önem taşısa da klinik kararlar ve hasta sonuçları açısından büyük önem taşıyabilecek ölçüm hataları olabilmektedir. Hatalı ölçümlerin yaygın nedenlerinden bazıları kalibrasyon hataları, farklı sensör teknolojileri, nem ve sıcaklık, kullanıcılar tarafından kötü nefes örnekleme ve cihazların eskimesidir. Sensörlerin hassasiyetinde artış olsa bile, performansları hem dış hem de iç faktörlerden etkilenebilir. Hatasız sonuçlar için incelemede cihazların periyodik olarak yeniden kalibre edilmesi, uygun şekilde kullanılması ve gelişmiş teknolojilerle güncellenmesi vurgulanmaktadır. Bu, ekshale edilen CO ölçüm cihazlarıyla ilgili sorunların çoğunun üstesinden gelinmesine yardımcı olacak ve sürekli ve doğru veriler hem klinik hem de acil kullanım için sağlanacağından güvenilirliklerini artıracaktır.

Anahtar kelimeler: Karbon monoksit, nefes testleri, sigara içme, önyargı, sonuç ölçüm hataları

Introduction

The Exhalation Breath Test provides a non-invasive and practical method of assessing human health. This test is based on the principle of analyzing various gaseous and dissolved substances present in the breath, which vary according to the physical environment, dietary habits and health status of the individual. The study of these components in the breath can be used to diagnose diseases of the lungs and other organs or to monitor the effectiveness of drug treatments. Carbon monoxide (CO) is a common gas produced by organic combustion and is also produced naturally in the body as a by-product of metabolism. At high concentrations it can bind to hemoglobin and inhibit oxygen transport, while at low levels it may play a role in cellular homeostasis and vascular function. Exhaled CO (eCO) has been studied as a biomarker for several inflammatory conditions, including smoking and lung disease¹.

Correspondence Address / Yazışma Adresi

İzzet Fidancı, Hacettepe University, Faculty of Medicine, Department of Family Medicine, Ankara, Türkiye e-mail: izzetfidanci@gmail.com

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Many devices called exhaled carbon monoxide meters are available for the detection of smoking and carbon monoxide exposure. These devices play a critical role in smoking cessation programs, with an emphasis on the assessment of people-smoking or not-based on their carbon monoxide (CO) levels. They are also used in emergent situations such as fire exposures and carbon monoxide poisoning. Inaccurate measurements may adversely affect clinical decisions leading to inaccurate assessment of patients ²⁻⁵.

There are many factors that contribute to the incorrect results from CO measuring devices. These include calibration errors, the use of different technologies within the devices, conditions of the setting of exposure, user errors, and aging of devices ^{2,3}. Appropriately accurate calibration of the devices, their use under appropriate conditions, and updating them in accordance with new technologies are vital in obtaining accurate results ^{4,5}.

While sensing has improved with the advent of technology, there are many causes externally and internally which affect the measurement accuracy of such devices. Therefore, this review will completely address the causes of inaccurate measurements in carbon monoxide measuring devices and will reveal how these errors can be prevented.

Unlike previous reports that have primarily focused on isolated technical aspects or device-specific performance, this systematic review provides an integrated perspective by synthesizing technological, environmental, user-related, and clinical factors together. In doing so, it offers a comprehensive framework that clarifies how these multiple sources of error interact and presents practical recommendations that go beyond the scope of earlier studies.

Materials and Methods

The review was done in relation to the determination of causes of inaccurate measurements by exhaled carbon monoxide meters. A full description of data sources and methods used is provided below.

Data Sources

Information was sourced from scientific databases: PubMed, Google Scholar, Cochrane, Web of Science, and ResearchGate⁶⁻¹⁰. These databases have the most updated and reliable sources on research concerning the accuracy and reliability of medical devices. Studies reviewed ranged from technological development in carbon monoxide measuring devices to user errors, environmental factors, device calibration problems, and sensor error effects.

- Google Scholar: A search for comprehensive studies on the factors affecting exhaled CO meters' performance.
- PubMed was used to identify reliable articles and reports regarding clinical application of the devices.
- Cochrane: Systematic reviews and meta-analyses of studies that investigated the accuracy and reliability of devices.
- The literature review related to sensor technologies, calibration requirements, and user experiences have been done by conducting both general and academic searches in Web of Science and ResearchGate.

These would include terms like "exhaled carbon monoxide measurement", "CO measurement errors", "calibration errors in CO devices", "environmental factors affecting CO measurement", and "exhaled CO sensor technology". These keywords were used to search for studies between 2010 and 2024.

Selection Criteria

The following were the selection criteria for the reviewed studies:

1. Language: The language was limited to English.
2. Year of Publication: A comprehensive search of the entire literature was conducted, and all relevant studies were systematically reviewed. The earliest publication on this topic was identified in 1994, marking the beginning of the scientific discourse in this field.

3. Type of Study: The types of studies included experimental and observational studies, systematic reviews, meta-analyses and case studies.
4. Inclusion Criteria: We focused on those studies that discussed the factors affecting device performance and described, from that perspective, the various challenges they faced.

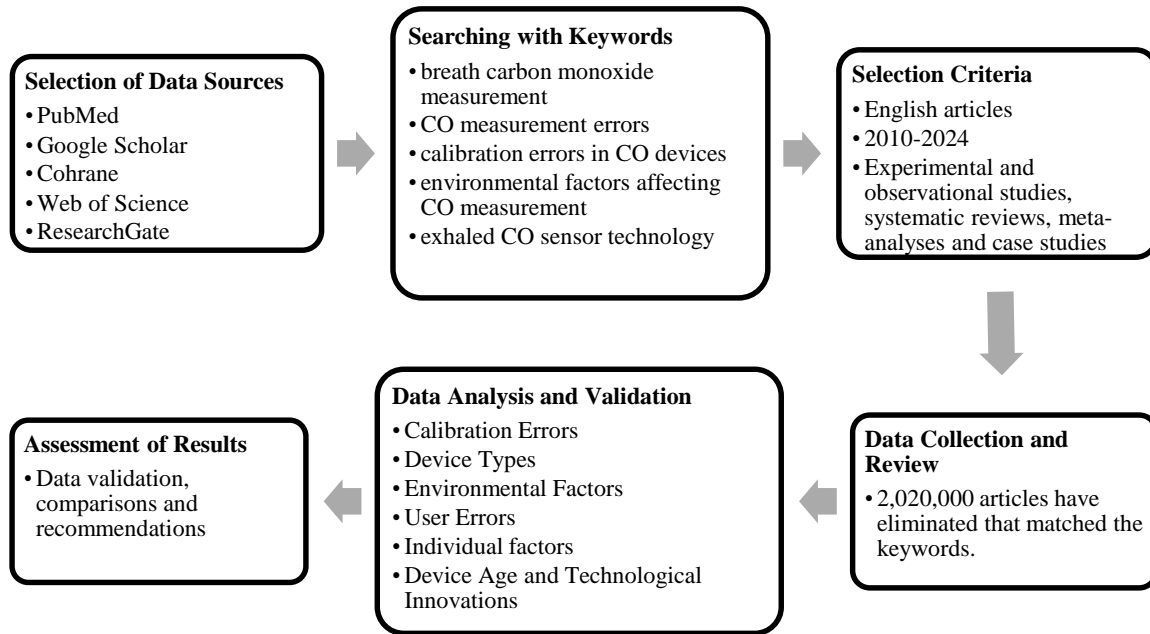


Figure 1. Flowchart of the methodology.

Study Selection and PRISMA Flow

The study selection process was carried out according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. A total of 312 records were identified through electronic database searching (PubMed, Google Scholar, Cochrane Library, Web of Science, ResearchGate) and manual reference screening. After removing 54 duplicates, 258 records remained for title and abstract screening. Of these, 210 were excluded for not meeting the eligibility criteria. The full texts of 48 articles were assessed for eligibility, and 28 were excluded due to insufficient data or methodological limitations. Finally, 20 studies met the inclusion criteria and were included in the systematic review. The PRISMA flow diagram depicting this process is provided in Figure 2.

Results

Data Analysis

The retrieved studies were assessed for the following aspects:

1. Calibration Errors: Calibration errors, which arise because most of the CO measurement devices are not calibrated on a routine basis and performance degradation of sensors over time, were considered for analysis from ^{2,3}.
2. Variations in the Types of Devices and Technologies: Performance variations between devices depending on device technologies (electrochemical sensors, infra-red sensors) were assessed from ⁴.
3. Ambient Environment: A review of how some environmental factors such as ambient temperature, humidity, and air pressure influence the accuracy of the devices has been done ^{5,11}.

4. User Errors: Those made when users do not apply appropriate breathing techniques or fail to use the device in accordance with its instructions were analyzed ¹².
5. Individual factors: In addition to acute and chronic diseases, medication can also affect carbon monoxide measurements ^{13,15-20}.
6. Device Age and Technological Innovations: The aforementioned factors include lower performance from older devices compared with improvements provided by new technologies ^{13,14}. The major factors contributing to errors in exhaled carbon monoxide meters and some suggested solutions to reduce the errors are identified within Table 1.

Data Validation

The results were analyzed using cross-validation from different database studies. Results showed consistency in findings. Comparison of data between systematic reviews and meta-analysis to the results obtained in individual studies showed general trend findings, which pointed out several points that would go on to be considered in the use of the devices.

In the end, the review assessed causes of inaccurate measurements encountered in the exhaled CO meters from different angles and gave recommendations to minimize those errors.

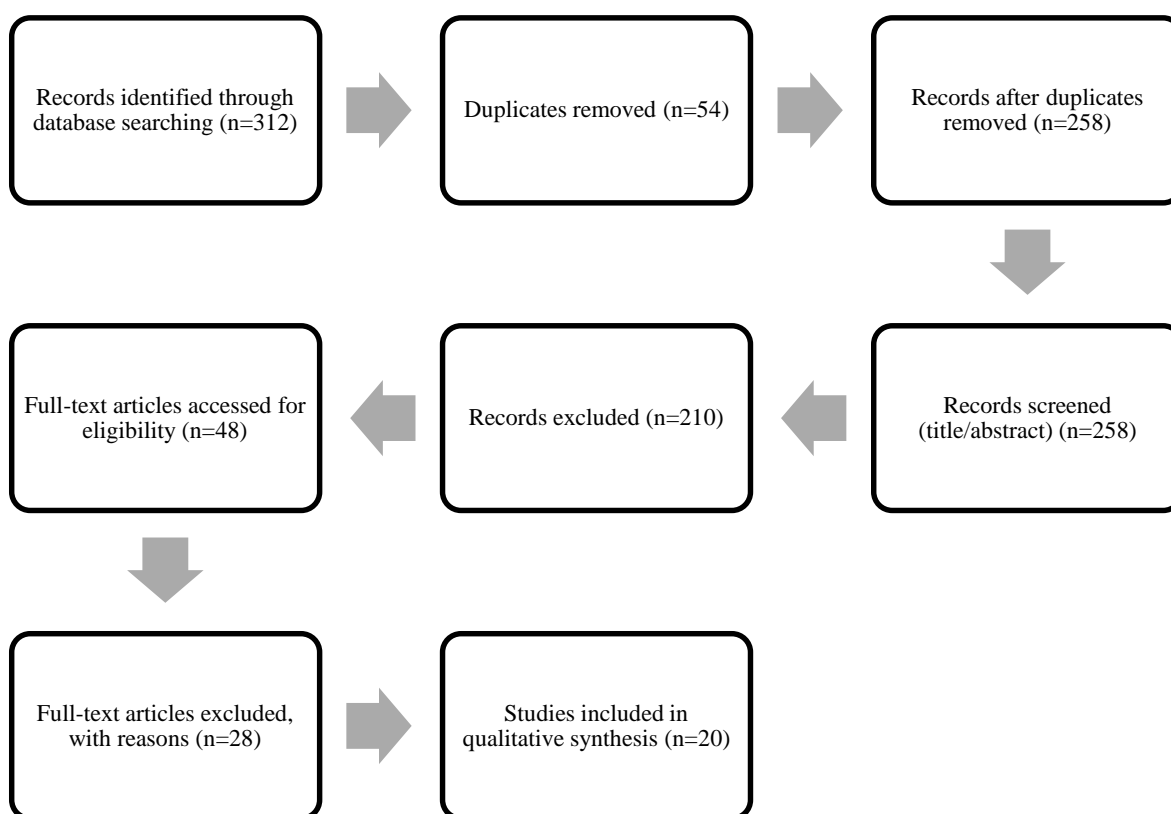


Figure 2. PRISMA flow diagram of study selection process

Table 1. Exhaled carbon monoxide measurement devices: key factors contributing to erroneous measurements

Study Reference	Sample size	Methodology	Key Findings	Device Type (Error Type)	Recommendations
Vreman et al. ² 1994	108 Neonates	Experimental study on semiportable electrochemical instruments	Calibration of CO meters has a significant impact on measurement accuracy	Electrochemical (Calibration Errors)	Regular calibration is essential to maintain accuracy
Bailey et al. ⁴ 1997	23 (precision), 12 (O ₂ sat.), 28 (Hb linearity) Post-op ICU and cardiac catheterization patients)	Evaluation of different sensor technologies	Significant differences found between infrared and electrochemical sensors in accuracy	Spectrophotometric, cuvette-based (Sensor Technology)	Prefer infrared sensors for higher accuracy, though costly
Olson et al. ⁵ 2010	16 Postmortem heart blood samples	Study on environmental impact on CO measurements	High humidity and temperature negatively affect sensor accuracy	Diametrics Medical CO-oximeter; UV spectrophotometer (Environmental Factors)	Perform tests in controlled environments to minimize errors
Sato et al. ¹² 2003	Outpatients with asthma (n=161) and COPD (n=170)	User behavior analysis during CO measurement	Incorrect breathing techniques lead to inaccurate results	Electrochemical sensor-based portable CO monitor (User Errors)	Training users in proper breathing techniques is essential
Montuschi et al. ¹⁸ 2015	10 healthy nonsmokers, 12 healthy smokers, 15 ex-smoker COPD, 15 current smoker COPD (n=52)	Study on CO levels in COPD patients	Exhaled CO levels increase in respiratory infections, leading to misleading results	Electrochemical CO monitor integrated with chemiluminescence analyzer	CO levels should be interpreted cautiously in patients with respiratory infections

Discussion

In contrast to earlier publications that addressed individual sources of error separately, the present review advances the field by systematically integrating evidence across calibration, technology, environmental, and user-related domains, thereby offering a broader and more clinically applicable perspective.

Calibration Errors

Calibration is an important aspect of the instruments in making correct measurements. Unless the instruments are regularly calibrated, the sensors lose sensitivity, thus reflecting incorrect results after some period. In the study done by Vreman et al., it was shown that the calibration of the meters of CO has a great impact on their accuracy². Any lack of calibration might result in the delivery of incorrect results during clinical use. This can prove hazardous during treatments and follow-up with patients. Periodic calibration of instruments should therefore be ensured according to the instructions of the manufacturer and through regular maintenance (Figure 3)³.

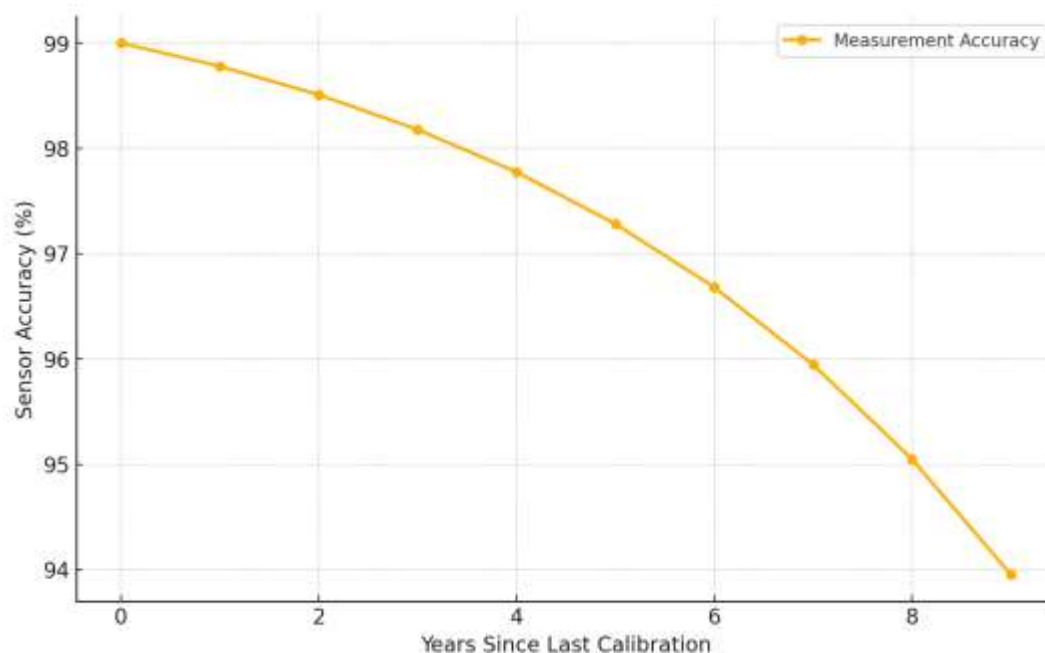


Figure 3. Effect of Calibration Errors on Measurement Accuracy

Variations in the Types of Devices and Technologies: The sensors within CO meters will also differ in type—for example, electrochemical or infra-red—and there are differences in performance between instruments. Generally, the most common sensor type used, the sensitivity and accuracy decrease over time. Infra-red sensors could potentially be less vulnerable to certain environmental factors but may be more costly. While Bailey et al. have clearly illustrated, through their experiments, the performance difference of devices employing different technologies, there is a loss in the sensitivity of electrochemical sensors over their lifetime, which has a negative impact on measurement accuracy ^{4,5}.

Infrared and electrochemical exhaled carbon monoxide meters differ in several technical specifications: the infrared method is very sensitive—in many cases, enabling ppm (parts per million) level measurements—with a response time in milliseconds. However, this usually involves larger instruments and requires regular calibration processes that are rather complex. The response time is generally of the order of seconds with a comparable measurement accuracy and moderate precision from the electrochemical method. In general, electrochemical instruments are smaller and portable, require less regular calibration, and can be easier to use. Each one of these technical features certainly influences the range of applications and user preferences significantly (Table 2) (Figure 4) ^{2-5,11,12}.

Table 2. Comparison of infrared and electrochemical methods for measuring exhaled carbon monoxide

Feature	Infrared (IR)	Electrochemical (EC)
Measurement Sensitivity	High, usually at the ppm level	Medium, usually at the ppm level
Response Time	Usually fast, milliseconds	Usually slower, seconds
Device Size	Often large, difficult to transport	Usually small, portable
Calibration Requirements	Requires regular and complex calibration	Requires less regular and simpler calibration
Possibility of Inaccurate Measurement	It can be affected by environmental conditions (e.g. humidity and temperature changes); the accuracy of the instrument requires regular calibration and maintenance.	Measurement errors can occur due to sensor life and contamination; generally, less affected by environmental conditions.

* Details regarding sample size, study population, and device type corresponding to the studies compared in this table are provided in Table 1.

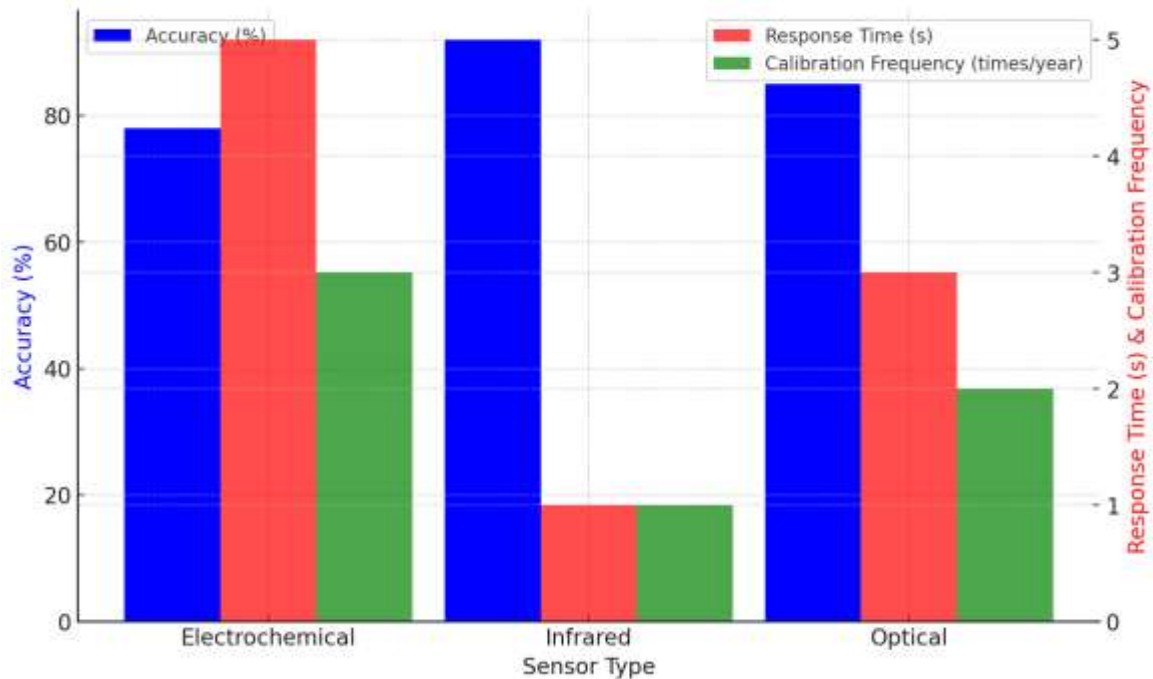


Figure 4. Comparison Of Different Sensor Technologies.

Various technical problems during the measurement of exhaled carbon monoxide with the help of measuring devices can yield incorrect results. A frequent malfunction includes sensor degradation due to time elapsed since, for example, electrochemical and infrared sensors lose their sensitivity with age. Clearly, the regular replacement of sensors or the upgrade to more resistant technologies will do much to alleviate this problem. Moreover, an older edition of firmware or software could also include calculation mistakes; therefore, periodic updating of those with the latest patches is recommended. Other possible problems could be instability in either batteries or power supplies, yielding variable readings, and faulty displays or interfaces could potentially deceive users into interpreting results incorrectly ^{4-5,11}.

Devices are also susceptible to external factors, including electromagnetic interference from other nearby electronics, which can affect sensor performance. Such risks can be minimized by proper shielding and isolation of the device. Besides, defective seals or gaskets may develop air leaks that could interfere with internal pressure and take its toll on the accuracy of sensors. These need to be replaced and inspected routinely to avoid any failure. Finally, blockages in the flow path due to dust, debris, or condensation may interfere with the air reaching the sensor, therefore making the measurement quality poor. Regular maintenance of the device, such as cleaning the device, is very important in the device's proper functioning ^{4-5,11}.

There is no consensus on the appropriate period of smoking abstinence before exhaled CO measurement. Recommendations range from 12 to 24 hours, although some suggest a shorter period such as 20 minutes to 1 hour. This discrepancy in results arises because the period required to be measured would depend on individual metabolism and pattern of smoking, also considering that sometimes the sensitivity of devices may vary. More research needs to be undertaken to make the protocols uniform and enhance test procedures to obtain more clinically valid results ^{5,11,12}.

Ambient Environment

The performance of exhaled CO meters will be influenced directly by the environmental conditions. More precisely, ambient temperature, humidity, and air pressure interfere with correct sensor function. Olson et

al. investigated the effect of environmental conditions on the results of CO measurement and concluded that high humidity had especially affected the accuracy of the devices negatively ⁴. It is consequently appropriate to pay attention to the conditions surrounding the devices in use and, if possible, carry out measures in standardized environments. Other environmental factors that may affect the accuracy of CO meters are ambient temperature and moisture. High levels of humidity interfere with the internal mechanisms and give false results from the instrument. On the other hand, intensely hot or cold air can lead to the failure of sensors to respond appropriately. Sensors may also undermeasure carbon monoxide in conditions of high humidity ^{11,12}.

User Errors

Another significant factor contributing to the accuracy of the results by the exhaled CO meters involves user-created errors. Amongst the major reasons behind faulty results is that individuals operating the device do not apply appropriate breathing techniques or are not following instructions for the use of the device. Inadequate breathing leads to the sensors not making correct measurements. Sato et al. demonstrated that users who did not apply correct breathing techniques obtained incorrect results ¹². It is, therefore, of utmost importance that the users are enlightened on the use of the device and taught the proper techniques. Failure to breathe or use the device in line with instructions could also lead to incorrect measurements. Failure to breathe profoundly might result in a situation where the levels of CO measured by the device may be lower than it is. It is, therefore, essential that the users use the device right and conduct the test accordingly ¹³.

The incorrect measurement of carbon monoxide of smokers is either because of errors in usage or varies according to personal factors. Conditions such as inflammatory processes (respiratory tract infections) could interfere with levels of exhaled CO and further damage the accuracy of measurement. Respiratory tract infection, particularly lower respiratory tract infection, may cause transient inflammation that increases the level of exhaled CO. This may interfere with proper results by combining with CO levels related to smoking^{18,19}.

During an infection of the respiratory tract, inflammation may lead to epithelium destruction and oxidative stress, which increases CO production. This may complicate the evaluation of smoking in patients due to a transient rise in the exhaled CO level. In a study conducted by Montuschi et al., it was stated that in patients with COPD (Chronic Obstructive Pulmonary Disease), the exhaled CO levels increased, and this is representative of the inflammatory response. The situation becomes more complicated in cases of respiratory tract infections since the increase in CO can be independent of smoking as reflected in measurements¹⁸.

All CO exhaled measurements done in the presence of infection should, therefore, be interpreted with a lot of caution. Particularly in inflammatory diseases and acute respiratory tract infections, the levels of CO in exhaled air may mislead one from the facts. Pellegrino et al. identified infection and inflammation as some of the factors that surround the interpretation of pulmonary function tests. According to them, this increased inflammation due to infection might affect the lung function to cause a deviation from the real value of CO measurements (Figure 4)¹⁹.

Individual factors

Most commonly, smoking is evaluated by measuring exhaled CO. However, the measurements may be misleading in patients with chronic diseases and/or using medications. These are conditions of diseases that chronically affect the lungs-particularly COPD and asthma, which might increase endogenous production of CO and give rise to increases. Indeed, in the study performed by Montuschi et al. COPD patients had higher exhaled CO compared to healthy subjects due to increased production of CO because of inflammation in the airways. Similarly, more severe inflammation in asthma may result in increased levels of exhaled CO. However, metabolic diseases including diabetes mellitus may also affect CO through increased systemic inflammation. Increased inflammation and oxidative stress in uncontrolled diabetic patients may raise CO production and make the exhaled CO measurements misleading. For this reason, health professionals assessing smoking should consider this, based on chronic diseases of patients ¹⁸⁻²⁰.

Besides chronic diseases, some medicines applied can change the level of exhaled CO. Anti-inflammatory medication, like corticosteroids, suppresses inflammation in the airways and hence decreases the levels of exhaled CO. These medications, widely used in diseases such as COPD and asthma, might have a direct influence on measurement results by reducing the inflammation. On the other hand, statins have a systemic inflammation-reducing impact that also decreases the levels of exhaled CO. Such drugs can suppress the inflammatory response and result in lower levels of CO. To interpret correctly the results of exhaled CO measurement, the current pharmaceutical treatment of a person must be paid attention to too. In case these effects of drugs and diseases on CO levels are ignored, a wrong result may be obtained, and the process of evaluating smoking can be misleading. It is in this regard that the characteristics of diseases and drugs in the exhaled CO measurements bear serious importance to be considered while making correct clinical decisions¹⁷⁻²⁰.

Measurement errors in exhaled carbon monoxide (eCO) assessment have consequences that extend beyond technical issues and may directly influence both clinical practice and public health. Clinically, misclassification of smoking status due to inaccurate CO readings can lead to inappropriate counselling and failure to provide timely cessation interventions, thereby reducing the effectiveness of treatment programs and follow-up care^{12,17}. In patients with chronic respiratory conditions, such as COPD or asthma, misleading CO values may obscure disease activity and interfere with therapeutic decision-making¹². On a broader scale, inaccurate eCO data can distort smoking prevalence estimates, undermine surveillance of tobacco control measures, and misguide allocation of healthcare resources at the population level^{18,19}. Therefore, improving the accuracy of CO measurement is essential not only for ensuring reliable patient care but also for safeguarding the validity of public health initiatives targeting tobacco use.

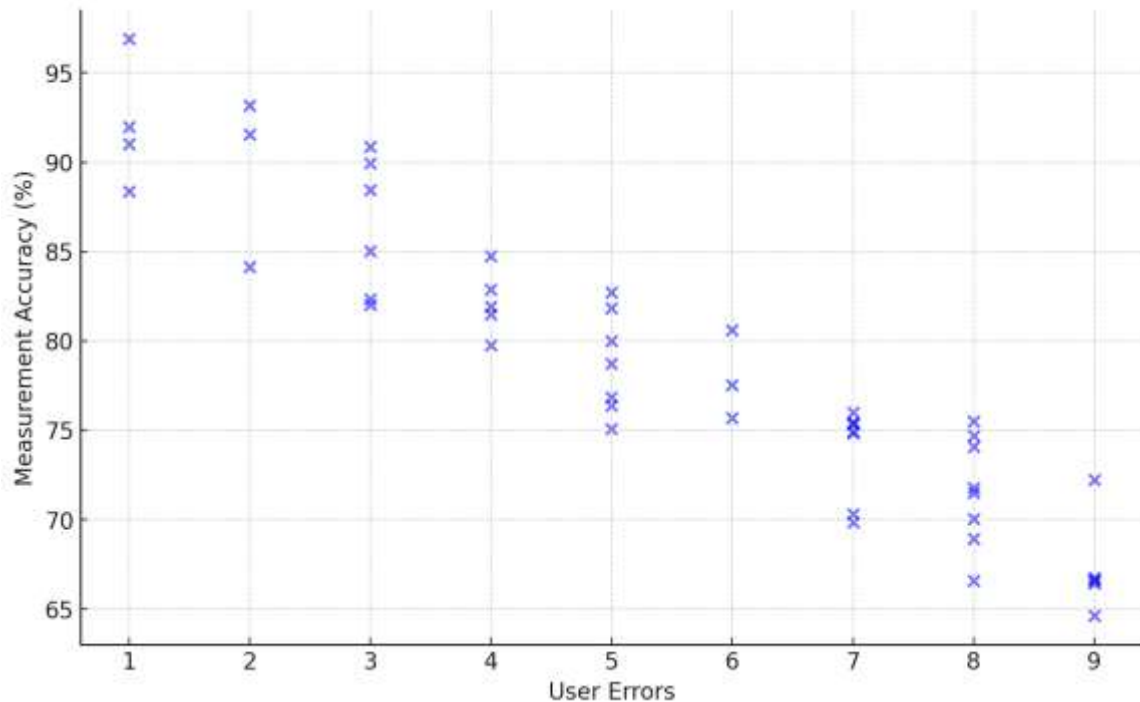


Figure 4. Impact of Environmental Factors on Measurement Error.

Device Age and Technological Innovations

It includes those operating on very outdated technology and the failure to upgrade to new sensor technologies resulting in faulty measurements. It has been observed that older devices remain behind in performance compared to those possessing the latest technological advancements. Wigfield and Hollebne's

studies mentioned that with increased age, the performance of the sensors deteriorates, hence providing an adverse impact on the accuracy of measurement⁸. Regular renewal of the devices by updating them with the latest technologies is thus essential to obtain more reliable results. Generally, sensors lose their accuracy as time passes. Regular checking of the devices and replacing of the sensors should be made when required. Especially in the devices used for a long time, reduced sensitivity of sensors may result in erroneous measurement (Figure 5)¹⁴.

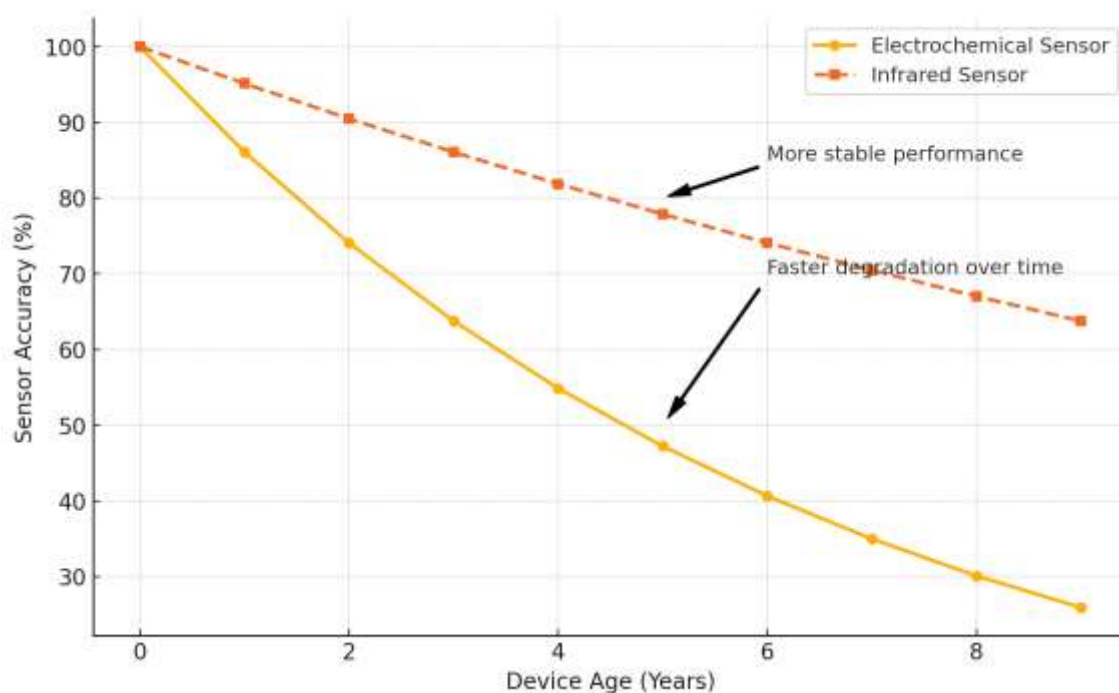


Figure 5. Effect of Device Aging on Sensor Accuracy: Comparison Between Electrochemical and Infrared Sensors.

Conclusion

CO meters play an important role in smoking cessation and in the assessment of acute CO exposure. Usually, the accuracy of a measurement is compromised for several reasons: poorly calibrated devices, outdated sensor technologies, and temperature or humidity environmental influences being only a few. Besides, incorrect breathing by users adds to the inaccuracy of the reading. These, through regular calibration, routine maintenance of devices, and education of users on proper handling, will improve the clinical reliability of the CO meters.

Apparently, in the clinically practical application of exhaled CO measurement assessing smoking status, there is no consensus on what period of abstinence from smoking is advisable before testing. Current recommendations cover very different time periods. This variation owes to individual metabolism, pattern of smoking, and sensitivity of devices which may measure the CO level. Further studies are required to arrive at uniformity in protocols and improvement in testing procedures for more clinically helpful results.

Soon, the development of more advanced CO meters using enhanced sensor technology, which has a much smaller susceptibility to environmental conditions, is likely to result in better diagnostic precision. It would, on the one hand, provide more reliability in the detection of active status, but also acute CO exposure would benefit from it. If this integration into practice by clinicians is done, this would indeed help them to make better judgments for better patient management and sensible smoking cessation programs.

References

1. Ryter SW, Choi AM. Carbon monoxide in exhaled breath testing and therapeutics. *J Breath Res.* 2013;7:017111.
2. Vreman HJ, Stevenson DK, Oh W, et al. Semiportable electrochemical instrument for determining carbon monoxide in breath. *Clin Chem.* 1994;40:1927–33.
3. Mahoney JJ, Vreman HJ, Stevenson DK, Van Kessel AL. Measurement of carboxyhemoglobin and total hemoglobin by five specialized spectrophotometers (CO-oximeters) in comparison with reference methods. *Clin Chem.* 1993;39:1693–700.
4. Bailey SR, Russell EL, Martinez A. Evaluation of the AVOXimeter: precision, long-term stability, linearity, and use without heparin. *J Clin Monit.* 1997;13:191-8.
5. Olson KN, Hillyer MA, Kloss JS, Geiselhart RJ, Apple FS. Accident or arson: is CO-oximetry reliable for carboxyhemoglobin measurement postmortem? *Clin Chem.* 2010;56:515–9.
6. PubMed®. National Library of Medicine. The United States National Library of Medicine (NLM). <https://pubmed.ncbi.nlm.nih.gov> (Accessed: 26 August 2025).
7. Google Scholar. GOOGLE, Alphabet Inc. <https://scholar.google.com.tr> (Accessed: 26 August 2025).
8. Cochrane Library: Cochrane reviews. Wiley. <https://www.cochranelibrary.com>.
9. Web of Science™. Clarivate. <https://www.webofscience.com/wos/woscc/basic-search> (Accessed: 26 August 2025).
10. Researchgate. © 2008-2025 ResearchGate GmbH. <https://www.researchgate.net> (Accessed: 26 August 2025).
11. Ramieri A Jr, Jatlow P, Seligson D. New method for rapid determination of carboxyhemoglobin by double-wavelength spectrophotometry. *Clin Chem.* 1974;20:278–81.
12. Sato S, Nishimura K, Koyama H et al. Optimal cutoff level of breath carbon monoxide for assessing smoking status. *Chest* 2003;124:1749-54.
13. Wigfield DC, Hollebene BR, MacKeen JE, Selwin JC. Assessment of the methods available for the determination of carbon monoxide in blood. *J Anal Toxicol.* 1981;5:122–5.
14. Widdop B. Analysis of carbon monoxide. *Ann Clin Biochem.* 2002;39:122–5.
15. Miller MR, Hankinson J, Brusasco V et al. Standardisation of spirometry. *Eur Respir J.* 2005;26:319-38.
16. Pickering TG, Hall JE, Appel LJ et al. Recommendations for blood pressure measurement in humans and experimental animals: Part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. *Hypertension.* 2005;45:142-61.
17. Middleton ET, Morice AH. Breath carbon monoxide as an indication of smoking habit. *Chest.* 2000;117:758-63.
18. Montuschi P, Kharitonov SA, Barnes PJ. Exhaled carbon monoxide and nitric oxide in COPD. *Chest.* 2001;120:496-501.
19. Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R et al. Interpretative strategies for lung function tests. *Eur Respir J.* 2005;26:948-68.
20. Högman M, Lafih J, Meriläinen P, Bröms K, Malinowski A, Janson C. Extended NO analysis in a healthy subgroup of a random sample from a Swedish population. *Clinical Physiology and Functional Imaging.* 2009;29:18-23.