Review

Sensor technologies to detect out-of-hospital cardiac arrest: A systematic review of diagnostic test performance

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Abstract

Aim: Cardiac arrest (CA) is the cessation of circulation to vital organs that can only be reversed with rapid and appropriate interventions. Sensor technologies for early detection and activation of the emergency medical system could enable rapid response to CA and increase the probability of survival. We conducted a systematic review to summarize the literature surrounding the performance of sensor technologies in detecting OHCA.

Methods: We searched the academic and grey literature using keywords related to cardiac arrest, sensor technologies, and recognition/detection. We included English articles published up until June 6, 2022, including investigations and patent filings that reported the sensitivity and specificity of sensor technologies to detect cardiac arrest on human or animal subjects. (Prospero\# CRD42021267797).

Results: We screened 1666 articles and included four publications examining sensor technologies. One tested the performance of a physical sensor on human participants in simulated CA, one tested performance on audio recordings of patients in cardiac arrest, and two utilized a hybrid design for testing including human participants and ECG databases. Three of the devices were wearable and one was an audio detection algorithm utilizing household smart technologies. Real-world testing was limited in all studies. Sensitivity and specificity for the sensors ranged from 97.2 to 100% and 90.3 to 99.9%, respectively. All included studies had a medium/high risk of bias, with 2/4 having a high risk of bias.

Conclusions: Sensor technologies show promise for cardiac arrest detection. However, current evidence is sparse and of high risk of bias. Small sample sizes and databases with low external validity limit the generalizability of findings.

Keywords: Cardiac Arrest, OHCA, Arrhythmia, 9-1-1, Emergency Medical System, Wearables, Health technology, Sensors, Implantable sensor

Introduction

Out-of-hospital cardiac arrest (OHCA) is a major population health issue in the US and Canada, resulting in the death of 430,000 per year.\textsuperscript{1,2} Survival to hospital discharge in North America ranges from 5 to 7 % for Emergency Medical Services (EMS)-attended OHCA, and an estimated 18 % of discharged patients experience moderate to severe long-term functional impairment.\textsuperscript{2} OHCA is highly time-sensitive and requires immediate intervention to maximize chances for survival to hospital discharge and recovery.\textsuperscript{3-4} One of the major barriers to increasing survival from this condition is that approximately-one-half of OHCA are “unwitnessed”: cases where no bystanders are present to activate the emergency medical system and provide immediate life-saving interventions.\textsuperscript{5}

Unwitnessed OHCA occurs in isolation, preventing the prompt administration of critical interventions through bystander recognition and action. While survival to hospital discharge from witnessed OHCA has been estimated to be approximately 10.5 %, survival to hospital discharge from treated but unwitnessed OHCA is even lower at approximately 4.4 %.\textsuperscript{6} Further, approximately half of unwitnessed cardiac arrests are not treated at all by EMS due to delays in recognition and subsequent EMS arrival, resulting in an assessment of futility.\textsuperscript{7-8} One intervention that has been proposed to address the problem of unwitnessed OHCA is to integrate the use of health sensors (technologies that measure physiological parameters for moni-
We included studies that: (1) were conducted with mammalian participants; (2) evaluated the performance of sensor technologies to detect cardiac arrest (or ventricular tachycardia/fibrillation), either through direct circulatory monitoring or monitoring of associated parameters (such as tissue temperature, arterial oxygen saturation, movement, respiratory rate, abnormal respirations, etc., or any combination); (3) have feasible utility in the out-of-hospital consumer setting. Sensor technologies include wearable technologies (e.g., watch, patch, textiles), non-wearable technologies (e.g., computer vision, audio monitoring, movement sensor, etc.), as well as implantable devices. To satisfy our inclusion criteria for evaluating sensor performance, studies must have reported sensitivity (the ability of the sensor to correctly identify cases of cardiac arrest) and/or specificity (the ability of the sensor to correctly identify cases that do not have cardiac arrest) to detect cardiac arrest.

Full-text case reports, observational studies, clinical trials, and meta-analyses investigating the performance of sensor technologies to detect cardiac arrest from January 1, 1950 to June 6th, 2022 were included in the search. Mixed methods studies were only included if data from the quantitative component could be clearly extracted. Although review articles that did not include meta-analyses were not eligible for this review, the reference lists of relevant review articles were searched for additional eligible studies.

Methods

Design & search strategy

This systematic review was reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols extension for Diagnostic Test Accuracy studies (PRISMA-DTA) checklist and was registered with PROSPERO (CRD42021267797).

We conducted a literature search of PubMed, MEDLINE, Web of Science, COMPENDEX, Science Direct, and EMBASE, to identify studies that investigated recognition and/or detection of cardiac arrhythmias or cardiac arrest, and at least one of the following factors: wearable sensors; non-wearable sensors; health technologies; implantable sensors. The keywords used were Medical Subject Headings (MeSH) related to the parameters of interest and were combined using AND and OR logistic operators. The full search strategies used for all databases are shown in Appendix A, Table A1.

In addition, we conducted a search of grey literature to identify any commercial technologies or patent descriptions for sensors that detect cardiac arrest. We searched the internet for company websites and press release articles using the Google search engine, as well as registered patents using Google Patents. For both searches, the terms “cardiac arrest”, “device”, and “continuous monitoring and detection” were combined with the AND logistic operator.

Inclusion criteria

We included studies that: (1) were conducted with mammalian participants; (2) evaluated the performance of sensor technologies to detect cardiac arrest (or ventricular tachycardia/fibrillation), either through direct circulatory monitoring or monitoring of associated parameters (such as tissue temperature, arterial oxygen saturation, movement, respiratory rate, abnormal respirations, etc., or any combination); (3) have feasible utility in the out-of-hospital consumer setting. Sensor technologies include wearable technologies (e.g., watch, patch, textiles), non-wearable technologies (e.g., computer vision, audio monitoring, movement sensor, etc.), as well as implantable devices. To satisfy our inclusion criteria for evaluating sensor performance, studies must have reported sensitivity (the ability of the sensor to correctly identify cases of cardiac arrest) and/or specificity (the ability of the sensor to correctly identify cases that do not have cardiac arrest) to detect cardiac arrest.

Full-text case reports, observational studies, clinical trials, and meta-analyses investigating the performance of sensor technologies to detect cardiac arrest from January 1, 1950 to June 6th, 2022 were included in the search. Mixed methods studies were only included if data from the quantitative component could be clearly extracted. Although review articles that did not include meta-analyses were not eligible for this review, the reference lists of relevant review articles were searched for additional eligible studies.

Study selection

All identified citations were loaded into the online Joanna Briggs Institute (JBI) System for the Unified Management of the Assessment and Review of Information (SUMARI) system.13 After the removal of duplicates, titles and abstracts were screened by two independent reviewers (JH and SL) for assessment against the inclusion criteria. Potentially relevant studies progressed to full-text screening. Reasons for exclusion of full text reviewed studies that do not meet the inclusion criteria were recorded and included in Fig. 1. At this step, the reference lists of all excluded review articles were uploaded into the review software for a second round of title and abstract screening followed by full-text screening. Any disagreements that arose between the reviewers at each stage of the study selection process were resolved through discussion in reference to the inclusion/exclusion criteria.

Risk of bias assessment and data extraction

Studies selected for inclusion were appraised by two independent reviewers (JH and SL) for methodological validity using the University of Bristol Quality Assessment of Diagnostic Accuracy Studies-2 tool (QUADAS-2).14 Any disagreements that arose between the reviewers were resolved through discussion in reference to the QUADAS-2 checklist.

Data were extracted from the appraised studies by two independent reviewers (JH and SL) using a data extraction instrument for evaluating studies for diagnostic test accuracy in Joanna Briggs Institute (JBI) SUMARI.15 Extracted data include details about the population (participant demographics and sample size), context (period that study was carried out, geographical location, setting, persons executing and interpreting reference/index tests, etc.), technology tested (index and reference tests), study methods, and reported accuracy of the technology (sensitivity, specificity, false positives/negatives). The extracted parameters are summarized in Appendix B. Any disagreements that arose between the reviewers were resolved through discussion in reference to the digital data extraction instrument. Due to the heterogeneity of evaluated technologies and methodologies, we did not conduct a meta-analysis and report results following the Synthesis Without Meta-analyses (SWiM) guidelines.16

Results

Results of published literature search

Our search of the published literature retrieved 1307 citations. Results of the search are detailed in a PRISMA flow diagram (Fig. 1). We identified an additional 681 citations for screening from the reference lists of review articles in the initial search. Together, this produced 1666 citations after duplicates were removed. All titles and abstracts were assessed according to our inclusion criteria for initial screening, followed by more detailed full-text screening. One study which described an implantable cardiac arrest sensor, but in testing utilized an alternate electrode, was excluded but described in Appendix D. Four studies met our criteria to be included in this review. The full results of the risk of bias assessment can be found in Appendix C.
Results of grey literature search

The search of company websites and press release articles as well as registered patents on the Google search and Google patent engines was conducted on the 6th of June, 2022, and produced approximately 9,600,000 and 18,700 results, respectively. For both searches, screening was limited to the first 20 pages of results (a total of 400 search results) due to results on later pages losing relevance with regards to the search terms. There were four results from these searches that were selected for further screening. One of the four selected technologies, The Heart Sentinel App by Gaibazzi et al., also appeared in our search of published literature and was included in our review as one of the five selected published literature studies. The remaining three grey literature technologies were excluded, as no data on sensor performance was available but are described in Appendix D.

Characteristics of included studies

The study characteristics are summarized in Table 1. All included studies were published in English in full-text research articles published between 2006–2022, reporting the results of primary research efforts. All included studies utilized a quasi-experimental design and reported at least one of sensitivity or specificity to detect cardiac arrest or an associated parameter. Of the four included studies, two were at “High” risk of bias, and the remaining two were at “Medium” risk of bias. We found no randomized control trials on this topic. Sensor test performance is summarized in Table 2.

Rickard et al. (2011) tested a wearable watch-based device (the Wriskwatch) for recognition of pulselessness. Pulselessness was achieved by two methods: (1) applying a blood pressure cuff to occlude the brachial artery (pulselessness confirmed with human palpation), and (2) inducing ventricular fibrillation (VF) during implantable cardioverter defibrillator (ICD) implantation surgery (VF was confirmed by a cardiologist). The study enrolled 34 patients; however, excluded several participants prior to analysis primarily due to poor signal. Among the 21 participants analyzed in the blood pressure occlusion group (17 cases, and 4 controls), the device identified pulselessness in 16/17 (sensitivity = 94 %) and correctly identified no loss of pulse in 3/4 (specificity = 75 %). Among the 8 participants analyzed in the ICD VF group, pulselessness was correctly identified by the device at the time of VF in 7/8 (sensitivity 89 %). Investigators also calculated the sensitivity and specificity of the device to detect pulselessness in individual 15-s time intervals, using observation data from all patients combined.

Sugano et al. (2011) introduced an integrated remote healthcare system composed of a wireless vital signs monitoring sensor, multiple receivers, and a triage engine installed in a personal computer. The study team described the physical sensor as a commercially available wearable patch in Japan which can continuously measure ECG, body surface temperature, and 3D acceleration for 48 hours, but did not specify the exact sensor used. The objective was to demonstrate sensor classification accuracy for the recognition of daily activities (e.g. walking, running, lying, etc.), as well as lethal

Fig. 1 – Article selection process (PRISMA Flow-Chart) and exclusion tags.
Table 1 – A summary of the included papers and study characteristics after full-text screening.

| Article           | Setting                                      | No. of Samples                                                                 | Outcome                                      |
|-------------------|----------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------|
| Rickard et al., 2011 | 1. Clinical  
2. Clinical                         | 1. Blood Pressure Occlusion Arm (n = 21) used to calculate sensitivity and specificity  
2. ICD Implantation arm(n = 8) used to calculate specificity                        | Detection of pulselessness                    |
| Sugano et al., 2011  | 1. Clinical  
2. Database                              | 1. Subjects Performing Daily Activities (n = 7): used to calculate specificity  
2. Database data (n = 19): used to calculate sensitivity                          | Detection of lethal arrhythmia               |
| Gaibazzi et al., 2018 | 1. Clinical  
2. Sensor connected to ECG simulator with Database Data | 1. Subjects Performing Physical Activity (n = 30 over 829 hours): used to calculate specificity  
2. Database data (n = 140 sequences): used to calculate sensitivity             | Detection of cardiac arrest (motionless and ventricular fibrillation) |
| Chan et al., 2019   | 1. Real-world recordings  
2. Real-world recordings | 1. 162 9–1-1 calls with agonal breathing: used to calculate sensitivity  
2. Audio from sleeping patients not in cardiac arrest (n = 12 over 83 hours): used to calculate specificity | Detection of agonal respiration             |

Table 2 – A summary of diagnostic test accuracy results for sensor technologies to detect cardiac arrest.

| Article             | Index Test & (Parameter) | Sensor Technology                  | Reference Standard            | Physically Tested on Humans? | Sensitivity | Specificity | Risk of Bias |
|---------------------|--------------------------|------------------------------------|------------------------------|-------------------------------|-------------|-------------|--------------|
|                      |                          |                                    |                              |                               | Sensitivity | Specificity |              |
| Rickard et al., 2011 | Wristwatch (Radial Pulse) | Mechanical plethysmography (piezoelectric) | Clinician confirmed         | Yes                           | 99.9 %      | 90.3 %      | Medium       |
| Sugano et al., 2011  | Commercially available wireless vital sensor | ECG, accelerometer, temperature | Annotated ECG data         | No                            | 100 %       | 99.99 %     | High         |
| Gaibazzi et al., 2018 | Wahoo Tickr and T-Shirt (Sensoria Inc.) and smart phone accelerometers | ECG & Accelerometer             | Simulated ECG for arrhythmias | No                            | 99.8 %      | 100 %       | High         |
| Chan et al., 2019   | Smart device (Amazon Echo and Apple iPhone 5 s) | Audio classifier             | Annotated audio database    | No                            | 97.24 % (96.86–97.61 %)* | 99.51 % (99.35–99.67 %)* | Medium       |

* Confidence intervals were provided in the study. The remainder of the studies did not include these intervals, nor were the full datasets provided to allow for this calculation.
We searched the available published and grey literature to identify all studies investigating the performance of cardiac arrest detection technologies. Overall, we found few studies meeting our inclusion criteria, and none included testing of a sensor on an actual cardiac arrest. For studies that evaluated sensors that detected malignant arrhythmias such as ventricular fibrillation or ventricular tachycardia, the use of a simulation or database approach was common. Across all included studies, testing conditions were frequently idealized, using high-quality data, and often only a specific component of the sensor system was evaluated. Overall, while sensor technologies hold promise for cardiac arrest detection, the available evidence is unable to provide estimates of performance that are generalizable to real-world conditions.

In a majority of the included studies, the researchers assessed specificity through direct sensor deployment on humans but utilized simulated data or annotated databases for the assessment of sensitivity. In such studies, specificity was assessed on real-life raw data, including noise and motion artifacts. Compared to the highly idealized and noise-free database or simulation approach for assessing sensitivity, the applied methods for assessing specificity were more representative of the out-of-hospital setting. When comparing the discrepancies in testing environments in the assessment of sensitivity and specificity, it is possible that the trained algorithms are in fact detecting differences in environment (strength of the signal, amount of noise or motion artifacts, etc.) rather than detecting the actual cardiac arrest or associated parameter. Further, the detection of certain arrhythmias from a database does not equate to detecting cardiac arrest in real people. Previous studies demonstrate that the initial recorded rhythm is ventricular fibrillation in only a minority of cases. In our searches, other than the single study evaluating agonal breathing from historical records (which is present in approximately 50 % of cardiac arrest cases),25 we did not encounter a single study referencing the evaluation of these technologies in patients in cardiac arrest in the out-of-hospital setting. This approach increases the risk of bias away from the null in the evidence base, as issues such as measurement variability, device contact, data loss, and other entropic factors are artificially controlled for in a way that is not reflective of the true conditions under which these devices are intended to function. As such, the performance of these devices in a real-world setting is unclear.

The discrepancy between lab-based and real-world testing conditions is not the only challenge in assessing the relevance of findings from the evidence base for OHCA detection. Typically, when designing technologies that aim to provide alerts of critical health emergencies, developers will optimize the sensitivity of the detection algorithm to increase the likelihood of detecting a life-threatening change in physiological state (the true-positive rate). While this results in an optimized ability to detect cardiac arrest, it also increases the likelihood of a false-positive activation, where the device indicates that a cardiac arrest has occurred when it has not (the false-positive rate). For developers designing health technologies for use in the public emergency health space, the impact of false-positive device activations on EMS operations should be considered. Currently, EMS systems are overburdened and substantially impacted by surges in demand.

Consideration of this overburdening risk in the context of widespread adoption of such devices should allow developers to contextualize the desirable sensor function as providing a balance between sensitivity and specificity. Devices engineered to detect cardiac arrest should balance specificity and sensitivity in the context of individual level accuracy as well as EMS function. There is a trade-off between these two metrics for sensor accuracy. Sensors can be designed to either detect all cases of OHCA (high sensitivity), and produce high rates of false positives; or sensors can be designed to only detect cases that are very obviously cases of OHCA, thus leaving a portion of OHCA cases undetected. Developers may also consider designing devices that utilize a multi-channel approach to...
parameter measurement, as a device that triggers an alert using a signal based on two measurements with the same specificity demonstrated above would reduce the daily false positive rate significantly and aid in achieving widespread adoption of these devices.

In addition to algorithmic development, the device form factor also plays a role in the likelihood of adoption. Wearable devices can travel with the user, increasing the chances of detecting an arrest where it occurs. Conversely, audio or camera-based, non-contact devices would only be able to detect an arrest within the physical confines of a room and would require several installed devices to cover a wider range of detection locations. While a multi-channel approach to parameter measurement may address concerns related to false-positive activations, users may prefer a smaller and lighter device with fewer sensor types, illustrating another trade-off between accuracy and implementation.

In addition to considerations at the design stage, integration of sensor technologies into the 911 chain of care will require careful testing and development. This would likely involve the participation of EMS agencies and commercial partners to connect EMS dispatch systems to external alerting software infrastructure. Software platforms capable of connectivity across a range of sensor devices, as well as those that secure the relevant partnerships with EMS agencies will likely be best positioned to assist in the market uptake of such technologies. Opportunities also exist to incorporate sensor technologies into a new wave of technology-assisted EMS system innovations, as introduced as the “Systems Saving Lives” concept by Semeraro, et al. (2021).25 Connectivity with citizen responder mobile applications as well as AED drone delivery programs will serve to create an integrated technology ecosystem for rapid recognition and response to OHCA, with sensor technologies serving as the foundation. It is essential that developers of these technologies conceptualize this interconnected system of response from the design to the implementation stage, optimizing the potential for integration with other commercial products, as well as the relevant EMS agencies.

Although this review outlined studies that provide evidence of detecting lethal arrhythmias or cardiac arrest conditions, we observed low rates of subsequent publication and further testing of the described devices. Considering that much of the included evidence utilizes a proof-of-concept approach to testing, we expected to find evidence of ongoing evaluation of these technologies prior to clinical implementation. The general lack of uptake of these devices, including the devices observed in the grey literature search (Appendix D), alludes to consistent obstacles that prevent the widespread acceptance of such technologies. Such obstacles could be a lack of user interest due to the highly specific nature of the technology, or a lack of reliable methods to test and validate the detection of lethal arrhythmias or cardiac arrest conditions. Commercial forces and market conditions likely play a significant role in the uptake of these technologies, and it is possible that manufacturers are either unaware of the potential impact of these devices or appraise the market for such technologies as currently not viable. Future developers, scientists, and clinicians in this area should consider partnering with EMS stakeholders to focus on developing technologies that are not only highly accurate but also consider the context of device use at the design stage, and are likely to be embraced by end-users that are concerned with such factors as functionality, fashion, and intrusiveness.

**Limitations**

Throughout the evidence base, sample sizes are small, blinding is varied, and study designs are highly heterogeneous. Studies that utilize arrhythmia databases for evaluation or algorithm training are at risk of selection bias, and data used is often acquired under controlled conditions using clinical-grade equipment. Some studies that included heart rate and accelerometry detection systems only tested their devices on heart rate data, leaving the accelerometry component of their devices untested, due to their static and motionless study settings.13 Several studies evaluated algorithms, but not the sensor that would collect physiological data for the algorithm, or the infrastructure to relay this data to the computing module. Due to these limitations, we are unable to generalize accuracy rates in the included papers for use in the out-of-hospital setting, and further evaluation of these or similar technologies will need to occur to understand the feasibility of biosensors for OHCA detection.

**Conclusion**

We performed a systematic review of the literature to summarise the currently available evidence demonstrating the performance of sensor technologies to detect cardiac arrest. While reported metrics for sensitivity and specificity were high, no published experiment has actually tested a sensor on an actual cardiac arrest case. Widespread and reliable sensing technologies with high sensitivity and specificity are needed for real-time and rapid detection of sudden cardiac arrest to increase survival in the out-of-hospital setting.

**Author Contributions**

SL and JH contributed equally to the design of the research proposal, as well as the execution of the systematic review and manuscript development.

**CRediT authorship contribution statement**

Jacob Hutton: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Writing – original draft, Writing – review & editing. Saud Lingawi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. Joseph H. Puyat: Writing – review & editing. Calvin Kuo: Writing – review & editing. Babak Shadgan: Writing – review & editing. Jim Christenson: Funding acquisition, Resources, Writing – review & editing. Brian Grunau: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing.

**Conflicts of Interest**

The authors declare no conflicts of interest.
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Appendix A: Search terms and an example of a completed search strategy in MEDLINE

The literature search strategy for the systematic review of diagnostic test accuracy for sensor technologies to detect out-of-hospital cardiac arrest is provided below. The searched databases include PubMed/MEDLINE, Web of Science, COMPENDEX, and EMBASE, and the search was restricted to articles in English within the date range of January 1, 1950 to June 6, 2022. Case reports, clinical trials, and meta-analyses were included in the search.

Search terms

The terms used in this search fit broadly under two classifying categories: terms for cardiac arrest and dangerous cardiac arrhythmias, and terms for continuous monitoring and detection of physiological parameters. As such, the relevant search terms are:

| Cardiac Arrest and Dangerous Cardiac Arrhythmias | Continuous Monitoring and Detection of Physiological Parameters |
|--------------------------------------------------|---------------------------------------------------------------|
| Heart arrest                                     | Physiological monitoring                                     |
| Sudden cardiac death                            | Wearable electronic devices                                  |
| Out-of-hospital cardiac arrest                   | Detect*                                                       |
| Cardiac arrhythmias                              | -                                                             |

When necessary, keywords were shortened and truncated with an asterisk (e.g. detect*) to retrieve unlimited suffix variations (e.g. detect, detecting, detectable, etc.).

MEDLINE example search

The search terms were combined in a way to encompass the most relevant results while limiting the possibility of pre-filtering articles that would otherwise fit the search criteria. An example search is as follows:

((heart arrest OR sudden cardiac death OR out-of-hospital cardiac arrest or cardiac arrhythmias) AND (physiological monitoring OR wearable electronic devices OR detect*)).

On MEDLINE, all of the search terms used, with the exception of detect*, were Medical Subject Headings (MeSH). Broader MeSH were selected to encompass relevant subcategories when necessary. For example, the heart arrest MeSH includes the subheadings sudden cardiac death and out-of-hospital cardiac arrest, both of which were also selected to focus on the search for specific aspects of the arrest. Below is a more detailed representation of this search strategy.

Detailed MEDLINE Search Strategy

#Searches

1 heart arrest/ or death, sudden, cardiac/ or out-of-hospital cardiac arrest/ or arrhythmias, cardiac/ OR heart failure/

2 Monitoring, physiologic/ or detect*.mp

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Table A1 – An overview of search phrases and databases used during article retrieval. Numbers indicate the number of identified articles during the two literature searches.

| Database                     | Search Phrase                                                                 | Results |
|------------------------------|-------------------------------------------------------------------------------|---------|
| Web of Science Core Collection | TOPIC: (sensor* AND (“cardiac arrest” OR “heart arrest” OR “OHCA” OR “CPR”) AND (“recognition” 127 OR “recognize” OR “detect” OR “predict” OR “prediction”)) |         |
|                              | Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI, CPCl-S, CPCl-SSH, ESCI. |         |
| MEDLINE                      | Search 1: (exp Wearable Electronic Devices AND (heart arrest/ OR death, sudden, cardiac/ OR out-of- hospital cardiac arrest/ OR arrhythmias, cardiac/ OR heart failure/)) 204 |         |
|                              | Search 2: (exp Death, Sudden, Cardiac/ or exp Death, Sudden/ or (exp Heart Arrest/ or exp Out-of-Hospital217 Cardiac Arrest/)) and Sensor* | 281     |
|                              | Search 3: (out-of-hospital cardiac arrest) AND detect* |         |
| COMPENDEX                    | ((“cardiac arrest” OR “heart arrest”) AND (“sensor” OR “wearable” OR “device”)) WN ALL | 180     |
| ScienceDirect                | ("cardiac arrest" OR “heart arrest”) AND (“sensor” OR “wearable” OR “device”) AND (“detection” OR “prevention” OR “recognition”) AND (“911”) |         |
| EMBASE                       | (cardiac stress monitoring system/ OR cardiovascular monitoring device/ OR ambulatory monitoring/ OR 209 blood pressure monitoring/ OR electrocardiography monitoring/ OR patient monitoring/ OR biological monitoring/ OR monitoring/ OR physiologic monitoring) AND (heart arrest/ OR cardiopulmonary arrest/ OR out of hospital cardiac arrest/) AND (detect*)) | 209     |
| PubMed                       | Cardiac arrest AND detect* AND physiological monitoring | 362     |
## Appendix B: Characteristics of included studies

See Table B1.

### Table B1 – Characteristics of Included Studies - Diagnostic Test Accuracy Form.

| Study | Country | Setting/context | Year/timeframe for data collection | Participant characteristics | Reference test descriptions and samples | Index test description and sample | Description of main results (including adverse events from tests) |
|-------|---------|-----------------|-----------------------------------|-----------------------------|----------------------------------------|---------------------------------|----------------------------------------------------------|
| Chan J, Rea T, Gollakota S, Sunshine JE. 2019. | USA | Prehospital | 2017 | Labelled audio data of the patient in cardiac arrest | The model was evaluated using audio data known to demonstrate evidence of agonal breathing. Agonal breathing ground truth was evaluated by trained reviewers and overseen by a specialist physician. Data was collected from 9-1-1 calls that demonstrated agonal breathing. | Audio classification algorithm | Classifier model demonstrated overall sensitivity and specificity of 97.24 % (95 % CI: 96.86–97.61 %) and 99.51 % (95 % CI: 99.35–99.67 %). The detection algorithm ran in real-time on a smartphone natively and classified each 2.5 s audio segment within 21 ms. With the smart speaker, the algorithm ran within 58 ms. |
| Rickard J, Ahmed S, Baruch M, Klocman B, Martin DO, Menon V. 2011. | United States | Cleveland Clinic - in ED and OR to 2011 | Unknown - prior to 2011 | In the hospitalized arm: patients wore the watch on their arm and a blood pressure cuff was inflated until the radial pulse was occluded for 10 seconds. This provided the reference of pulselessness. In the ICD arm: patients receiving implantation wore the watch and VF was induced and confirmed with telemetry. | Two study arms: 1) 24 patients who were plethysmograph hospitalized for any reason 2) 10 patient's piezoelectric crystal who presented to the lab capable of detecting pulse motion and artifact, which is then converted to a voltage, digitized, sent to a microprocessor and filtered algorithmically to produce a pulse detection signal. | The final cohort contained 30 patients: 22 in the hospitalized arm and 8 in the ICD testing arm. Overall, the Wriskwatch was worn for a total of 561.2 minutes. Pulselessness was present for 5.8 minutes. The sensitivity of the watch to detect pulse status (based on 15-second time intervals) was 99.9 %, specificity was 90.3 %, and positive and negative predictive values were 99.9 % (95 % confidence interval 99.67 %–99.99 %) and 90.3 % (95 % confidence interval 74.3 %–98.0 %), respectively. |
| Sugano H, Hara S, Tsujioka T, Inoue T, Nakajima S, Kozaki T, et al. 2011. | Japan | Database and Laboratory | Unknown - prior to 2011 | The lethal arrhythmia database is annotated by medical specialists and 19 subject data containing VF signal or VT signal were used as test data. | Tested the arrhythmia detection algorithm using the sudden cardiac death Holter monitor database. Used 19 subject data as the test data. | A commercially available sensor that is reliable enough for the detection of lethal arrhythmia can continuously measure ECG, body arrhythmias with surface temperature sensitivity of 100 % and 3D acceleration and specificity of 99.9 %, wireless for more than forty-eight days. |
Appendix C.: Critical Appraisal results

Risk of bias was ascertaining through the QUADAS-2 tool, which provides guiding questions to arrive at a conclusion on bias. The QUADAS-2 tool questions, along with our reported answers, are provided below. Table C1/Table C2.

Critical Appraisal Questions:

Q1: Was a consecutive or random sample of patients enrolled? (yes, no, unclear, N/A).
Q2: Was a case-control design avoided? (yes, no, unclear, N/A).
Q3: Did the study avoid inappropriate exclusions? (yes, no, unclear, N/A).
Q4: Were the index test results interpreted without knowledge of the results of the reference standard? (yes, no, unclear, N/A).
Q5: If a threshold was used, was it pre-specified? (yes, no, unclear, N/A).
Q6: Is the reference standard likely to correctly classify the target condition? (yes, no, unclear, N/A).
Q7: Were the reference standard results interpreted without knowledge of the results of the index test? (yes, no, unclear, N/A).
Q8: Was there an appropriate interval between index test and reference standard? (yes, no, unclear, N/A).
Q9: Did all patients receive the same reference standard? (yes, no, unclear, N/A).

Table C1 – Risk of Bias Assessment.

| Citation | Risk of Bias |
|----------|--------------|
| Chan J, Rea T, Gollakota S, Sunshine JE. 2019. | Medium |
| Gaibazzi N, Siniscalchi C, Reverberi C. 2018. | High |
| Sugano H, Hara S, Tsujioka T, Inoue T, Nakajima S, Kozaki T, et al. 2011. | High |
| Rickard J, Ahmed S, Baruch M, Klocman B, Martin DO, Menon V. 2011. | Medium |
Appendix D:

Results from grey literature and screened citations that detail cardiac arrest technologies.

Results of grey literature search
Excluding the HeartSentinel App by Gaibazzi et al., which was included in the systematic review, there were three additional results that the search of grey literature uncovered. The two technologies revealed through a Google search of company websites and press release articles are the iBeat Heart Watch (iBeat, San Francisco, USA) and the Wristwatch (CardiacSense, Caesarea, Israel). The registered patent uncovered through the patent search is an implantable cardiac device by Medtronic Inc (European Patent Office, EP2753234A1).

The iBeat Heart Watch received publicity in 2018 for being the first wrist-worn device to detect cardiac arrest and initiate an emergency sequence accordingly, based on heart rate and blood flow analysis. The watch was designed to trigger a message to the user when an emergency is detected to verify whether or not the user is conscious and would then contact emergency services if the user remains unresponsive. Despite the publicity that this technology had gained, there does not appear to be published data on the accuracy or validation of the device. The device has since been abandoned, and the company has ceased operations as well.

The CardiacSense Wristwatch is a device that is still under development. It is meant to be able to detect cardiac arrest and trigger an audible alarm response; however, validation and device accuracy studies are yet to be conducted. Results from such trials are expected to be available in the upcoming years. The implantable cardiac device by Medtronic Inc was first registered in 2011, and is ongoing until 2032. It is designed to detect motions of the cardiac wall to detect OHCA. Despite this device fitting the criteria of OHCA detection and having support from a large biomedical company, we were unable to obtain further information regarding its current state of development outside of the published patent document.

None of the three results outlined in this appendix met the inclusion criteria of our systematic review and were therefore excluded from the review.

Results from peer-reviewed literature
The CardioAlarm subcutaneous sensor is an implantable electrode-based cardiac monitoring device that communicates to an external module via Bluetooth automatically or following user activation. It produces an alert that is relayed to an external telephone module when a potentially dangerous cardiac arrhythmia is detected. In our search, we captured a report by Arzbaecher et al. (2006) detailing testing this system for lethal arrhythmia detection, further examination revealed that the report focused on a purely computational testing design that evaluated the ability of the device algorithm to detect lethal arrhythmias using the MIT-BIH arrhythmia database and did not involve placing the physical sensor on human participants. As such, the study did not fit the criteria for inclusion in the systematic review, but is detailed here as the described technology may be a candidate for future evaluation.

| Citation                                                                 | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 |
|-------------------------------------------------------------------------|----|----|----|----|----|----|----|----|----|-----|
| Chan J, Rea T, Gollakota S, Sunshine JE. 2019.                         | N  | Y  | Y  | N  | N/A| Y  | N  | N/A| Y  | Y   |
| Gaibazzi N, Siniscalchi C, Reverberi C. 2018.                          | N  | Y  | Y  | U  | U  | Y  | U  | N/A| Y  | Y   |
| Sugano H, Hara S, Tsujikia T, Inoue T, Nakajima S, Kozaki T, et al. 2011.| N  | N  | Y  | U  | U  | Y  | U  | N/A| Y  | Y   |
| Rickard J, Ahmed S, Baruch M, Klocman B, Martin DO, Menon V. 2011.     | Y  | Y  | U  | N  | U  | Y  | N  | N/A| Y  | N   |
# Appendix E. Papers excluded at full text screening

| Year | Authors | Title | Journal | VolumeIssuePage | DOI | Excluded reason |
|------|---------|-------|---------|-----------------|-----|----------------|
| 2019 | Ip James E | Evaluation of Cardiac Rhythm Abnormalities From Wearable Devices. | JAMA | 321 11 1099 | [dx.doi.org/10.1001/jama.2019.1681](https://dx.doi.org/10.1001/jama.2019.1681) | Review article |
| 2018 | Cheung Christopher CKrahn Andrew DAndrade Jason G | The Emerging Role of Wearable Technologies in Detection of Arrhythmia. | The Canadian journal of cardiology | 34 8 1087 | [dx.doi.org/10.1016/j.cjca.2018.05.003](https://dx.doi.org/10.1016/j.cjca.2018.05.003) | Review article |
| 2018 | Ryvlin Philippe Ciumas Carolina Wisniewski Ilona Beniczky Sandor | Wearable devices for sudden unexpected death in epilepsy prevention. | Epilepsia | 59 Suppl 1 66 | [dx.doi.org/10.1111/epi.14054](https://dx.doi.org/10.1111/epi.14054) | Review article |
| 2017 | Sadrawi Muammar Lin Chien-Hung Lin Yin-Tsong Hsieh Yita Kuo Chia-Chun Chien Jen Chien Harakawa Koichi Abbud Maysam FSchieh Jiann-Shing | Arrhythmia Evaluation in Wearable ECG Sensors (Basel, Switzerland) Devices. | Sensors (Basel, Switzerland) | 17 11 | [dx.doi.org/10.3390/s17112445](https://dx.doi.org/10.3390/s17112445) | Ineligible study design |
| 2019 | Sajeev Jithin KKoshy Anoop NTeh Andrew W | Wearable devices for cardiac arrhythmia Internal medicine journal detection: a new contender?. | Internal medicine journal | 49 5 573 | [dx.doi.org/10.1111/imj.14274](https://dx.doi.org/10.1111/imj.14274) | Review article |
| 2019 | Sajeev Jithin KKoshy Anoop NTeh Andrew W | Wearable devices for cardiac arrhythmia Internal medicine journal detection: a new contender?. | Internal medicine journal | 49 5 573 | [dx.doi.org/10.1111/imj.14274](https://dx.doi.org/10.1111/imj.14274) | Duplicate study |
| 2019 | Samol Alexander Bischof Kristina Luani Blirim Pascut Dan Wiener Marcus Kaese Sven | Single-Lead ECG Recordings Including Einthoven and Wilson Leads by a Smartwatch: A New Era of Patient Directed Early ECG Differential Diagnosis of Cardiac Diseases?. | Sensors (Basel, Switzerland) | 19 20 | [dx.doi.org/10.3390/s19204377](https://dx.doi.org/10.3390/s19204377) | Ineligible index test |
| 2004 | Feldman Arthur MKlein Helmut Tchou Patrick Murali Srinivas Hall W Jackson Mancini Donna Boehmer John Harvey Mark Heilman M Stephen Szymkiewicz Steven JMoss Arthur JWearIT investigators and coordinators nullBIROAD investigators and coordinators null | Use of a wearable defibrillator in terminating tachyarrhythmias in patients at high risk for sudden death: results of the WEARIT/BIROAD. | Pacing and clinical electrophysiology: | 27 1 9 | Ineligible outcomes |
| 2019 | Elola Andoni Aramendi Elisabetelrusta Una Picon Artzai Alonso Eriklsasi Iraldris Ahamed | Convolutional Recurrent Neural Networks to Characterize the Circulation | Annual International Conference of the IEEE Engineering in Medicine and Biology Society | 2019 1925 | [dx.doi.org/10.1109/EMBC.2019.8857758](https://dx.doi.org/10.1109/EMBC.2019.8857758) | No full text available |
| Year   | Authors                                      | Title                                                                 | Journal                          | VolumeIssuePage | DOI                                      | Excluded reason                      |
|--------|----------------------------------------------|-----------------------------------------------------------------------|----------------------------------|----------------|------------------------------------------|---------------------------------------|
| 2018   | Latimer Andrew J McCoy Andrew M Sayre       | Emerging and Future Technologies in Out-of-Hospital Cardiac Arrest Care. | Cardiology clinics               | 36 3 441       | https://dx.doi.org/10.1016/j.ccl.2018.03.010 | Review article                        |
| 2018   | Douma Matthew J                              | Automated video surveillance and machine learning: Leveraging existing infrastructure for cardiac arrest detection and emergency response activation. | Resuscitation                    | 126           | https://dx.doi.org/10.1016/j.resuscitation.2018.02.010 | Ineligible study design               |
| 2019   | Elola Andoni Aramendi Elisabetelrusta       | This Smart Watch Detects Cardiac Arrest, and Summons Help - IEEE Spectrum | Cardiology clinics               | 57 2 462       | https://doi.org/10.1007/s11517-018–1892-2 | Excluded due to JBI software bug - imported again into full text screening |
| 2019   | Lee Yoonje Shin Hyungchoo Hyuk Joong Kim Changsun | Can pulse check by the photoplethysmography sensor on a smart watch replace carotid artery palpation during cardiopulmonary resuscitation in cardiac arrest patients? a prospective observational diagnostic accuracy study | BMJ Open                         | 9 2           | https://doi.org/10.1136/bmjopen-2018–023627 | Duplicate study                      |
| 2015   | Fung Erik J jarelvelin Marjo Riitta Doshi   | Electrocardiographic patch devices and contemporary wireless cardiac monitoring | Front Physiol                    | 6             | https://doi.org/10.3389/fphys.2015.00149 | Review article                       |
| 2020   | Dagan O j Mechanic                          | Use of ultra-low cost fitness trackers as clinical monitors in low resource emergency departments | Cardiology clinics               | 36 3 441       | https://doi.org/10.15441/ceem.19.081    | Review article                       |
| 2018   | Gaibazzi C Siniscalchi C Reverberi          | The Heart SentinelTM app for detection and automatic alerting in cardiac arrest during outdoor sports: Field tests and ventricular fibrillation simulation results | Cardiology clinics               | 36 3 441       | https://doi.org/10.1016/j.jicard.2018.07.062 | Duplicate study                      |
| 2017   | Chorin A Hochstadt R Rosso L Schwartz S Viskin | Continuous heart rate monitoring for automatic detection of life-threatening arrhythmias with novel bio-sensing technology | Cardiology clinics               | 36 3 441       | https://doi.org/10.1016/j.jicard.2018.07.062 | No full text available               |
| 2016   | C Jungen C Eickholthj Muelhlsteff K Dellimore V Aarts N Gosau B a Hoffmann Pexperience with a sensor located at the carotid artery | No full text available | Cardiology clinics               | 36 3 441       | https://doi.org/10.1016/j.jicard.2018.07.062 | No full text available               |
| Year | Authors | Title | Journal | Volume | Issue | Page | DOI | Excluded reason |
|------|---------|-------|---------|--------|-------|------|-----|-----------------|
| 2017 | Barai A.R., Rahman M.R., Sarkar A.K. | Comparison of Noninvasive Heart Rate Monitoring System using GSM Module and RF Module | 4 | https://doi.org/10.1109/CEEE.2017.8412905 | Ineligible outcomes |
| 2018 | Schellenberger Sven, Shi Kilin, Steigleder Tobias, Michler Fabian, Lurz Fabian, Weigel Robert, Koelpin Alexander | Support vector machine-based instantaneous presence detection for continuous wave radar systems | 2018-November | 1467 | https://doi.org/10.23919/APMC.2018.8617181 | Ineligible study design |
| 2013 | Kim Yong-Hoon, Lee Myung-Hwan, Murakami Yuichi, Inaba Hisashi, Tokuda Kiyohito | Study of heart detection doppler radar development for automotive application | Article not in English |
| 2017 | Aarts Vincent, Delligmore Kiran H., Wijshoff Ralph, Derkx Rene, Van De Laar Jakob, Muehlsteff Jens | Performance of an accelerometer-based pulse presence detection approach compared to a reference sensor | 168 | https://doi.org/10.1109/BSN.2017.7936033 | Ineligible index test |
| 2008 | Leijdekkers Peter, Gay Valerie | A self-test to detect a heart attack using a mobile phone and wearable sensors | 98 | https://doi.org/10.1109/CBMS.2008.59 | Ineligible study design |
| 2020 | Malepati Niyatha Rubia Gupta, Swarnima Ramsali Vaishnavi, Rk Shobha, Shobha | Portable ECG Device for Remote Monitoring and Detection of Onset of Arrhythmia | https://doi.org/10.1109/CONECT50063.2020.9198658 | Excluded due to JBI software bug - imported again into full text screening |
| 2020 | Jayaweera K.N., Kallora K.M.C., Subasinghe N.A.C.K., Rupasinghe Lakmal, Liyanapathirana C. | An integrated framework for predicting health based on sensor data using machine learning | 48 | https://doi.org/10.1109/ICAC51239.2020.9357134 | Ineligible outcomes |
| 2020 | Reddy Sashank, Seshadri Surabhi B., Sankesh Bothra G., Suhas T., Thundiyil Saneesh Cleatus | Detection of Arrhythmia in Real-time using ECG Signal Analysis and Convolutional Neural Networks | https://doi.org/10.1109/CPEE50798.2020.9238743 | Excluded due to JBI software bug - imported again into full text screening |
| 2008 | Leijdekkers Peter, Gay Valerie | A self-test to detect a heart attack using a mobile phone and wearable sensors | Proceedings of the 21st IEEE International Symposium on Computer-Based Medical Systems | 98 | https://doi.org/10.1109/CBMS.2008.59 | Duplicate study |
| 2012 | Birkholz T., Fernsner S., Irouschek A., Wettach D., Schmidt J., Einhaus F., Bolz A., Jaeger M. | Detection of Cardiac Arrest with an Integrated Sensor System | Notarzt | 28 | 3 | 113 | https://dx.doi.org/10.1055/s-0031-1299000 | No full text available |
| 2018 | Syvaoja Sakari, Rissanen Tuomas, Hiltunen Pamela, Castren Maaret, Mantyla Pirjo, Kivela Anti, Iusarop Ari, Jaanti Helena | Ventricular fibrillation recorded and analysed within an area the size of a mobile phone: could it enable cardiac arrest recognition? | European Journal of Emergency Medicine: Official Journal of the European Society for Emergency Medicine | 25 | 6 | 399 | https://doi.org/10.1097/MEJ.0000000000000473 | Ineligible study design |
| 2019 | Lee Yoonje Shin Hyungoo, Choi Hyuk Joong Kim, Changsun | Can pulse check by the photoplethysmography sensor on a mobile phone detect a heart attack? | BMJ Open | 9 | 2 | https://doi.org/10.1136/bmjopen-2018-| Duplicate study |
| Year | Authors | Title                                                                                                                                                                                                 | Journal                                                                                                                                  | Volume | Issue | Page | DOI                                                                 | Excluded reason                      |
|------|---------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------|--------|------|------|---------------------------------------------------------------------|--------------------------------------|
| 2016| Dellimore Kiran Wijhoff Ralph Haarburger Christoph Aarts Vincent Derkx Renevan de Laar Jakob Nammi Krishnakant Russell James Hubner Pia Sterz Fritz Muehlsteff Jens | Towards an algorithm for automatic accelerometer-based pulse presence detection during cardiopulmonary resuscitation.                          | Annual International Conference of the IEEE Engineering in Medicine and Biology Society. IEEE Engineering in Medicine and Biology Society. Annual International Conference | 2016   | 3534 | 10.1109/EMBC.2016.7591490                                         | Ineligible reference test - associated parameter |
| 2006| Arzbaecher Robert Jenkins Janice Burke Martin Song Zhendong Garrett Michael | Database testing of a subcutaneous monitor with wireless alarm.                                                                                                                                   | Journal of electrocardiology                                                                                                           | 39     | 4    | 3    | Suppl                                                               | Duplicate study                      |
| 2017| Trummer Stephanie Ehrmann Andrea Buesgen Alexander                            | Development of Underwear with Integrated 12 Channel ECG for Men and Women                                                              | Autex Research Journal                                                                                                                | 17     | 4    | 349  | https://doi.org/10.1515/aut-2017–0008                              | Ineligible reference test            |
| 1978| Mirowski MMower M MLanger A Heilman M S Schreibman J                          | A chronically implanted system for automatic defibrillation in active conscious dogs. Experimental model for treatment of sudden death from ventricular fibrillation. | Circulation                                                                                                                             | 58     | 1    | 4    |                                                                    | Ineligible outcomes                 |
| 2012| Vijayalakshmi S.R. Muruganand S.                                              | Real-time monitoring of ubiquitous wireless ECG sensor node for medical care using ZigBee                                             | International Journal of Electronics                                                                                                  | 99     | 1    | 89   | https://doi.org/10.1080/00207217.2011.609981                      | Ineligible study design             |
| 2019| Y Lee H Shin Hj C Kim                                                          | Can pulse check by the photoplethysmography sensor on a smart watch replace carotid artery palpation during cardiopulmonary resuscitation? | Journal of the American College of Cardiology                                                                                           | 17     | 4    | 132  | https://dx.doi.org/10.1007/s11897-020-00467-x                     | Duplicate study                      |
| 2020| Zhao Yang Shang Zhongxia Lian Yong                                              | A 13.34 muW Event-Driven Patient-Specific ANN Cardiac Arrhythmia Classifier for Wearable ECG Sensors.                                 | IEEE transactions on biomedical circuits                                                                                              | 2      | 197  | 10.1109/TBCAS.2019.2954479                                      | Ineligible study design             |
| 2020| Singhal Arvind Cowie Martin R                                                  | The Role of Wearables in Heart Failure. Current heart failure reports                                                                  | Journal of the American College of Cardiology                                                                                           | 75     | 13   | 1592 | https://dx.doi.org/10.1016/j.jacc.2020.01.046                     | Review article                      |
| 2020| Sana Furrukhisselbacher Eric MSingh Jagmeet P Heist E Kevin Pathik Bhumesh Armoundas Antonis A                                       | Wearable Devices for Ambulatory Cardiac Monitoring: JACC State-of-the-Art Review.                                                       | Journal of the American College of Cardiology                                                                                           | 75     | 13   | 1592 | https://dx.doi.org/10.1016/j.jacc.2020.01.046                     | Review article                      |
| 2020| Sperzel Johannes Hamm Christian WHain Andreas                                   | Over- and undersensing-pitfalls of arrhythmia detection with implantable devices and wearables.                                           | Herzschrittmachertherapie & Elektrophysiologie                                                                                           | 31     | 3    | 287  | https://dx.doi.org/10.1007/s00399-020-00710-x                     | Review article                      |
| Year | Authors | Title | Journal | Volume Issue Page | DOI | Excluded reason |
|------|---------|-------|---------|-------------------|-----|-----------------|
| 2019 | Sanders David, Ungar Leo, Eskander Michael A, Seto Arnold H | Ambulatory ECG monitoring in the age of smartphones | Cleveland Clinic journal of medicine | 86 7 493 | https://dx.doi.org/10.3949/ccjm.86a.18123 | Review article |
| 2019 | Almqvist Mans, Mattsson Gustav, Magnusson Peter | [The wearable cardioverter defibrillator - Lakartidningen temporary protection against sudden cardiac death] | Journal of the American College of Cardiology | 75 13 1592 | https://dx.doi.org/10.1016/j.jacc.2020.01.046 | Ineligible study design |
| 2019 | Hartwell Leland, Ross Heather M, La Belle Jeffrey T | Project honeybee: Clinical applications for wearable biosensors | Biomedical microdevices | 21 2 | https://dx.doi.org/10.1007/s10544-019-0392-y | Ineligible reference test |
| 2019 | Ip James E | Wearable Devices for Cardiac Rhythm Diagnosis and Management | JAMA | 321 4 338 | https://dx.doi.org/10.1001/jama.2018.20437 | Review article |
| 2020 | Sana Furrukhisselbacher Eric MSingh Jagmeet PHeist E KevinPathik BhupeshArmoundas Antonis A | Wearable Devices for Ambulatory Cardiac Monitoring: JACC State-of-the-Art Review. | Journal of the American College of Cardiology | 75 13 1592 | https://dx.doi.org/10.1016/j.jacc.2020.01.046 | Duplicate study |
| 2019 | Sanders David, Ungar Leo, Eskander Michael A, Seto Arnold H | Ambulatory ECG monitoring in the age of Cleveland Clinic journal of medicine smartphones | Cleveland Clinic journal of medicine | 86 7 493 | https://dx.doi.org/10.3949/ccjm.86a.18123 | Duplicate study |
| 2019 | Ip James E | Wearable Devices for Cardiac Rhythm Diagnosis and Management | JAMA | 321 4 338 | https://dx.doi.org/10.1001/jama.2018.20437 | Duplicate study |
| 2018 | Cheung Christopher CK, Rahn Andrew D, Andrade Jason G | The Emerging Role of Wearable Technologies in Detection of Arrhythmia. | The Canadian journal of cardiology | 34 8 1087 | https://dx.doi.org/10.1016/j.cjca.2018.05.003 | Duplicate study |
| 2019 | Almqvist Mans, Mattsson Gustav, Magnusson Peter | [The wearable cardioverter defibrillator - Lakartidningen temporary protection against sudden cardiac death] | Journal of the American College of Cardiology | 75 13 1592 | https://dx.doi.org/10.1016/j.jacc.2020.01.046 | Duplicate study |
| 2018 | Zylla Maura M, Hillmann Henrike A, KProctor TanjaKieser MeinhardScholz EberhardZitron EdgarKatus Hugo AThomas Dierk | Use of the wearable cardioverter-defibrillator (WCD) and WCD-based remote rhythm monitoring in a real-life patient cohort. | Heart and vessels | 33 11 1402 | https://dx.doi.org/10.1007/s00380-018-1181-x | Ineligible outcomes |
| 2010 | Dillon Katie ASzymkiewicz Steven JKLeventhal Thomas E | Evaluation of the effectiveness of a wearable cardioverter defibrillator detection algorithm. | Journal of electrocardiology | 43 1 7 | https://dx.doi.org/10.1016/j.jelectrocard.2009.05.010 | Ineligible study design |
| 2018 | Zylla Maura M, Hillmann Henrike A, KProctor TanjaKieser MeinhardScholz EberhardZitron EdgarKatus Hugo AThomas Dierk | Use of the wearable cardioverter-defibrillator (WCD) and WCD-based remote rhythm monitoring in a real-life patient cohort. | Heart and vessels | 33 11 1402 | https://dx.doi.org/10.1007/s00380-018-1181-x | Duplicate study |
| 2018 | Zylla Maura M, Hillmann Henrike A, KProctor TanjaKieser MeinhardScholz EberhardZitron EdgarKatus Hugo AThomas Dierk | Use of the wearable cardioverter-defibrillator (WCD) and WCD-based remote rhythm monitoring in a real-life patient cohort. | Heart and vessels | 33 11 1402 | https://dx.doi.org/10.1007/s00380-018-1181-x | Ineligible outcomes |

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| Year | Authors | Title | Journal | Volume/Issue/Page | DOI | Excluded reason |
|------|---------|-------|---------|-------------------|-----|-----------------|
| 2020 | Hubner Pia; Wijshoff Ralph; C G RMuehlsteff Jenn; Wallmuller Christian; Warenits Rex; Magnet Ingrid; Anna Maria Nammi Krischanak; Russel James; K Sterz Fritz | On detection of spontaneous pulse by photoplethysmography in cardiopulmonary resuscitation. | The American journal of emergency medicine | 38/3/533 | https://dx.doi.org/10.1016/j.ajem.2019.05.044 | Ineligible outcomes |
| 2018 | Zengin Suat; Gumusboga Hasan; Sabak Mustafa Eren; Sekvi; Hakan Altunbas; Gokhan Al Behcet | Comparison of manual pulse palpation, cardiac ultrasonography and Doppler ultrasonography to check the pulse in cardiopulmonary arrest patients. | Resuscitation | 133/64 | https://dx.doi.org/10.1016/j.resuscitation.2018.09.018 | Ineligible study design |
| 2019 | Majumder A K M; Jahangir Alam; El Saadany Yusuf; Amr Young Roger; Ucci Donald R. | An Energy Efficient Wearable Smart IoT System to Predict Cardiac Arrest | | | | Duplicate study design |
| 2019 | Kami Ali; Aida Fister Iztok; Turkanovi A; Muhamed Karakati Sa A | Sensors and functionalities of non-invasive wrist-wearable devices: A review | Nat Rev Cardiol | 19 | https://doi.org/10.1038/s41569-018-00522-7 | Review article |
| 2020 | Hahnen Christina; Freeman Cecilia G.; Halder Nilanjana; Hamati Jacquelyn N.; Bard Dylan M.; Murali Vignesh Merli; Josey Jeffrey; I. van Helmond Noud | Accuracy of Vital Signs Measurements by a Smartwatch and a Portable Health Device: Validation Study | | 8/2 | https://doi.org/10.2196/16811 | Ineligible reference test |
| 2017 | Ahn Hyun Jun; You Sung Min Cho Kyeongwon Park Hoong Ki Kim In Young | | | | | Article not in English |
| 2021 | Martins J; Machado da Silva D; Guimaraes L; Martins M; Vaz Da Silva | Monitor: The start of a new era of ambulatory heart failure monitoring? Part II - Design | | | | Ineligible study design |
| 2012 | Jaeger S; Fersmner D; Wettkuch F; Einhaus J; Schmidt A; Bolz T; Birkholz | Non-invasive detection of changes in arterial blood pressure with novel nonlinear capacitive resonance circuit technology | | | | Ineligible reference test |
| 2012 | Birkholz S; Fersmner A; Irouschek D; Wettkuch F; Schmidt F; Einhaus A; Bolz M | Detection of cardiac arrest with an integrated sensor system. [German] | | | | No full text available |

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| Year | Authors | Title | Journal | Volume | Issue | Page | DOI | Excluded reason |
|------|---------|-------|---------|--------|-------|------|-----|-----------------|
| 2011 | BirkholzM, PetruninaS, FernsnerD, WettachA, IrouschekF, EinhausJ, SchmidtM, Jaeger | Detection of prehospital cardiac arrest by lays: Validation of a miniaturized sensor system in patients with cardiopulmonary bypass |  |  |  |  | https://doi.org/10.1016/S0300-9572(11)70033-8 | No full text available |
| 2010 | Bonato | Advances in wearable technology and its medical applications |  |  |  |  |  | Review article |
| 1973 | David R.M, Portnoy W.M. | A low cost, portable ventricular fibrillation cardiac arrest discriminator | Medical Instrumentation | 7 | 4 | 239 |  | No full text available |
| 2017 | Nishitha Reddy A, Mary Marks A, Prabaharan S.R, Muthulakshmi S. | IoT augmented health monitoring system |  |  |  | 254 | https://doi.org/10.1109/ICNETS2.2017.8067942 | Ineligible study design |
| 2017 | Ferretti Jacopo Di, Pietro Licia De Maria Carmelo | Open-source automated external defibrillator | HardwareX | 2 | 70 |  | https://doi.org/10.1016/j.ohx.2017.09.001 | Ineligible index test |
| 2010 | Bonato Paolo | Advances in wearable technology and its medical applications |  |  |  | 2024 | https://doi.org/10.1109/IEMBS.2010.5628037 | Review article |
| 2014 | Shivakumar Nair Siddharth Sasikala M. | Design of vital sign monitor based on wireless sensor networks and telemedicine technology |  |  |  |  | https://doi.org/10.1109/ICGCCEE.2014.6922257 | Ineligible study design |
| 2019 | Mahajan Sonali Birajdar A.M. | IOT based Smart Health Monitoring System for Chronic Diseases |  |  |  |  | https://doi.org/10.1109/PuneCon46936.2019.9105717 | Ineligible study design |
| 2016 | Kassem Abdallah Hamad Mustapha Moucary Chady El Fayad Elie | A smart device for the detection of heart abnormality using R-R interval |  | 0 | 296 |  | https://doi.org/10.1109/ICM.2016.7847873 | Ineligible study design |
| 2021 | Roy Etee Kawa Kher Shubhalaxmi | Smart assist system for driver safety | AISC | 1252 | 187 |  | https://doi.org/10.1007/978-3-030-55190-2_14 | Ineligible reference test |
| 2020 | Kristoffersson Annica Linden Maria | Wearable sensors for monitoring and preventing noncommunicable diseases: A systematic review | Information (Switzerland) | 11 | 11 | 31 | https://doi.org/10.3390/info1110521 | Review article |
| 2017 | Sun Fangmin Yi Chenfuli Weinan Li Ye | A wearable H-shirt for exercise ECG monitoring and individual lactate threshold computing | Computers in Industry | 92–93 | 11 |  | https://doi.org/10.1016/j.cmpind.2017.06.004 | Ineligible outcomes |
| 2010 | Arzbaecher Robert Hampton David R. Burke Martin C. Garrett Michael C. | Subcutaneous electrocardiogram monitors and their field of view | Journal of electrocardiology | 43 | 6 | 605 | https://doi.org/10.1016/j.jelectrocard.2010.05.017 | Review article |
| 2012 | Bose Sumanta Prabu K. Kumar D. Sriram | Real-Time Breath Rate Monitor based Health Security System using Non-invasive Biosensor | 2012 Third International Conference on Computing Communication & Networking Technologies (Icccnt) |  |  |  |  | Ineligible study design |
| 2017 | Tan Tan-Hsu Gochoo Munkhjargal Chen Yung-Fu Hu Jin-Jia Chang John Y. Chang | System Based on Wireless Biosensors, | Sensors | 17 | 1 |  | https://doi.org/10.3390/s17010202 | Ineligible study design |

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| Year | Authors | Title | Journal | Volume/Issue | Page | DOI | Excluded reason |
|------|---------|-------|---------|--------------|------|-----|-----------------|
| 2017 | Kim Kwang-il, Gollamudi Shreya S., Steinhubl Steven | Digital technology to enable aging in place | Experimental gerontology | 88 | 31 | https://doi.org/10.1016/j.exger.2016.11.013 | Review article |
| 2017 | Sun Fangmin, Yi Chenfu, Li Weinan, Li Ye | A wearable H-shirt for exercise ECG monitoring and individual lactate threshold computing | Computers in Industry | 92–93 | 11 | https://doi.org/10.1016/j.compind.2017.06.004 | Duplicate study |
| 2017 | Wei Liang, Chen Gang, Yang Zhengfei, Yu Tao Quan, Weilun Li, Yong Qin | Detection of spontaneous pulse using the Plos One acceleration signals acquired from CPR feedback sensor in a porcine model of cardiac arrest | Plos One | 12 | 12 | e0189217 | Ineligible index test |
| 2019 | Majumder A. K. M., Jahangir Alam, ElSaadany Yosuf Amr, Young Roger, Ucci Donald R. | An Energy Efficient Wearable Smart IoT System to Predict Cardiac Arrest | Advances in Human-Computer Interaction | 2019 | | https://doi.org/10.1155/2019/1507465 | Ineligible outcomes |
| 2010 | Bonato Paolo | Advances in wearable technology and its medical applications. | IEEE Engineering in Medicine and Biology Society. Annual International Conference | 2010 | 4 | https://dx.doi.org/10.1109/EMBS.2010.5628037 | Duplicate study |
| 2000 | Aly A F, Afchine D, Esser M, Niewerth Tellem | Telemetry as a new concept in long term monitoring of SIDS-risk infant. | European journal of medical research | 5 | 1 | 22 | Ineligible reference test |
| 1985 | Munley A J, Raitton R, Fisher J, Barclay R | Infant respiration monitoring—evaluation of a simple home monitor. | Journal of medical engineering & technology | 9 | 6 | 5 | Ineligible outcomes |
| 2019 | Elola Andoni, Aramendi Elisabete, Irusta Unai, Del Ser Javier, Alonso Erik, Daya Mohamud | ECG-based pulse detection during cardiac arrest using random forest classifier | Medical & Biological Engineering & Computing | 57 | 2 | 462 | Ineligible index test |
| 2020 | Reddy null S. B., Seshadri null G., Sankesh Bothra null T. G., Suhas null S., Thundiyil null | Detection of Arrhythmia in Real-time Using ECG Signal Analysis and Convolutional Neural Networks | 2020 IEEE 21st International Conference on Computational Problems of Electrical Engineering (CPEE) | 4 | | | Ineligible index test |
| 2021 | Bayoumy Karim, Gaber Mohammed Elshafeey, Abdallah Mhaimeed Omar, Dineen Elizabeth H., Marvel Francoise A., Martin | Smart wearable devices in cardiovascular care: where we are and how to move forward | Nat Rev Cardiol | 19 | | | Review article - round 2 |
| Year | Authors | Title | Journal | Volume | Issue | Page | DOI | Excluded reason |
|------|---------|-------|---------|--------|-------|------|-----|-----------------|
| 2019 | Elola Andoni Aramendi Elisabetelrusta Unai Del Ser Javier Alonso Erik Daya Mohamud | ECG-based pulse detection during cardiac arrest using random forest classifier | Med Biol Eng Comput | 57 | 2 | 462 | https://doi.org/10.1007/s11517-018-1892-2 | Duplicate study |
| 2016 | Gjoreski Martin Gjoreski Hristijan Lučtrek Mitja Gams Matjaž Aščičk | How Accurately Can Your Wrist Device Recognize Daily Activities and Detect Falls? | Sensors (Basel) | 16 | 6 | | https://doi.org/10.3390/s16060800 | Ineligible reference test |
| 2013 | Hsu Yu-Pin Young Darrin J. | Skin-surface-coupled personal health monitoring system | | 4 | | | https://doi.org/10.1109/ICSENS.2013.6688176 | Ineligible reference test |
| 2016 | Kroll Ryan R. Boyd J. Gordon Maslove David M. | Accuracy of a Wrist-Worn Wearable Device for Monitoring Heart Rates in Hospital Inpatients: A Prospective Observational Study | J Med Internet Res | 18 | 9 | | https://doi.org/10.2196/jmir.6025 | Ineligible study design |
| 2017 | Kroll Ryan R. McKenzie Erica D. Boyd J. Gordon Sheth Prameet Howes Daniel Wood Michael Maslove David M. | Use of wearable devices for post-discharge monitoring of ICU patients: a feasibility study | J Intensive Care | 5 | | | https://doi.org/10.1186/s40560-017-0261-9 | Ineligible index test |
| 2017 | Lee Chieh-Sen Wu Chun-Yi Kuo Yen-Liang | Wearable Bracelet Belt Resonators for Noncontact Wrist Location and Pulse Detection | | 65 | 11 | 4482 | https://doi.org/10.1109/TMTT.2017.2684118 | Ineligible reference test |
| 2020 | Hankey Martha E. Foster James | Care event detection and alerts | | | | | | Ineligible study design |
| 2014 | Appelboom Geoff Camacho Elvis Abraham Mickey E. Bruce Samuel S. self-assessment and monitoring Dumont Emmanuel LP Zacharia Brad E. D'ale Amico Randy Slomian Justin Reginster Jean Yves Bruyère | Smart wearable body sensors for patient Archives of Public Health | 72 | 1 | | https://doi.org/10.1186/2049-3258-72-28 | Review article - round 2 |

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| Year | Authors | Title | Journal | VolumeIssuePage | DOI | Excluded reason |
|------|---------|-------|---------|-----------------|-----|-----------------|
| 2018 | Narasimha Deepika Hana Nader Beck Hiroko Chaskes Michael Glover Robert Gatewood Robert Bourji Mohamad Gudleski Gregory D. Danzer Susan Curtis Anne B. | Validation of a smartphone-based event recorder for arrhythmia detection | 41 | 5 | 494 | https://doi.org/10.1111/pace.13317 | Ineligible study design |
| 2019 | Sohn Kwang Hyun Merchant Faisal M. Abohashem Shady Kulkarni Kanchan Singh Jagmeet P. Heist E. Kevin Owen Chris Jr Jesse D. Roberts Sisselbacher Eric M. Sana Furrukh Armoundas Antonis A. | Utility of a smartphone based system (cvrphone) to accurately determine apneic events from electrocardiographic signals | 14 | 6 | | https://doi.org/10.1371/journal.pone.0217217 | Ineligible outcomes |
| 2015 | Hernandez Javier McDuff Daniel J. Picard Roosand W. | Biophone: Physiology monitoring from peripheral smartphone motions | 7 | 1 | 7183 | https://doi.org/10.1109/EMBC.2015.7320048 | Ineligible outcomes |
| 2017 | Kiranyaz Serkan Ince Turker Gabbouj Moncef | Personalized Monitoring and Advance Warning System for Cardiac Arrhythmias Estimation Using Head-mounted Motion-sensitive Sensors | 7 | 1 | | https://doi.org/10.1038/s41598-017-09544-z | Ineligible index test |
| 2014 | Barrett Paddy M. Komatireddy RavIhaaser Sharon Topol Sarah Sheard Judith Encinas Jackie Fought Angela J. Topol Eric J. | Comparison of 24-hour Holter monitoring with 14-day novel adhesive patch electrocardiographic monitoring | 127 | 1 | 17 | https://doi.org/10.1016/j.amjmed.2013.10.003 | Duplicate study |
| 2014 | Schreiber Donald Sattar AyeshadriGallah Dorian Higgins Steven | Ambulatory Cardiac Monitoring for Discharged Emergency Department Patients with Possible Cardiac Arrhythmias | 15 | 2 | | https://doi.org/10.5811/westjem.2013.11.18973 | Ineligible index test |
| 2018 | Narasimha Deepika Hana Nader Beck Hiroko Chaskes Michael Glover Robert Gatewood Robert Bourji Mohamad Gudleski Gregory D. Danzer Susan Curtis Anne B. | Validation of a smartphone-based event recorder for arrhythmia detection | 41 | 5 | 494 | | Duplicate study |
| 2017 | Cadmus-Bertram Lisa Gangnon Ronald Wirkus Emily J. Thraen-Borowski Keith M. Gorgellitz-Liebhauser Jessica | The Accuracy of Heart Rate Monitoring by Some Wrist-Worn Activity Trackers | 166 | 8 | 612 | https://doi.org/10.7326/L16-0353 | Ineligible reference test |
| 2017 | Paradkar Neeraj Chowdhury Shubhajit Roy | Cardiac arrhythmia detection using photoplethysmography | 2017 | 116 | | https://doi.org/10.1109/EMBC.2017.8036775 | No full text available |
| 2019 | Ip James E. | Wearable Devices for Cardiac Rhythm Diagnosis and Management | 321 | 4 | 338 | https://doi.org/10.1001/jama.2018.20437 | Review article - round 2 |
| 2013 | Lobodzinski S. Suave | ECG patch monitors for assessment of | 56 | 2 | 229 | | Review article - |
| Year | Authors | Title | Journal | VolumeIssuePage | DOI | Excluded reason |
|------|---------|-------|---------|-----------------|-----|-----------------|
| 2019 | Majumder AKM Jahangir Alam El Saadany Yosuf Amr Young Roger Ucci Donald R. | An Energy Efficient Wearable Smart IoT System to Predict Cardiac Arrest | pcad.2013.08.006 | 2019 | Duplicate study |
| 2021 | Krittanawong Chayakrit Rogers Albert J. Johnson Kipp W. Wang Zhen Turakhia Mintu P. Halperin Jonathan L. Narayan Sanjiv M. | Integration of novel monitoring devices with machine learning technology for scalable cardiovascular management | Nat Rev Cardiol | 18 2 91 | Review article - round 2 |
| 2014 | Walsh Joseph A. Topol Eric J. Steinheilb Steven R. | Novel Wireless Devices for Cardiac Monitoring | JAMA Cardiology | 130 7 581 | Review article - round 2 |
| 2017 | Wang Robert Blackburn Gordon Desai Milind Phelan Dermot Gillinov Lauren Houghtaling Penny Gillinov Marc Charles G. | Accuracy of Wrist-Worn Heart Rate Monitors | npj Digit. Med. | 2 1 106 | Ineligible reference test |
| 2013 | Winokur Eric S. Delano Maggie K. Sodini Charles G. | A Wearable Cardiac Monitor for Long-Term Data Acquisition and Analysis | Sensors and Functionalities of Non-Invasive Wrist-Wearable Devices: A Review | 18 6 | Review article - round 2 |
| 2019 | Lee Yoonje Shin Hyungoo Choi Hyuk Joong Kim Changsuns | Can pulse check by the photoplethysmography sensor on a smart watch replace carotid artery palpation during cardiopulmonary resuscitation in cardiac arrest patients? a prospective observational diagnostic accuracy study | BMJ Open | 9 2 | Ineligible index test |
| 2018 | Kami A. Ali A. Aida Fister Iztok Turkanovi A. Muhammed Karakati A. Sa A. o | Sensors and Functionalities of Non-Invasive Wrist-Wearable Devices: A Review | Sensors and Functionalities of Non-Invasive Wrist-Wearable Devices: A Review | 18 6 | Review article - round 2 |
| 2021 | Fine Jesse Branar Kimberly L. Rodriguez Sources of Inaccuracy in Photoplethysmography for Continuous Cardiovascular | Andres J. Boonya-Ananta Tananant Ajmal Monitoring. [Review] null Ramella-Roman Jessica C. McShane Michael J. Cote Gerard L. | BMJ Open | 9 2 | Ineligible index test |
| Year | Authors | Title | Journal | Volume | Issue | Page | DOI | Excluded reason |
|------|---------|-------|---------|--------|-------|------|-----|----------------|
| 2020 | Elayi Claude S, Erath-Honold Julia W, Jabbari Reza, Roublle Francois, Silvain Johanne Barra Sergio, Provodencia Rui, Njeim Mario, Narayanan Kumar, Deharo Jean-Claude, Defaye Pascal, Boveda Serge, Leclercq Christophe, Marijon Eloi | Wearable cardioverter-defibrillator to reduce the transient risk of sudden cardiac death in coronary artery disease, electrophysiology: journal of the working groups on cardiac pacing, arrhythmias, and cardiac cellular electrophysiology of the European Society of Cardiology | Europace: European pacing, arrhythmias, and cardiac electrophysiology: journal of the working groups on cardiac pacing, arrhythmias, and cardiac cellular electrophysiology of the European Society of Cardiology | 22 | 10 | https://dx.doi.org/10.1093/europace/euaa045 | |
| 2020 | Hahnen Christina, Freeman Cecilia G., Haldar Nilanjan, Hamati Jacquelyn N., Bard Dylan M., Murali Vignesh, Merli Geno J., Joseph Jeffrey I., van Helmond Noud | Accuracy of Vital Signs Measurements by a Smartwatch and a Portable Health Device: Validation Study | Accuracy in Wrist-Worn, Sensor-Based Measurements of Heart Rate and Energy Expenditure in a Diverse Cohort | 38 | 6 | 335 | https://doi.org/10.9718/JBER.2017.38.6.330 | Duplicate study |
| 2015 | Fung Erik, Årvein Marjo-Riitta, Doshi Rahul N., Shinbane Jerold S., Carlson Steven K., Grauzette Luanda P., Chang Philip M., Sangha Rajbir S., Huikuri Heikki, V. Peters Nicholas S. | Electrocardiographic patch devices and contemporary wireless cardiac monitoring | Electrocardiographic patch devices and contemporary wireless cardiac monitoring | 6 | | | https://doi.org/10.3389/fphys.2015.00149 | Duplicate study |
| 2017 | Ahn Hyun Jun, You Sung Min, Cho Kyeongwon, Park Hoon Ki, Kim In Young | Accuracy in Wrist-Worn, Sensor-Based Measurements of Heart Rate and Energy Expenditure in a Diverse Cohort | Accuracy in Wrist-Worn, Sensor-Based Measurements of Heart Rate and Energy Expenditure in a Diverse Cohort | 38 | 6 | 335 | https://doi.org/10.9718/JBER.2017.38.6.330 | Duplicate study |
| 2012 | Ackermans Paul A. J., Solosko Thomas A., Spencer Elise C., Gehman Stacy E., Nammi Krishnakant, Engel Jan, Russell James K. | A user-friendly integrated monitor-adhesive patch for long-term ambulatory electrocardiogram monitoring | J Electrocardiol | 45 | 2 | 153 | https://doi.org/10.1016/j.jelectrocard.2011.10.007 | Ineligible outcomes |
| 2014 | Barrett Paddy M., Komatireddy Ravi Haaser Sharan, Topol Sarah, Sheard Judith Encinas Jackie, Fought Angela J., Topol Eric J. | Comparison of 24-hour Holter Monitoring with 14-day Novel Adhesive Patch Electrocardiographic Monitoring | Am J Med | 127 | 1 | | https://doi.org/10.1016/j.amjmed.2013.10.003 | Ineligible index test |
| 2015 | Bolourchi Meena, Batra Anjan S. | Diagnostic yield of patch ambulatory electrocardiogram monitoring in children (from a national registry) | Am J Cardiol | 115 | 5 | 634 | https://doi.org/10.1016/j.amjcard.2014.12.014 | Ineligible index test |
| 2017 | Zimetbaum Peter, Goldman Alena | Ambulatory Cardiac Monitoring for Discharged Emergency Department Patients with Possible Cardiac Arrhythmias | Circulation | 122 | 16 | 1636 | https://doi.org/10.1161/CIRCULATIONAHA.109.925610 | Review article - round 2 |
| 2017 | An Byeong Wan, Shin Jung Hwal, Kim So-Yun, Kim Joohes, Ji Sangyoon, Park Jihun Lee, Youngjin, Jang Jiuk Park Young- | Smart Sensor Systems for Wearable Electronic Devices | Smart Sensor Systems for Wearable Electronic Devices | 9 | 8 | | https://doi.org/10.3390/polym9080303 | Review article - round 2 |
| Year | Authors | Title | Journal | Volume | Issue | Page | DOI | Excluded reason |
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| 2011 | Lee Sang-Suk, Son Il-Ho, Choi Jong-Gu, Nam Dong-Hyun, Hong You-Sik, Lee Woo-Beom | Estimated Blood Pressure Algorithm for a Wrist-wearable Pulsimeter Using Hall Device | J Kinesiol | 58 | 2 | 352 | https://doi.org/10.3938/jkps.58.349 | Ineligible outcomes |
| 2016 | Khan Yasser, Ostfeld Aminy E, Lochner Claire M, Pierre Adrien, Arias Ana C. | Monitoring of Vital Signs with Flexible and Wearable Medical Devices | Adv Mater | 28 | 22 | 4395 | https://doi.org/10.1002/adma.201504366 | Review article - round 2 |
| 2015 | Bloss Richard | Wearable sensors bring new benefits to continuous medical monitoring, real time physical activity assessment, baby monitoring and industrial applications | Human health monitoring technology | Review article - round 2 |
| 2012 | Malhi Karandeep, Mukhopadhyay Subhas Chandra, Schnepper Julia, Haefke Mathias, Ewald Hartmut | A Zigbee-Based Wearable Physiological Parameters Monitoring System | JSEN | 12 | 3 | 430 | https://doi.org/10.1109/JSEN.2010.2091719 | Ineligible index test |
| 2014 | Tamura Toshiyo, Maeda Yuka, Sekine Masaki | Wearable Photoplethysmographic Sensors: Past and Present | Sensors (Basel) | 3 | 2 | 302 | https://doi.org/10.3390/sensors14030302 | Review article - round 2 |
| 2018 | Koydemir Hatice Ceylan, Ozcan Aydogan | Wearable and Implantable Sensors for Biomedical Applications | Annu Rev Anal Chem (Palo Alto Calif.) | 11 | 1 | 146 | https://doi.org/10.1146/annurev-anchem-061417–125956 | Review article - round 2 |
| 2011 | Ding Dan, Cooper Rory A, Pasquina Paul F, Fici-Pasquina Lavinia | Sensor technology for smart homes | Maturitas | 69 | 2 | 136 | https://doi.org/10.1016/j.maturitas.2011.03.016 | Review article - round 2 |
| 2020 | Kristoffersson Annica, Lind Maren Maria | A Systematic Review on the Use of Wearable Body Sensors for Health Monitoring: A Qualitative Synthesis | Sensors (Basel) | 20 | 5 | | https://doi.org/10.3390/s20051502 | Review article - round 2 |
| 2011 | Scholten Annemieke C, van Manen Jeanette G, van der Worp Wim E, IJzerman Maarten J, Doggen Carine J, M. | Early cardiopulmonary resuscitation and use of Automated External Defibrillators by laypersons in out-of-hospital cardiac arrest using an SMS alert service | Resuscitation | 82 | 10 | 1278 | https://doi.org/10.1016/j.resuscitation.2011.05.008 | Ineligible outcomes |
| 2018 | King Christine E, Sarrafzadeh Majid | A Survey of Smartwatches in Remote Health Monitoring | J Healthc Inform Res | 2 | 1 | 24 | https://doi.org/10.1007/s41666-017-0012-7 | Review article - round 2 |
| 2021 | Zompanti Alessandro, Sabatini Anna Grasso Simone, Pennazza Giorgio, Ferri Giuseppe, Barile Gian Luca, Chello Massimo, Lusini Mario Santonico Marco | Development and Test of a Portable ECG Device with Dry Capacitive Electrodes and Driven Right Leg Circuit. | Sensors (Basel, Switzerland) | 21 | 8 | | https://dx.doi.org/10.3390/s21022777 | |
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| 2018 | Kekade Shwetambara, Hsieh Chung-Hol, Islam Md. Mohaimenul Atique | The usefulness and actual use of wearable devices among the elderly | Computer Methods and Programs in Biomedicine | 153 | 159 | | https://doi.org/10.1016/j.cmpb.2017.10.008 | Review article - round 2 |

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| 2016 | Piwek Lukasz Ellis David A. Andrews Sally Joinson Adam | The Rise of Consumer Health Wearables: Promises and Barriers | PLOS Medicine | 13 2 | https://doi.org/10.1371/journal.pmed.1001953 | Review article - round 2 |
| 2017 | Vegesna Ashok Tran Melody Angelaccio Michele Arcona Steve | Remote Patient Monitoring via Non-Invasive Digital Technologies: A Systematic Review | | 23 1 17 | https://doi.org/10.1089/tmj.2016.0051 | Review article - round 2 |
| 2020 | Vardas Panos Cowie Martin Dagres Nikolaos Asvestas Dimitrios Tzeis Stylianos Vardas Emmanuel P. Hindricks Gerhard Camm John | The electrocardiogram endeavour: from the Holter single-lead recordings to multilead wearable devices supported by computational machine learning algorithms | Europace | 22 1 23 | https://doi.org/10.1093/europace/euz249 | Review article - round 2 |
| 2020 | Kurath-Koller Stefan Salmond Hannes Scherr Daniel Bisping Egbert Burmas Ante Knez Igor Koestenberger Martin | Wearable cardioverter-defibrillator as bridging to ICD in pediatric hypertrophic cardiomyopathy with myocardial bridging - a case report. | BMC pediatrics | 20 1 | https://dx.doi.org/10.1186/s12887-020-02113-w | |
| 2020 | Shah Amit Isakadze Nino Levantsevych Oleksiy Vest Adriana Clifford Gari Nemati Shamim | Detecting heart failure using wearables: a physiological measurement pilot study. | Physiological measurement | 41 4 | https://dx.doi.org/10.1088/1361–6579/ab7f93 | |
Appendix F. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.resplu.2022.100277.

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