
# Wearable devices to prevent Covid-19 transmission in the workplace: a systematic review

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**The PROTECT COVID-19 National Core Study on transmission and environment is a UK-wide research programme improving our understanding of how SARS-CoV-2 (the virus that causes COVID-19) is transmitted from person to person, and how this varies in different settings and environments. This improved understanding is enabling more effective measures to reduce transmission – saving lives and getting society back towards 'normal'.**

Little is known regarding the use of bespoke wearables to prevent transmission of COVID-19. Defined as electronic devices that can be worn on the body, wearables have seen huge growth in use prior to the pandemic. Given the heightened risk of COVID-19 transmission in workplaces and the need to 'learn to live' with the virus moving forwards, it is important to understand the use of bespoke wearable devices and whether any existing evidence exists for their future use.

The aim of this review was to summarise the available published evidence around wearables in the workplace using specific and repeatable search criteria. The studies were predominantly conducted within a pilot or feasibility setting with only a small sample of participants taking part. The studies generally concluded that bespoke wearables were feasible and acceptable. However, six out of the seven studies were in health care workers which means results on feasibility and acceptability are unlikely to translate to other workplaces. There is limited evidence for the use of wearables in the workplace.

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# Wearable devices to prevent Covid-19 transmission in the workplace: a systematic review

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# Key messages

A wide variety of new health technologies have been developed at pace during the COVID-19 pandemic including vaccines, diagnostics, therapeutics and digital technologies such as mobile phone apps.

Less is known regarding the use of bespoke wearables to prevent transmission of COVID-19 in the workplace. As countries begin to ‘learn to live’ with COVID-19 it is important to understand what technologies can be placed within workplaces feasibly to mitigate risk.

A systematic review using bespoke search strategies was conducted using the databases: PubMed, Embase and the WHO – COVID-19 Global literature on coronavirus disease. A total of 1,268 potential references were found with seven included for selection.

Most studies were small pilots investigating the feasibility of using wearables. Two studies investigated acceptability and another investigated early symptom monitoring for diagnosis. Most studies were conducted in health care workers in the United States, with one study from Australia and another from Singapore. Methodological approaches were varied across the studies with many investigating proximity (contact within 1.5 metres for more than five seconds) as the primary outcome measure.

Studies found were small and were mainly pilots in groups of health care workers. Whilst the studies suggested wearables were feasible for contact / proximity tracing and were acceptable to users, the evidence is of poor quality and is not likely to be generalisable to a UK audience.

# Executive Summary


## Background

Defined as electronic devices that can be worn on the body, wearables have seen huge growth in use prior to the pandemic. Given the heightened risk of COVID-19 transmission in workplaces and the need to 'learn to live' with the virus moving forwards, it is important to understand the use of bespoke wearable devices and whether any existing evidence exists for their future use.

## Aim

The aim of this systematic review was to summarise the available published evidence around wearables in the workplace using specific and repeatable search criteria.

Key objectives were to understand whether wearables in the workplace were:

- effective at encouraging or monitoring social-distancing;
- acceptable to users;
- used in particular sectors or types of workplace.

## Methods

A systematic review following Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) and the Joanna Briggs Institute recommendations was conducted. We included interventional or observational studies evaluating the efficacy/effectiveness and acceptability of wearables in a workplace setting, with or without a comparator. We also included studies which attempted to find out the feasibility or acceptability of wearables by conducting qualitative research with users. We collected data on country of origin for the study, workplace setting, study methodology including sample size, results, evidence gaps, risk of bias, conflicts of interest and key conclusions of study authors.

## Findings

Publication years ranged from 2020 to 2021 and five of the seven studies were developed in the United States. Categorising broadly, from the seven published papers included in this systematic review, five evaluated contract tracing or proximity measurement, one early symptoms identification and two analysed acceptability. Only one study included some form of comparator. The studies were predominantly conducted within a pilot or feasibility setting with only a small sample of participants taking part. The studies generally concluded that bespoke wearables were feasible and acceptable. However, six out of the seven studies were in health care workers which means results on feasibility and acceptability are unlikely to translate to other workplaces. Due to the sample sizes, methodological approaches and reporting, the studies found were generally of low quality.

## Conclusions

There is limited evidence for the use of wearables in the workplace. There is no published evidence of using wearables in a UK or European workplace. Studies found were of low quality and in populations which are unlikely to be generalisable to the UK.

# 1. Introduction

## Background

On the 30th January 2020, the World Health Organisation (WHO) declared the novel coronavirus (2019-nCoV) to be a Public Health Emergency of International Concern (PHEIC). On March 11th, the WHO declared COVID-19 to be a pandemic. Two years later, COVID-19 is still having a material impact on workplaces, health and social care systems, as well as the basic functioning of societies.

Owing to the novelty of the disease, early governmental responses focused on the use of non-pharmaceutical interventions (NPIs) such as contact tracing, social distancing, closure of educational institutions and national 'lockdowns'[1, 2]. During the first national lockdown, UK residents were told to 'work from home, where you can'[3] reflecting the theory that workplace transmission was likely to be a key driver for the spread and transmission of COVID-19. As understanding of the virus improved it became increasingly apparent that transmission risk was highest where individuals clustered close together, indoors, in poorly ventilated spaces, which is often the setting for many workplaces[4]. Reducing transmission within workplaces consequently became an important focus for guidance as economies began to unlock[5].

The pandemic has also led to a transformational approach to research and development in the life sciences. New health technologies such as diagnostic tests, therapeutics and novel vaccines have been researched, and then implemented at rapid and unprecedented pace. Telemedicine approaches for home-based monitoring of lung function in those at highest risk have also been widely adopted[6, 7]. Meanwhile, digital technologies such as the ZOE mobile phone app have been incredibly popular, allowing users to track and record symptoms alongside their COVID-19 status[8].

Perhaps, the largest digital intervention employed is the NHS COVID-19 app which had 6 million downloads on its first day with hundreds of thousands of users per week instructed to self-isolate during the summer of 2021. Owing to its automated tracking and tracing, the app had created what some had dubbed a 'pingdemic'[9] with staff shortages and some workers encouraged to delete the app or pause contract tracing whilst at work[10]. Such experience highlights the challenges of employing and using generic digital technologies in a workplace setting where individuals are likely to be in close contact with one another.

Defined as electronic devices that can be worn on the body, wearables have seen huge growth in use prior to the pandemic[11]. Given the heightened risk of COVID-19 transmission in workplaces and the need to 'learn to live' with the virus moving forwards, it is important to understand the evidence for the use of bespoke wearable devices[12].

## Research Aim

The aim of this systematic review was to summarise the available published evidence around wearables in the workplace using specific and repeatable search criteria.

Key objectives were to understand whether wearables in the workplace were:

- effective at encouraging or monitoring social-distancing;
- acceptable to users;
- used in particular sectors or types of workplace.

# 2. Methodology

The review protocol was published online at the Open Science Framework (OSF) on https://osf.io/fcuhp (Registration DOI 10.17605/OSF.IO/FCUHP).

### Eligibility Criteria

A systematic review following Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) and the Joanna Briggs Institute recommendations was conducted[13]. The search strategy and inclusion criteria were directed by the Population, Intervention, Comparator, Outcome, Study design (PICOS) framework[14] as described in Table 1 below.

**Table 1: PICOS criteria for the systematic review**

| | |
|---|---|
| Population | People in a community/group or work setting at risk or susceptible to COVID-19 infection |
| Intervention | Wearables – worn electronic devices able to track and trace COVID-19 cases by proximity and/or by identifying initial symptoms. By wearable, the following will be included the following: Smartwatch, Wi-fi/wireless sensor, Wrist-worn electronic device, any other technology similar to digital solutions |
| Comparator | Not using any wearable device or any of the following: Traditional or manual contact tracing, Self-reported diaries and surveys, paper form, self-isolation, Interviews, any other method to determine close contacts, any other technology like digital solutions. |
| Outcomes | Effectiveness of preventing COVID-19 transmission measured by: contact tracing, reduction in transmission, outbreak response, proximity tracing, symptom tracking, identification of secondary cases and close contacts, time to complete contact tracing, acceptability and accessibility issues, privacy and safety concerns, average number of secondary cases per index case or effective reproductive number (R(eff)). |
| Study designs | Randomised controlled trials (RCTs), Prospective cohort studies, Retrospective cohort studies, Case-control studies, Systematic reviews of above, Pilot Studies, Feasibility Studies |

Hence, we included interventional or observational studies evaluating the efficacy/effectiveness and acceptability of wearables in a workplace setting, with or without a comparator. We also included studies which attempted to find out the feasibility or acceptability of wearables by conducting qualitative research with users. Exclusion criteria comprised articles published in non-Roman characters and studies conducted with COVID-19 positive patients or that did not address the outcomes of interest.

## Information sources

Searches were performed in the online databases Pubmed, Embase and WHO - COVID-19 Global literature on coronavirus disease without limits for timeframe or language. A trial search was first run on 15th of February to refine the search strategy. The final search was undertaken on the 2nd of March 2022.

## Search Strategy

The developed search strategy included descriptors related to COVID-19 and wearables combined with the Booleans AND and OR. The search strategy was optimised for each database considering the database specific variations. Search terms were used to minimise redundancies and to identify the most relevant articles. Manual searches of the reference lists from the included studies were also conducted. As we intended to perform a highly comprehensive search, descriptors for the study design, population, comparator and outcomes were not included in the search strategy. Full search strategies can be found in full in the Appendix 7.1.

## Study Records

### Data management

Endnote™ and Rayyan were used to upload, manage, cite and review the selected literature.

### Selection process

All stages of the study were conducted by two independent reviewers (AT, LL). Titles and abstracts were screened to identify irrelevant records. Then, full-text articles were appraised. In case of disagreements, a third reviewer would act as a referee, although this was not necessary.

A standardised form to collect data was developed with information collected on country of origin for the study, workplace setting, study methodology including sample size, results, evidence gaps, risk of bias, conflicts of interest and key conclusions of study authors.

### Risk of bias

The methodological quality of included studies was assessed using the Newcastle-Ottawa Scale (NOS)[15] and can be found in the Appendix 7.2.

### Synthesis

It was expected that the nature of studies found would be highly variable making formal quantitative analysis, such as meta-analysis, unfeasible. Therefore, review data were summarised in a narrative style.

# 3. Overview of the evidence

A total of 1,268 potential references were identified using the search strategy described, after removing 120 duplicates. After screening processes and following the inclusion and exclusion criteria, 7 papers were included. A schematic of the search and review process is provided in Figure 1.

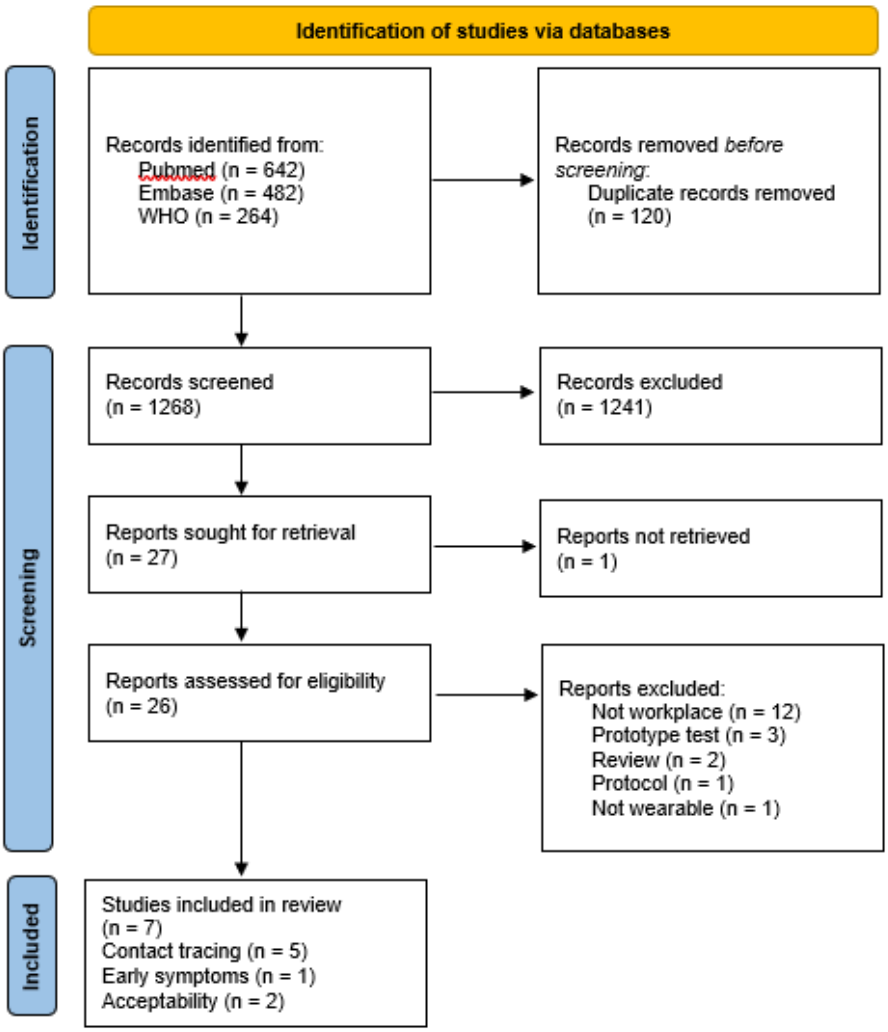


**Figure 1: PRISMA 2020 flow diagram[16]**

Categorising broadly, from the seven published papers included in this systematic review, five evaluated contract tracing or proximity measurement[17-21], one early symptoms identification[22] and two analysed acceptability[21, 23]. A complete characteristic description of the included papers is summarised in Table 2.

Publication years ranged from 2020 to 2021 and five of the seven studies were developed in the United States[19-23]. Of the five studies investigating contract tracing or proximity measurement, all were pilots with sample sizes of less than fifty participants. Only one study included some form of comparator with Sick-Samuels et al[19] adopting a 'before and after' design. The remaining four studies did not include a comparator[17, 18, 20, 21]. To validate the proximity measurements, two studies[17, 19] used direct observation of study participants, one

study used participant checking of the results each day[21] and one study used electronic medical health records[17]. Curtis et al[18] did not use any validation method.

Table 3 describes the population and the outcomes of each of the included studies. As the searched evidence was from a workplace setting only studies that included workers and/or were developed in a workplace were included. None of the studies attempted to directly ascertain the impact of wearables on transmission of COVID-19. Most of the studies (86%) were conducted with healthcare workers who were conducting their work functions in close proximity with suspected or positive cases of COVID-19[17-20, 22, 23]. Studies assessing proximity used a variety of different distances and time periods to define contact.

Regarding conflict of interests, one study[23] had a co-author as shareholder (<0.05% stock) in the technology company used for the research, two other studies declared conflicts of interest[21, 22] and only two studies disclosed not having conflicts[17, 18]. Two studies[19, 20] were funded by the Centers for Disease Control and Prevention Epicenter Program, COVID-19 supplement to grant number 6U01CK000554-02-02.

The Newcastle-Ottawa Quality Assessment Scale (NOS), recommended for observational studies, was used to extract data. The NOS contains 8 items which are grouped into 3 different categories: selection, comparability, and exposure. It is scored using a star system, with a maximum of 9 stars able to be awarded over the 3 categories[24, 25]. The mean NOS score for the included studies was 5 (ranging from 4 to 6) showing low-moderate methodologic quality.

**Table 2: Characteristics of the included studies**

| Author; Year | Country | Period of study | Technology type | Design | Comparator | Sample size n [Follow-up /compliance] | Validation |
|---|---|---|---|---|---|---|---|
| Curtis,SJ; 2021[18] | Australia | 13 April – 18 April 2021 | Contract tracing or proximity | Pilot cohort / network study | None | 27 [NR] | None. |
| Huang,Z; 2020[17] | Singapore | May 10 – May 20, 2020 | Contract tracing or proximity | Pilot cohort study. | None | 18 [NR] | Electronic medical records used to cross-check interactions. |
| Keller,SC; 2021[20] | USA | Sept 28 – Oct 28, 2020 | Contract tracing or proximity | Pilot cohort study. | None | 14 [mean 6.52] | Visual feedback from the device was checked with a tape measure.<br>Time data validated using direct observation |
| Sick-Samuels,AC; 2021[19] | USA | Dec 1 2020 – Feb 28, 2021 | Contract tracing or proximity | Pilot cohort study | Before and after | 40 [mean 13] | Regression analysis used to estimate the intervention impact. Direct observation of interactions using a semi-structured observation form. |
| Shelby,T; 2021[21] | USA | June – July 2020 | Contract tracing or proximity<br>& Acceptability | Pilot cohort study with post-participation survey. | None | 32 [NR] | Participant validation of identified and missed contacts each day. |
| Goodday,SM; 2021[23] | USA | May 1 – Nov 20, 2020 | Acceptability | Pilot cohort study | None | 365 [297] | N/A |
| Hirten,RP; 2021[22] | USA | April 29 – Sept 29, 2020 | Early symptoms identification | Cohort study | None | 297 [209] | COVID-19 confirmed diagnosis with nasal swab. |

NR = Not reported.

**Table 3: Description of population and outcomes of the included papers.**

| Author; Year | Population | Outcomes |
|---|---|---|
| Curtis,SJ; 2021[18] | **HCWs** (nurses and doctors) providing care to COVID-19 patient in a negative pressure room at the Alfred Hospital, Melbourne. | Frequency and duration of primary close contact.<br><br>Close contact defined as tags within 1.5 metres for at least 30 seconds. |
| Huang,Z; 2020[17] | **HCWs** - Physicians on 10-day rotating shifts at the COVID-19 screening center of the NCID in Singapore. All patients and physicians were issued temporary RTLS tags for contact tracing; mandatory use for entry into the centre. Physicians and patients installed the TraceTogether app (version 1.6) and activate their smartphone's Bluetooth function during their shifts or when medically attending patients. | Effectiveness of contact tracing. Proximity ≤ 2 metres. |
| Keller,SC; 2021[20] | **HCWs** from an inpatient, non-COVID, 24-bed medical unit in a tertiary care academic medical centre staffed by internal medicine nurses, resident physicians, and attending physicians. | Proximity < 6 feet for ≥ 5 seconds. |
| Sick-Samuels,AC; 2021[19] | **HCWs** - nurses, respiratory therapists, and clinicians (ie, advanced practice providers and attending, fellow, and resident physicians) at the Johns Hopkins Hospital Pediatric Intensive Care Unit (PICU) in Baltimore, Maryland. | Proximity < 6 feet for ≥ 5 seconds. Duration of time in minutes spent ≤ 6 feet apart and effective exposure risk score. |
| Shelby,T; 2021[21] | **Graduate students and researchers working** at a medium-sized private university in the US Northeast. Only essential personnel and select individuals were allowed on campus with prior approval. Campus-wide precautions included mask wearing, physical distancing, daily symptom assessments, and testing. | a) Close contact interactions defined as 15 minutes of interaction within 6 feet<br>b) Usability, acceptability, appropriateness and adherence. |
| Goodday,SM; 2021[23] | **Frontline HCWs** (medical doctors, doctors of osteopathy, physician assistants, registered nurses, advanced practice registered nurses, and other allied health care workers) working directly with patients with COVID-19 or work routines have been moderately or extremely impacted by the COVID-19 pandemic; older than 18 years; able to speak, write, and read English; able to provide informed consent; no known SARS-CoV-2 current or past infection; and owning a personal iOS mobile phone (OS11 and above) with willingness to download and use the study apps and sync phone with all study sensors. | Subjective and objective signs of stress. Feasibility, acceptability and adherence |
| Hirten,RP; 2021[22] | **HCWs** in the Mount Sinai Health System, that had an iPhoneSeries 6 or higher, and had or were willing to wear an AppleWatch Series 4 or higher. | Prediction and early identification of SARS-CoV-2 infections. |

# 4. Key findings

Only a small number of published studies were found exploring the impact of wearables on COVID-19 within the workplace. The studies focused on acceptability, symptom tracking or identifying contact / proximity rather than on direct transmission of COVID-19. The studies were predominantly conducted within a pilot or feasibility setting with only a small sample of participants taking part. Six out of the seven studies were in health care workers which in turn means results on feasibility and acceptability are unlikely to translate to other workplaces. Methodological approaches and reporting was varied with much of the focus of the published studies being on the technological solution rather than on the experimental approach. Smartphone apps, smartwatches, Bluetooth tags, smart rings, RTLS (real-time locating system) tags and beacons were the different types of technology applied as wearables in the included studies. Despite technical and conceptual differences, all of them were worn or carried on the participant's body.

### Contract tracing or proximity Tracing

One of the widely recognised preventive measures adopted during the COVID-19 outbreak was physical distancing (at least 6 feet or 2m apart from other individual) and this was a key approach to prevent transmission as recommended by the CDC and WHO [26, 27].

Two studies [19, 20] applied wearable proximity beacons (Estimote Technologies; Krakow, Poland) which are electronic devices with multiple sensors. The beacons were light and small and could be attached to the participant by lanyard, badge clip or carried in the pocket. Keller et.al.[20] was the pilot study conducted and Sick-Samuels et.al.[19] was the main study, however, they were conducted in different units with the main study presenting a multifaceted bundle of interventions to improve physical distancing. The authors conclude that their results show that beacon deployment is feasible in a workplace setting to monitor physical or to monitor the effectiveness of physical distancing mitigations. They argue that managers could use beacon data to target interventions to times or locations where physical distancing is challenging. The use of a beacon was argued to provide additional value to users by vibrating to remind them when they are standing in close proximity.

Wearable tags were another electronic device used for proximity tracing. Curtis et.al. (2021)[18] was a pilot study testing a Bluetooth Low Energy (BLE) wearable tag to be carried on the pocket, bag or clipped on an ID badge. This BLE system consisted of the tags, BLE receivers including two proximity sensors for tag recognition and an edge gateway device to securely receive, store and forward data to the cloud server via Wi-Fi. Interactions between tags and between the tag and the BLE receiver and data were regularly forwarded to the gateway via long-range data transmission. This device effectively identified close contacts and duration supporting the functionality of the proposed BLE approach to collect data on proximity networks in a workplace setting.

Shelby et.al. (2021)[21] also tested wearables tag based on Bluetooth functionality and a smartphone app. The tags recorded Bluetooth signals emitted from other tags, using signal strength to determine distance while recording the duration of interactions. Data were stored locally on the tags and routinely synced to a central server by study participants using a mobile app that paired with the participant's tag. The smartphone app functioned by

detecting Bluetooth signals emitted by other phones that had the same app downloaded and activated. The app estimated the distance between mobile phones based on signal strength while recording the duration of the interaction. The app only used Bluetooth to communicate with the tag while syncing and otherwise did not collect any additional data or use Bluetooth to communicate with any nonpaired tags or other devices. Data for contacts was compared and validated each day using participants self-judgment. Contacts missed were also reported by participants. The tag had significantly higher sensitivity compared to the app (46/49, 94% vs 35/61, 57%; P<0.001), as well as higher specificity (120/126, 95% vs 123/141, 87%; P=0.02). When false interactions were removed from the data set, sensitivity and specificity became 93% (43/46) and 100% (111/111), respectively.

Another study[17] also tested a Tag (RTLS [real-time locating system] Tag) and a smartphone app (TraceTogether). Exciters and wireless access points were fitted throughout the building to detect signals from RTLS tags. The tag received a signal whenever it passed a location exciter and sent a radio-frequency signal to the access points to determine the exact location of the RTLS tag. Radio-frequency identification technology was used to determine close contacts of ≤2 meters between staff and patients. The TraceTogether App exchanged Bluetooth signals with other nearby app users identifying proximity, and duration of users' contacts and storing the encrypted data locally in the smartphone.

Users were requested to upload the data captured on their smartphones should they be confirmed with COVID-19 infection to facilitate contact tracing. All contacts were compared and validated using the electronic medical record (EMR) System. The RTLS had a high sensitivity of 95.3% in detecting all patient contacts identified either by the RTLSsystem or TraceTogether app, while TraceTogether had an overall sensitivity of 6.5%. RTLS tags had high sensitivity (96.9%) and specificity (83.1%) while TraceTogether detected only 2 patient contacts with physicians who did not attend to them. Hence, the app had a sensitivity of 0% and specificity of 98.4%. The sensitivity of identifying patient contacts increased to 96.9% when both digital contact tracing tools were used simultaneously. The positive predictive value and negative predictive value of the RTLS were 59.6% and 99.0%, respectively, while those of TraceTogether were 0% and 79.2%, respectively. Due to the RTLS's moderately high positive likelihood ratio of 5.73 and high negative likelihood ratio of 0.04, the authors suggest that the RTLS is capable of ruling in and ruling out close contacts.

## Early symptom tracking and COVID-19 prediction

The Warrior Watch Study[22] employed a novel smartphone app to remotely enrol and monitor healthcare workers using a smartwatch. This digital platform enabled the delivery of remote surveys to Apple iPhones and passive collection of Apple Watch data, including heart rate variability (HRV). The time difference between heartbeats is classified as the inter beat interval (IBI), from which HRV is calculated. The Apple Watch and the Apple Health app automatically calculate HRV using the standard deviation of the IBI of normal sinus beats (SDNN), measured in milliseconds. This time domain index reflects both sympathetic and parasympathetic nervous system activity and is calculated by the Apple Watch during ultra–short-term recording periods of approximately 60 seconds. The Apple Watch generates several HRV measurements throughout a 24-hour period.

The study had 297 participants, with a median follow-up of 42 days (range 0-152 days). A median of 28 HRV samples (range 1-129) were obtained per participant. The HRV data

collected through the Apple Watch were characterised by a circadian pattern, a sparse sampling over a 24-hour period, and nonuniform timing across days and participants.

During the study, 13/297 participants (4.4%) reported a positive SARS-CoV-2 nasal swab PCR test, and diagnosis was informed on test day. Comparing with negative COVID-19 participants, positive participants presented significant difference in the circadian pattern of SDNN and significant difference (P=0.006) between the mean amplitude of the circadian pattern of SDNN (1.23 milliseconds, 95% CI –1.94 to 3.11) versus (5.30 milliseconds, 95% CI 4.97 to 5.65). Furthermore, significant changes in the circadian SDNN pattern were observed in participants during the 7 days prior to and the 7 days after the diagnosis of COVID-19.

As conclusions of the study, the authors suggest that their HRV metrics were found to be associated with a positive SARS-CoV-2 diagnosis and COVID-19 symptoms. They identified changes over the 7 days preceding the diagnosis of COVID-19 with significant alterations in amplitude when compared to individuals without COVID-19.

## Acceptability and privacy and safety concerns

Two of the included studies[21, 23] evaluated the acceptability and privacy and safety concerns. After testing the electronic devices (tag and app), Shelby et.al.[21] applied a post-participation survey focusing on their experiences using the pilot technology, as well as their perceptions regarding the appropriateness of technology-assisted tracing. The survey was adapted from a previously validated mHealth usability questionnaire and used a 7-point Likert scale ranging from strong agreement to strong disagreement, including a neutral response option and also contained a free-text question for any additional comments or suggestions about the technology.

Most participants felt that contact tracing via Bluetooth was appropriate but not GPS or Wi-Fi (26/32, 81% approval for Bluetooth vs 17/31, 55% approval for GPS/Wi-Fi; P=0.02). Most participants also preferred technology developed and managed by the university rather than a third party (27/32, 84%) and preferred to not download apps on their personal devices (21/32, 66%). Most participants (24/32, 75%) reported concerns about how their privacy would be protected. There were no differences between technologies regarding usability, considering both easy to install (25/31, 81%) and use (31/32, 97%). Regarding adherence, there was no difference between devices based on self-reported percentages of usage during the study time (mean 87%) but the tag device was considered more convenient to carry (11/12, 92% vs 11/20, 55%; P=0.03). Reasons for not carrying the device were forgetting the app device at home (2/13, 15%), or at a workstation (17/23, 74%). Tag pilot participants reported that charging the device interfered with adherence. All participants would be more likely to carry a Bluetooth device if it were smaller than a phone (19/20, 95%).

Goodday et.al (2021)[23] study comprised 3 main components: (1) active and passive assessments of stress and symptoms from a smartphone app (MyCap), (2) objective measured assessments of acute stress from wearable sensors (Oura smart ring and the Garmin smartwatch), and (3) a participant co-driven engagement strategy that centred on providing knowledge and support to participants (engagement strategy centred on providing information and support and Check-in Calls with specialists). Other optional technologies were offered as optional.

Of the 365 enrolled participants, 81.37% (n=297) completed the study. Participants adhered to wearing the Oura smart ring and the Garmin smartwatch for an average of 90.60% and 90.42% of study time, respectively. App-based daily, weekly, every 2 weeks, and monthly surveys were completed on average 69.18%, 68.37% (range across different tasks 64.44%-71.86%), 72.86% (range across different tasks 72.42%-73.30%), and 68.82% (range across different tasks 68.05%-69.82%) of study time, respectively. Every 2-week check-in phone calls were completed for an average of 75.62% of study time. The average check-in call length was approximately 14.5 minutes and ranged from 2 to 70 minutes.

Measures scheduled on Fridays and Saturdays had consistently lower adherence compared to other days of the week. Average adherence was higher for the active tasks (80.59%) compared to the cognition tasks (56.49%). Weekly average adherence on daily app measures across age categories were similar, and not statistically significant (F3=0.20; P=0.89), although there was a trend where higher age categories demonstrated higher adherence on Oura Ring use (F3=2.49; P=0.06). Adherence across other sample characteristics was not explored owing to small sample sizes across categories. Average adherence in the week after the joint participant-investigator Zoom call was held showed large increases for app-based daily surveys (82.93%), for cognition tasks (88.97%), and in Oura Ring use (97.89%). Overall feasibility and acceptability of the used approaches was 81% (n=297) retention, while average adherence for wearable sensor use and daily app-based assessments was approximately 90% and 70%, respectively.

# 5. Main Conclusions

- This systematic review found a very limited number of small pilot studies (n=7) that have investigated the impact of wearables within the workplace on COVID-19.
- Most studies (6/7, 86%) were conducted within health care workers. Most studies were in the United States (5/7, 71%). Both factors suggest limited generalisability to other workplace settings or countries.
- Studies focused on contact / proximity, symptom tracking and acceptability of wearables.
- Smartphone apps, smartwatches, Bluetooth tags, smart rings, RTLS (real-time locating system) tags and beacons were the different types of technology applied as wearables in the included studies.
- Methodological approaches were varied with the most frequent outcome measure for contact being within 1.5 metres of the wearable, for more than five seconds.
- One study suggested evidence that the use of apps had lower sensitivity than tags for identifying contacts.
- One study suggested evidence that smaller and more compact devices improve acceptability and adherence.
- Overall, the pilot studies provided evidence that wearables within the workplace were feasible for collecting data on contacts and were acceptable to users. However, previous comments regarding the generalisability of the studies to a UK setting, study variability and the small study sample sizes remain significant limitations with the existing evidence-base.

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# 7. Appendices

### 7.1 Search Strategy

**Pubmed/Medline**

#1
("COVID"[Title/Abstract]
OR "coronavirus"[Title/Abstract]
OR "Sars-cov-2"[Title/Abstract]
OR "covid 19"[MeSH Major Topic]
OR "Sars-cov-2"[MeSH Major Topic])
#2
("wearable electronic devic*"[Title/Abstract]
OR ("wearable"[Title/Abstract] AND "electronic"[Title/Abstract] AND "device"[Title/Abstract])
OR "wearable electronic devices"[MeSH Major Topic]
OR "wearabl*"[Title/Abstract]
OR ("electronic"[Title/Abstract] AND "devic*"[Title/Abstract])
OR "Smartwatch"[Title/Abstract]
#1 AND #2

**Embase**

#1
'coronavirus disease 2019':ab,ti
#2
('wearable device'/exp
OR 'wearable computer'/exp
OR 'wearable sensor'/exp
OR 'electronic device'/exp
OR 'smartwatch'/exp
#1 AND #2

**WHO – COVID-19 Global literature on coronavirus disease**

Title, abstract, subject: "wearable electronic device" OR "electronic device" OR "smartwatch"

## 7.2 Newcastle-Ottawa (NOS) scale

COHORT

| | Selection | | | | Comparability | Outcome | | |
|---|---|---|---|---|---|---|---|---|
| Study | Representativeness of the exposed cohort | Selection of the non exposed cohort | Ascertainment of exposure | Demonstration that outcome of interest was not present at start of study | Comparability of cohorts on the basis of the design or analysis | Assessment of outcome | Was follow-up long enough for outcomes to occur | Adequacy of follow up of cohorts |
| Hirten | * | | * | | | * | * | * |
| Keller | * | | * | | | * | * | * |
| Sick-Samuels | * | | * | * | | * | * | * |
| Shelby | | * | * | | * | * | * | * |
| Goodday | * | | * | | | * | * | |

CROSS-SECTIONAL

| | Selection | | | | Comparability | Exposure | |
|---|---|---|---|---|---|---|---|
| Study | Representativeness of the sample | Sample size | Non-respondents: | Ascertainment of the exposure (risk factor): | The subjects in different outcome groups are comparable, based on the study design or analysis. Confounding factors are controlled. | Assessment of the outcome: | Statistical test: |
| Huang | * | * | | * | * | * | |
| Curtis | * | * | | * | | * | |

**The PROTECT COVID-19 National Core Study on transmission and environment is a UK-wide research programme improving our understanding of how SARS-CoV-2 (the virus that causes COVID-19) is transmitted from person to person, and how this varies in different settings and environments. This improved understanding is enabling more effective measures to reduce transmission – saving lives and getting society back towards 'normal'.**



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