Signal Acquisition Methods for Vital and Nonvital Parameters in Electronic Health Devices: A Scoping Review

Thiago Cardoso Maia[1*], Maely Guilherme Botelho Coelho Filho[1], Yasmim Batista Oliveira[2], Luiza Zanoni Barbi[2], Thamiles Rodrigues de Melo[1], Valter Estevão Beal[1], Valéria Loureiro da Silva[1]
[1]SENAI CIMATEC University Center; Salvador, Bahia; [2]Academic Association of Technology and Inovation; Vitória, Espírito Santo, Brazil

This paper presents the most common vital and nonvital parameters in current wearable electronic devices, describing the respective signal acquisition methods. We included complete studies in indexed sources and accessible online in the consulted databases between the years 2017 to 2022. Nine studies focused on capturing at least one vital sign. Five addressed HR, four FR, two BP, four SpO_2, and seven body temperature. As for nonvital parameters, half of the total sample approached gait analysis, while one-third addressed non-invasive blood glucose sensors. The preparation of this material aimed to aid the scientific community by summarizing essential information to foster the development of new technologies capable of improving health decisions.
Keywords: Devices. Wearables. Sensory.

Introduction

The investment in wearables in the past few years has been increasing due to the growing unmet needs of health management, defined as the matching between available resources and optimal care. Wearables provide a suitable solution to the challenge of monitoring patients in varying systems of care, inpatient and outpatient, home or office.

Dias and Cunha (2018) [1] classified wearable electronic devices into two large groups: a) activity monitoring, which includes self-monitoring; and b) health-related, subdivided into three areas. The first area is prediction: It helps in clinical management, aiming at a better prognosis.The second area is anomaly detection, which identifies unusual patterns based on machine learning algorithms. Finally, the third area is diagnostic support, which sustains the diagnostic decision as informed by data from wearable devices.

Complementarily, El-Rashidy and colleagues (2021) [2] conceptualize remote monitoring systems in three stages. The first stage is the data acquisition by extracted parameters.

The second defines data transmission and storage for analysis, classification, and processing. Finally, the third stage consists of back-end systems with real-time data that support medical decisions according to patients' status.

Three aspects of technology development can be highlighted in this context: long-term stability, resilience, and biocompatibility [3]. It is thus fundamental to understand the context of wearable electronic device insertion, recognizing that devices increasingly enable bidirectional feedback between healthcare professionals and patients. Such technological advance corresponds to a complementary approach to health systems, favorable to expanding preventive medicine and reinforcing patient-centeredness [4,5].

This scoping review aims to synthesize the current wearable technology literature, focusing on the frequency of distinct methods to acquire vital and nonvital data and on the frameworks that contextualize wearable electronic devices.

This review has four primary purposes:

- Specifying vital and nonvital parameters most used in wearables;
- Elucidating the respective methods of capturing data;
- Describing the respective validation

Received on 25 September 2022; revised 30 November 2022.
Address for correspondence: Thiago Cardoso Maia. Rua Pedro Fonseca, 170, Monte Belo - Vitória - ES, Brazil. Zipcode: 29053-280. E-mail: thiago.maia@medsenior.com.br.
DOI 10.34178/jbth.v5i4.253.

J Bioeng. Tech. Health 2022;5(4):286-292

experiments, including both positive and negative technological consequences

- Discussing the applications of wearables.

Materials and Methods

The scoping review was the chosen study design to clarify, group, and synthesize the most relevant current knowledge about wearable electronic devices. First, the population, concept, and context (PCC) strategy was defined: a) in terms of population as non-invasive wearable electronic devices; b) concerning the concept as categorically presenting the means of capturing the vital parameters processed by such wearables; c) regarding the context as health care at primary, secondary and tertiary levels. From this, the question was established: What is the most relevant scientific evidence for capturing vital parameters in wearable health sensors? To answer this question, different types of literature were searched, including qualitative and quantitative analysis, primary studies, systematic reviews and scope reviews, master's dissertations, or doctoral theses published in journals or scientific conferences, in English or Portuguese, in available indexed sources. Studies on augmented reality (absence of technology in Software\Hardware) were excluded, as well as those that could have presented the methods for capturing vital and nonvital parameters. Besides, documents that presented non-wearable or non-portable hardware or described transcutaneous data capture methods were excluded.

The databases used were: Virtual Health Library (VHL), EMBASE for Excerpta Medica dataBASE (EMBASE), Google Scholar, and Online System of Search and Analysis of Medical Literature (Medline). To search the databases, controlled descriptors referenced by DeCs/MeSH were established, crossed with keywords in English, using the Boolean operator "AND". The review was restricted to studies published between 2017 to 2022. Table 1 described the detailed search strategy.

Observing Table 1, the Google Scholar search was used to ensure the retrieval of current and potentially eligible studies for this review. For this reason, four independent searches were carried out in this database, combining the descriptors and keywords since the unified search was impossible due to the number of characters. Thus, the articles from the first ten pages of the first search were included (100 articles), in addition to the first page of 10 first articles from other searches (30 articles), resulting in a total of 130 articles. All articles from the search strategies were initially selected from the other databases.

The articles were independently selected by title and abstract by two reviewers to minimize the risk of selection bias. Disagreements during the inclusion process were discussed between the reviewers and a final agreement was reached. After this initial phase, the full-text version of included studies was retrieved and read by reviewers. Reviewers extracted the following parameters from the included studies: identification of the selected material; year of publication; authors; language; study design, and inferred results, enabling the identification of similarities, differences, and complementarities. The Flowchart (Figure 1) depicts details in the inclusion and exclusion process, consistent with the PRISMA Guidelines.

Results and Discussion

The search in the four databases resulted in 316 articles; of these, 12 we selected for the final sample. Table 2 describes the studies in English. There is also regularity in the frequency of publication of articles per year related to the theme in the last decade: 2017 (8.33%), 2018 (8.33%), 2019 (25.00%), 2020 (16.66%), 2021 (25.00%) and 2022 (16.66%). It confirms the significant investment in the development of wearable sensors for health in recent years.

Up to 75% of studies focused on capturing at least one vital sign. Of these, 5 described HR uptake (55.55%), 4 addressed RF (44.44%), 2 acquired BP measurement (22.22%), 4 had SpO_2 (44,44%),

Table 1. Search strategy in the databases used to survey the literature.

Database	Strategy	Articles
BVS	(“Wearable Electronic Devices”) AND (“Vital Signs” OR Glucose) AND (“Health care”)	28
EMBASE	(‘wearable electronic devices’ OR ‘wearable sensors’ OR ‘health wearables’) AND (‘vital sign’/exp OR ‘arterial oxygen saturation’/exp OR ‘gait’/exp OR ‘walking speed’/exp OR ‘walking pace’ OR ‘glucose’/exp OR ‘body equilibrium’ exp OR ‘body equilibrium’ OR ‘body sway’ OR ‘equilibrium, body’ OR ‘musculoskeletal equilibrium’ OR ‘postural balance’ OR ‘postural equilibrium’) AND (‘primary health care’/exp OR ‘first line care’ OR ‘health care, primary’ OR ‘primary care nursing’ OR ‘primary health care’ OR ‘primary healthcare’ OR ‘primary nursing care’ OR ‘tertiary health care’/exp OR ‘health care delivery’/exp OR ‘community care’/exp OR ‘hospitals, rehabilitation’ OR ‘health care’/exp OR ‘care, health’ OR ‘comprehensive health care’ OR ‘health care’ OR ‘health system’ OR ‘healthcare’ OR ‘long stay care’) #1 AND (2017:py OR 2018:py OR 2019:py OR 2020:py OR 2021:py OR 2022:py)	147
Google Scholar	(“Wearable Electronic Devices” OR “Wearable sensors” OR “Health wearables”) AND (“Vital Signs”) AND (“Health care”) (“Wearable Electronic Devices” OR “Wearable sensors” OR “Health wearables”) AND (“Gait Analysis” OR “Walking speed”) AND (“Health care”) (“Wearable Electronic Devices” OR “Wearable sensors” OR “Health wearables”) AND (Glucose) AND (“Health care”) (“Wearable Electronic Devices” OR “Wearable sensors” OR “Health wearables”) AND (“Oxygen Saturation“) AND (“Health care”)	130
MedLine	Wearable Electronic Devices.mp. or Wearable Electronic Devices/ OR Wearable sensors.mp. OR Health wearables.mp. AND vital signs/ or blood pressure/ or body temperature/ or heart rate/ or respiratory rate/ OR Oxygen Saturation.mp. OR gait analysis/ or walking speed OR walking pace.mp. or Walking Speed/ OR Blood Glucose/ or Glucose.mp. OR Postural Balance.mp. or PosturalBalance/ AND Primary Health Care.mp. or Primary Health Care/ OR Tertiary Healthcare.mp. or Tertiary Healthcare/ OR Community Health Services.mp. or Community Health Services/ OR Hospitals, Rehabilitation.mp. or Hospitals, Rehabilitation/ OR Delivery of Health Care.mp. or “Delivery of Health Care”/	11

Figure 1. Prisma 2020 flow diagram (adapted) of the article selection process.

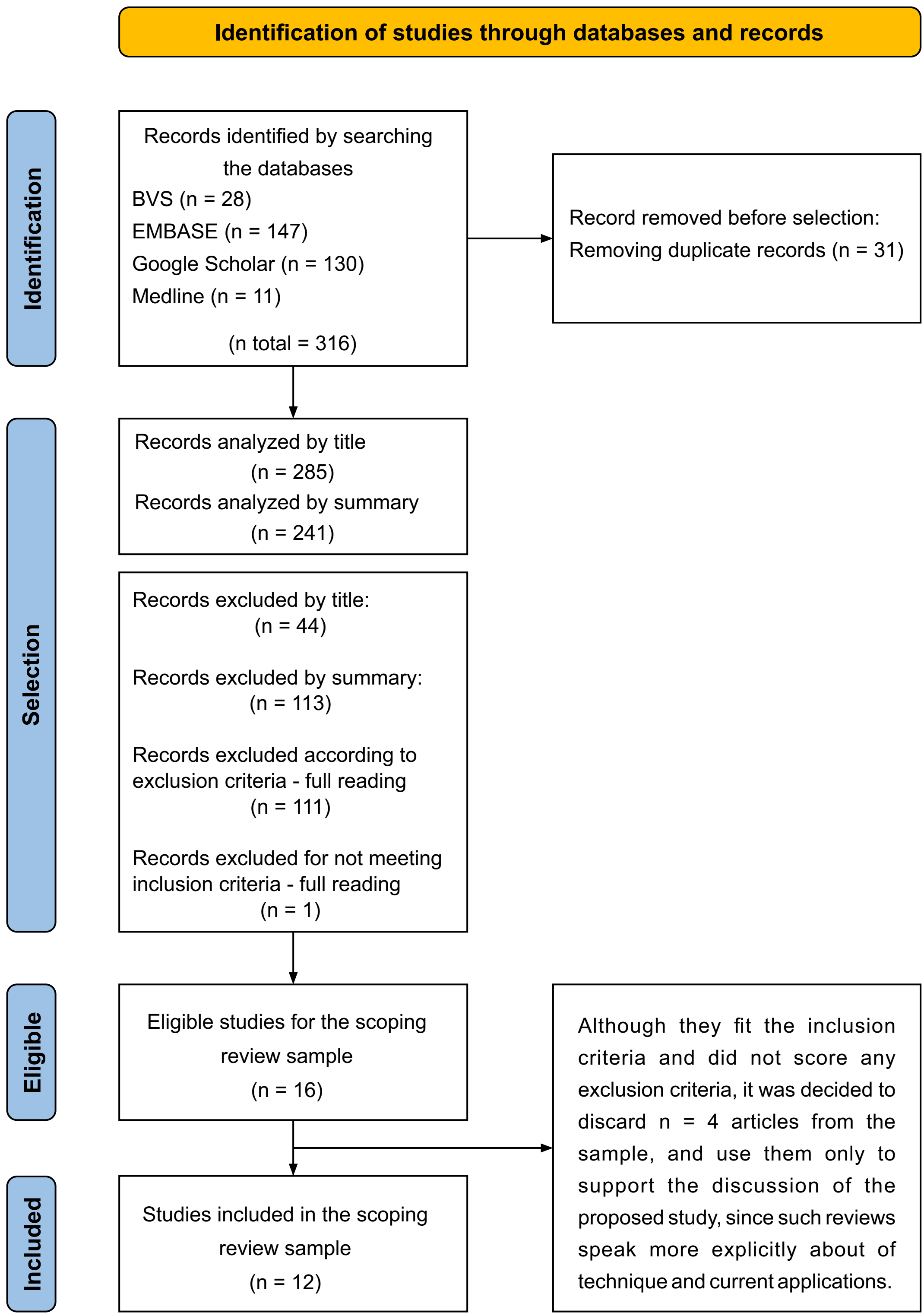

Table 2. Simplified description of selected studies.

Author	Title	Publication	Language	Study Type
Majumder and colleagues [6]	Wearable sensors for remote health monitoring	2017	English	Narrative review
Siddiqui and colleagues [7]	Pain-free blood glucose monitoring using wearable sensors: Recent advancements and future prospects	2018	English	Scope narrative
Yinji and colleagues [8]	Flexible hybrid electronics for digital healthcare	2019	English	Prospective observational
Weenk and colleagues [9]	Wireless and continuous monitoring of vital signs in patients at the general ward	2019	English	Randomized controlled trial
Witt and colleagues [10]	Windows into human health through wearables data analytics	2019	English	Literature review
Celik and colleagues [11]	Gait analysis in neurological populations: Progression in the use of wearables	2020	English	Scope narrative
Purohit and colleagues [12]	Smartphone-assisted personalized diagnostic devices and wearable sensors	2020	English	Scope narrative
Areia and colleagues [3]	A chest patch for continuous vital sign monitoring: Clinical validation study during movement and controlled hypoxia	2021	English	Prospective Cohort, observational cross-sectional
Haveman and colleagues [4]	Continuous monitoring of vital signs with the Everion biosensor on the surgical ward: A clinical validation study	2021	English	Prospective observational double-blind
Mejia Cruz and colleagues [13]	Walking Speed Measurement Technology: A Review of 2021	2021	English	Literature review
Haveman and colleagues [5]	Continuous monitoring of vital signs with wearable sensors during daily life activities: Validation study	2022	English	Validation study, Prospective observational
Yoon and colleagues [14]	Multifunctional hybrid skin patch for wearable smart healthcare applications	2022	English	Experimental

and 7 quantified body temperature (77.77%). In addition, one study analyzed the accuracy of detecting arrhythmias and normal cardiac rhythm. Regarding nonvital parameters, half of the total sample addressed, alone or not, wearables with a focus on gait analysis, while one-third addressed non-invasive blood glucose sensors.

Regarding body location chosen for wearable electronic devices, seven studies (31.81%) described bracelets, and three reported a chest patch (13.63%). The same proportion of studies described fingers, soles, and the hip (9.09%) as body location, whereas earlobe, spines, upper arm, lower limbs, and ring were described by 4.54% of the sample (i.e., one study each).

Based on the frequency of methods to capture vital and nonvital parameters, five categories were defined in this scoping review:

1. Types of sensors;
2. Acquisition methods covered in this scoping review;
3. Preferred insertion body sites for each type of sensor;
4. Available wearable electronic devices found and health outcomes.

Five vital parameters were reported for continuous patient monitoring, which is associated with better health outcomes: heart rate (HR), respiratory rate (RR), blood pressure (BP), blood oxygen saturation (SpO_2), and body temperature [9]. Regarding nonvital parameters, published studies tended to report on gait analysis – including counting steps and detecting the risk of falls [13] – and non-invasive glucose monitoring [7]. As such, continuous and remote monitoring of vital parameters, added on-demand to nonvital parameters, are tools for healthcare professionals to foster better care.

Conclusion

This scoping review presents a survey of wearable continuous monitoring systems aimed at the health area, focusing on acquiring vital and nonvital signs. In addition, there is an essential search for increasingly portable and preferably multisensory technologies, culminating in savings in health resources and greater patient engagement. It is inferred that the purpose of using wearable electronic devices is to contribute to optimizing and complementing the human work performed by health professionals, ensuring continuous surveillance and consequent improvement of patient care. It was found that continuous monitoring through wearable sensors, including data analysis and predictive algorithms, added to health interoperability. And it promotes better decision-making by professionals, greater assertiveness in decision-making and clinical outcome, better prognosis, and a shortening of the care journey time. Although not to exhaustion, the present study sought to provide a synthesized material capable of supporting the scientific community, encouraging the elaboration and development of new wearable technologies capable of facilitating and maximizing the improvement of decision-making in the health area.

References

1. Dias D, Cunha JPS. Wearable health devices—Vital sign monitoring, systems and technologies. Sensors 2018;18(8):2414. https://doi.org/10.3390/s18082414.
2. El-Rashidy N, El-Sappagh S, Riazul Islam SM, Hazem M, El-Bakry, Abdelrazek S. Mobile health in remote patient monitoring for chronic diseases: Principles, trends, and challenges. Diagnostics 2021;11(4):607. https://doi.org/10.3390/diagnostics11040607.
3. Areia C et al. A chest patch for continuous vital sign monitoring: Clinical validation study during movement and controlled hypoxia. 2021; 28 Abr:1-10.
4. Haveman M et al. Continuous monitoring of vital signs with the Everion biosensor on the surgical ward: A clinical validation study. Expert Review of Medical Devices 2021;18:sup1:145-152. DOI: 10.1080/17434440.2021.2019014.
5. Haveman M et al. Continuous monitoring of vital signs with wearable sensors during daily life activities: Validation study. JMIR Formative Research 2022:1-16.
6. Majumder S, Mondal T, Deen MJ. Wearable sensors for remote health monitoring. Sensors 2017:1-45.
7. Siddiqui S et al. Pain-free blood glucose monitoring using wearable sensors: Recent advancements and

future prospects. IEEE Reviews in Biomedical Engineering 2018.
8. Yinji M et al. Flexible hybrid electronics for digital healthcare. Advanced Materials 2019:1-23. https://doi.org/10.1002/adma.201902062.
9. Weenk M et al. Wireless and continuous monitoring of vital signs in patients at the general ward. Elsevier 2019:47-53.
10. Witt DR, Kellogg RA, Snyder MP, Dunn J. Windows into human health through wearables data analytics. Current Opinion in Biomedical Engineering 2019;9:28-46.https://doi.org/10.1016/j.cobme.2019.01.001.
11. Celik Y, Stuart S, Woo WL, Godfrey A.Gait analysis in neurological populations: Progression in the use of wearables. Medical Engineering & Physics 2021;87:9-29. https://doi.org/10.1016/j.medengphy.2020.11.005.
12. Purohit B, Kumar A, Mahato K, Chandra P. Smartphone-assisted personalized diagnostic devices and wearable sensors, Current Opinion in Biomedical Engineering 2020;13:42-50. https://doi.org/10.1016/j.cobme.2019.08.015.
13. Mejiacruz Y et al. Walking speed measurement technology: A review. Current Geriatrics Reports 2021:1-19.
14. Yoon S et al. Multifunctional hybrid skin patch for wearable smart healthcare applications. Biosensors and Bioelectronics 2022;196:113685. https://doi.org/10.1016/j.bios.2021.113685.