



## A Survey on IoT based Wearable Sensor for Covid-19 Pandemic

Noushini Nikeetha.P<sup>1</sup>, \*Pavithra.D<sup>2</sup>, Sivakarhiga.K<sup>3</sup>, Karthika.S<sup>4</sup>, Yashitha.R<sup>5</sup> and Kirubasri.G.V<sup>6</sup>

<sup>1,2,3,4,5,6</sup>Department of Biomedical Engineering, VelTech Multitech Dr.Rangarajan Dr.Sakunthala Engineering College, Chennai, India

[noushininikeetha@gmail.com](mailto:noushininikeetha@gmail.com), [pavidhushya1507@gmail.com](mailto:pavidhushya1507@gmail.com), [sivakarhiga2066@gmail.com](mailto:sivakarhiga2066@gmail.com),

[karthikas22@gmail.com](mailto:karthikas22@gmail.com), [yashurajesh22@gmail.com](mailto:yashurajesh22@gmail.com), [kirubavelu1611@gmail.com](mailto:kirubavelu1611@gmail.com)

\* Correspondence [pavidhushya1507@gmail.com](mailto:pavidhushya1507@gmail.com)

### Abstract

The COVID-19 pandemics have highlighted the importance of leveraging and harnessing our digital infrastructure enabling remote health monitoring. We foresee the need for more powerful diseases diagnosis and monitoring of personal and group health, which might be supported by wearable sensors, since conventional virus testing and vaccinations are delayed. Also, Internet of Things (IoT) has gained traction in a variety of research sectors, including academic and industrial settings, particularly in healthcare. By merging economic, social, and technological perspectives, IoT revolution reshapes today's healthcare systems. It evolves from traditional medical services to far more individualised programs that allow patient monitoring, diagnosis & treatment more convenient. IoT with wearable has recognized as a dominant component of healthcare transformation. When commonly diagnosed, wearable devices are linked to the internet, it may acquire vital information that might save lives. Also, models designed regulates and continuously monitors the condition of the patient by employing an network infrastructure during pandemics, reducing stress of health care providers, minimising medical errors, decrease the amount of work and medical staff productivity, lowering on-going medical cost and improving patient experience. Developing a convenient and accurate wearable device for earlier detection, assessment during social distance, as well as recovery is important during COVID-19 outbreak. As a result, numerous researchers devised wearable models; this study looks at the effect of wearable body sensors based on IoT technology in fighting COVID-19. In addition, the advantages of wearable devices are contrasted to those of traditional approaches.

**Keywords:** COVID-19, Coronavirus, Internet of things, Wearable devices, Body Sensors

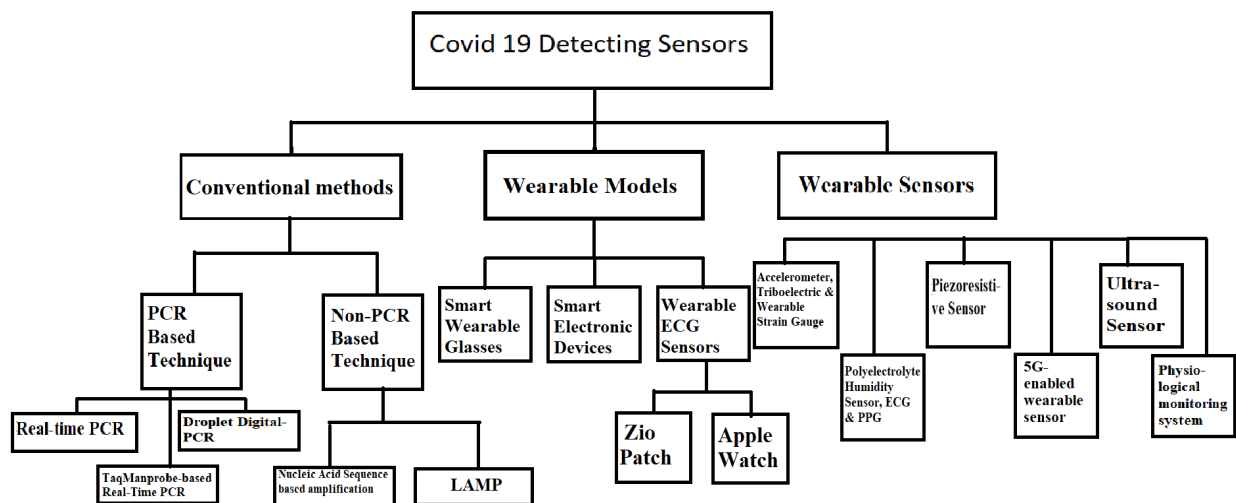
### 1.Introduction

Coronaviruses are a large group of viruses that can infect humans and animals. No one had heard of this new virus or the illness until it was discovered in Wuhan, China, in December 2019. COVID-19 is the world's first global coronavirus pandemic, and public knowledge of the virus is still growing. The COVID-19 epidemic has so far caused 2.6 million fatalities and 117 million illnesses worldwide [1]. COVID-19 detection and diagnosis rely heavily on big data, furthermore to modern equipment [2].

COVID-19 is transmitted from person to person via droplets or direct touch. COVID-19 infection symptoms typically occur after a 5.5-day incubation period. Fever, cough, and exhaustion are one of the most prevalent symptoms of COVID-19 infection. Other common complaints include muscle or body pain, headaches, new failure of smell or taste, dry mouth, and congestion [3]. Washing hands, covering one's mouth when trying to hack, avoiding contact with others, watching and isolating infected people are all recommended precautions. Travel limitations, isolations, curfews, occupational hazard evaluations, and facility closings resulted as a result of this [4].

Chemical analysis-based techniques, as indicated by Singh et al., are one type of COVID-19 detection technique. The techniques are polymerase chain reaction (PCR)-based (Real-time PCR, TaqManprobe-based Real-Time PCR, and Droplet Digital-PCR) and non-PCR-based (e.g., nucleic acid sequence-based amplification, and real-time quantitative loop-mediated isothermal amplification of DNA) [1]. Large amounts of data are expected to train the methodologies used for the detection techniques, which means that the (lengthy) studies would have to be repeated for each novel microorganism that creates various biological and activity signatures, further postponing enlistment. Moreover, the insufficiency of extra clinical information (the study relied solely on heart rate) has an impact on diagnostic accuracy. The availability of low-smart technologies could potentially enhance and increase these capabilities.[5].

A wide range of technologies, including cloud computing, edge computing, Internet of Things (IoT) devices, and artificial intelligence, have been introduced during COVID-19. Sensor device deployment has expanded dramatically. In response to the COVID-19 situation, IoT applications have seen a lot of innovation. The current state of the art for forecasting COVID-19 cases uses sensing devices to focus on IoT (Internet - of - things) parameters and possible sign characteristics. Wearable gadgets, clinical therapy, symptom monitoring, suspected case testing, and IoT features are all part of the working model [6]. As per our hypothesis, temperature data from portable sensing devices (wearables) with thermistors can provide some usable meaningful information while evaluating temp, making temperature records quite effective in flu identification [7]. The above research suggests a COVID-19 monitoring system based on traditional techniques and tracking systems which gather real-time disease information using portable models and monitoring devices. As a result of this study, an IoT infrastructure might be used to build a detection and monitoring system that tracks both prospects as well as proven infections, and also treatment responses of sick people who heal out from viral disease. In relation to real tracking, this technology might aid in the knowledge of a virus's behaviour by collecting, evaluating, and storing important information [8]. In **Figure 1**. We have discussed the overview of various methods and sensors used in COVID19 detection.



**Figure: 1 Overview of various Covid-19 Sensors and Methods**

## 2. Comparison of Existing Models

### 2.1 Conventional Methods to detect Covid-19

#### 2.1.1 PCR

The PCR (Polymerase Chain Reaction) is a familiar technique in molecular biology for duplicating a specific section of DNA multiple times. PCR is a fast and efficient method for amplifying DNA or RNA sequences from a variety of sources. Once the DNA has been sufficiently amplified, it can be sequenced, analysed by gel electrophoresis, or copied to a plasmid for purposes of research. As part of PCR, we need a template DNA, primers, nucleotides, and DNA polymerase. To make the PCR product, the DNA polymerase enzyme must combine individual nucleotides. Adenine, thymine, cytosine, and guanine (A, T, C, and G) are the four nucleotide bases found in DNA. These serve as the building blocks for the DNA polymerase to employ in producing the PCR product [9].

##### 2.1.1.1 Covid-19 PCR (Polymerase Chain Reaction)

The COVID-19 polymerase chain reaction (PCR) test is a molecular test that looks for SARS-CoV-2, the virus that causes COVID-19, genetic material (ribonucleic acid or RNA), in your upper respiratory specimen. A small quantity of RNA from specimens are amplified into deoxyribonucleic acid (DNA), which is duplicated until SARS-CoV-2 is detectable if present, using PCR technique. Since it is accurate and reliable, the PCR test has become the gold standard for diagnosing COVID-19[10].

##### 2.1.1.a Taqman Probe based Real Time PCR

The heat stable enzyme Taq DNA polymerase is derived from the thermophilic bacteria *Thermus aquaticus*. In *E. coli*, Taq, the much more widely used DNA polymerase for PCR, is currently being recombinantly expressed. SDS-PAGE analysis shows hardly any pollution from endonucleases or exonucleases, indicating that the enzyme can act as a 5' 3' polymerase and an exonuclease.

Norgen's COVID-19 TaqMan RT-PCR Kit (E/RdRP genes) is a multiplexed assay that uses TaqMan technology (FAM and HEX/VIC) to identify SARS-CoV-2 specific RNA in a simple, reliable, and rapid qualitative manner. The E gene/RP primer/probe combo targets the SARS-CoV-2-specific Envelope gene (E gene - FAM) as well as the human RNase P transcript (RP - HEX/VIC) as an internal control target to monitor for PCR inhibition and to evaluate the sample quality and detection result. The second Primer/Probe Mix detects two RNA-dependent RNA Polymerase (RdRP) targets, the first of which is SARS-CoV-2 specific (FAM), and the second of which is to detect SARS-CoV and bat-SARS-related CoVs (HEX).

##### 2.1.1.b Digital Polymerase Chain Reaction in Droplets

The droplet digital polymerase chain reaction is a method for precisely quantifying specific nucleic acids in a data set. This technique utilizes a mixture of microfluidics and proprietary surfactant chemistries to separate PCR specimens into the water-in-oil drops. It counts the molecules of nucleic acid enclosed in digitally, water-in-oil volumetrically defined droplets parts that will separate the template DNA molecules to obtain absolute quantities.

DdPCR of pure RNA extracts in COVID-19 patients shows promise for screening and diagnosis, especially in low-viral-load sick people. It is immune to response inhibition and calculates precise viral numbers from crude lysate without the use of a standard curve. The ddPCR yields reliable measurement of SARS-CoV-2 viral load when put

directly to crude lysate without RNA extraction. Furthermore, viral load calculations using ddPCR from crude lysate are similar to qRT-PCR from cleansed nucleic acid [11].

### 2.1.2 Non-PCR Techniques

Non-PCR-mediated aim amplification methodologies also use isothermal amplification. Because of the large volume of target created in a brief span of time, non-PCR-mediated aim amplification methodologies have the advantage of being particularly robust. They also save money on PCR-related royalties. They are, therefore, susceptible to contamination, much like any other amplification method [12].

#### a. Amplification of Nucleic Acid Sequences

It has been reported that increases of more than  $10^8$  copies of the target in 30 minutes have occurred. The method NASBA (nucleic acid sequence-based amplification) employs mRNA. The existence of a host bacterium and its ability to survive can be confirmed by measuring mRNA. The presence of DNA in samples will not result in false positives because NASBA only amplifies RNA. The procedure can be carried out isothermally, which eliminates the requirement for specialized equipment and making it appropriate for routine environmental sample monitoring. [13]

COVID-19 molecular diagnostic techniques target a single-stranded positive-sense RNA (+ssRNA) molecule, which is the virus's genetic material. Fluorescent Probes, Lateral Flow Assays, DNA Sequencing, and other Nucleic Acid Amplification Tests (NAATs) are focused on enhancing the aim sequence(s) and then detecting it using a read-out technique. These procedures can specifically attack SARS-CoV-2 nucleic acid in secretions, mucus, blood, nasopharynx or nasopharyngeal swab/wash/aspirate, throat/anal swabs, tracheobronchial suctioning liquid, biopsy or autopsy tissues, including respiratory system and excretions. NAATs seem to be the most common assessments used to detect the viral infection in positive samples, especially in the beginning of infectious disease, as per World Health Organization (WHO) standards [14].

#### b. Loop-Mediated Isothermal Amplification (LAMP)

Isothermal Amplification Using Loops (LAMP) is a technique for amplifying nucleic acids and for diagnosing infectious diseases that is quick, accurate, and simple to use. The LAMP reaction has a high specificity because the polymerases correctly recognise all 6 to 8 sections of a target Gene. LAMP tests for meningitis diagnosis also meet some important pathogen detection testing standards [15].

Zhang et al. employed LAMP technology successfully, using a graphic, colorimetric identification to detect COVID-19 viral RNA from cleansed. RNA or patient cell lysis. Penn-RAMP begins with an initial response that uses external LAMP primers sets to enhance those aims simultaneously using recombinase polymerase amplification (RPA). After that, a second, more specialised LAMP response is initiated. In the first stage, the external LAMP primer sets F3 and B3 are used, while another four RAMP primer pairs are combined in the second phase. This 'embedded' idea increased LAMP responsivity by 10–100-fold in contrast with frequent LAMP, and specific with purified and primitive specimens.[16]

## 2.2 Comparison based on Wearable Models

To detect and monitor COVID-19 instances, a team of scientists possess wearables which can be fixed on the breast or worn on the body. In this paper, we look at a variety of wearable devices, their applications, and the algorithms used to detect COVID-19[17]. The **Figure 2.** represents the various wearable models and their specifications.

### 2.2.1 Smart Wearable Glasses

Smart wearable glasses can identify the dispersion of COVID-19 inside the atmosphere or on living organisms by attaching sensors which have the same properties as just an electron microscopy to identify the motion of COVID-19 cells. These wearables are also capable of reducing infection rates by giving a prior detection of the patients who are at risk of infection. Owing to their accessibility of real-time data, wearable technologies could be utilized to decrease the occurrence of COVID-19 transmission between many sick people, clinicians, as well as other medical professionals. Those accessories are also used to provide tele-health and mobile health services through their biosensors [18].

### 2.2.2 Smart Electronic Devices

Wearable technologies are mobile gadgets that are chosen to wear mostly on the body and analyse and transmit data like signals relating to individual living organisms and regular physical activity. The advent of COVID-19 gives a chance to use wearable technologies to control the disease's spread, despite the fact that wearables has frequently been referred to as a beneficial strategy in the health sector. These wearables could provide real-world mobile detecting and sign prediction according to SpO2 levels, temperature of the body, pressure of the blood, sound of the lungs, and heart rate. Those wearable devices were utilized to raise awareness among users about a possible infection of COVID-19 before the onset of serious signs, due to their effective sensors. These wearables were also utilized to track a variety of physiological parameters in order to detect COVID-19 progression in patients earlier [18].

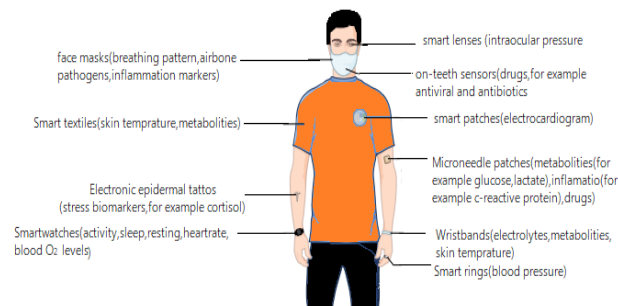


Figure 2 Wearable models and their specifications

### 2.2.3 Wearable ECG Sensors

Patients with chronic cardiac diseases, notably heart failure, who test positive for COVID-19 have a higher illness and mortality rates. At present it is abundantly clear that cardiac damage can occur to non-cardiac sick people, and cardiac brady- and tachyarrhythmias, in particular for critically sick patients, are of critical significance. COVID-19 appears to have a direct effect on the heart, according to emerging data. In COVID-19 patients, fulminant myocarditis and cardiogenic shock have been linked to atrial and ventricular arrhythmias [19]. As a result, Zio Patch and Apple Watch are used to monitor these cardiac abnormalities during COVID-19. Figure 3. describes the Monitoring system for wearable ECG sensors.

#### 2.2.3.a Zio Patch

The use of the ZioPatch (iRhythm Technologies) wearable sensor to monitor ECG at home in patients who are suffering of atrial fibrillation (AF) revealed the value of remote health monitoring of wearables in detecting AF and

initiating anticoagulants earlier. The ZioPatch, however, can only collect data for two weeks at a time but doesn't have real-time communication [19].

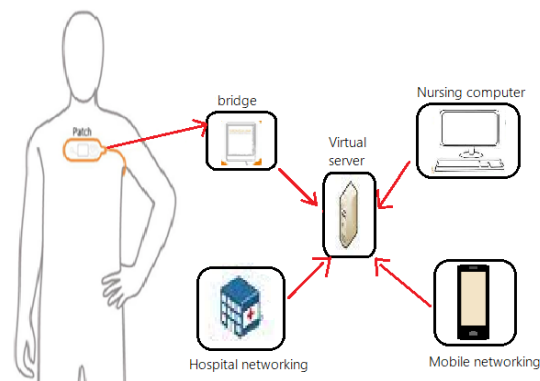


Figure:3 Monitoring System for Wearable ECG sensors

### 2.2.3.b Apple Watch

With the FDA's approval of Apple Watch Series 4 algorithm-based AF detection, a device for irregular heartbeat identification has been properly placed within customer's hands, who can now inactively gather truly continuous physiological signals and end up serving as gatekeeper to their little health information for the first time. The Apple Heart Study included a total 419,000 sick people in just eight months and discovered that 34% of sick people have already AF clarified along a sequential ECG patch, with a 0.84 good accuracy in detecting AF contemporaneously mostly on ePatch [19,24].

## 2.3 Comparison based on Sensors

### 2.3.1 Wearable Strain Gauge Sensors, Accelerometer-based Sensors, and Triboelectric Sensors

Because COVID-19 has such a serious impact more on lungs, the respiratory rate was among the most important indicators of infection. COVID-19 depicts a airway obstruction infection, which results in damage to the lung tissue, difficulty breathing, as well as choking. An individual with severe breathing problems has a breathing rate of less than 30 breaths per minute, which can result in acute respiratory distress syndrome (ARDS). Real-world and uninterrupted RR evaluation is critical for observing the present state, advancement, and therapy of COVID-19 infected patients. The RR is measured using accelerometers, triboelectric detectors, and wearable strain gauge detectors, with satisfactory results. Patients, on the other hand, may be uncomfortable wearing these belts [17].

### 2.3.2 Polyelectrolyte Humidity Sensor and Electrocardiography & Photoplethysmogram

Researchers have developed various detection approaches to identify Covid-19 based on current investigations. During the COVID-19 pandemic, Dai et al developed a polyelectrolyte moisture sensor, a type of humidity sensor that can be attached to a face mask and was broadly utilised. The system, however, may be not effective for individuals, and the device's mobility may affect precision [20]. Electrocardiography (ECG) and photoplethysmogram (PPG), which are easily collected by wearable devices, can also be used to determine respiratory rate (RR). Charlton et al. developed a technique for estimating RR from ECG and PPG that enhance prediction performance. As a result, COVID-19 sick people could use this system to monitor one's RR throughout the present disease outbreak [21].

### 2.3.3 Piezoresistive Sensor

COVID-19 has the potential to impair cardiac health and cause myocardial injury, causing permanent damage to the cardiovascular system. The COVID-19 virus causes physical tension in the muscles that is frequently manifested as a rise in heart rate (HR). COVID-19 patients' HR is monitored using wearable devices, which are both convenient and cost-effective. Quy et al. developed a wearable device with a piezoresistive sensor for tracking heart rate. This device continuously monitors your heart rate. Despite its small size, it is highly efficient, and precise. This gadget can be utilized for COVID-19 patients in addition to other clinical applications. One thing to keep in mind is that the device's piezo sensor should be placed perpendicular to the heart for maximum accuracy [22].

### 2.3.4 5G-Enabled Wearable Sensor

COVID-19-related deaths are frequently accompanied by concomitant cardiovascular illness. COVID-19 mortality rates could be reduced by using wearable medical devices to detect cardiovascular disease in real time. However, three major concerns arise as a result of technical restrictions. Firstly, conventional mobile communication for wearable technologies fails to meet the full range of real-world requirements. Secondly, existing detection systems lose efficient broadcast analysis techniques for dealing with large amounts of real-time cardio - vascular information. Thirdly, monitoring platform diagnosis is generally manual, making it difficult to make certain that sufficient physicians are available to offer a rapid diagnosis that is quick and accurate. Researchers propose a deep learning-based 5G-enabled real-time cardio - vascular tracking system for COVID-19 patients to improve the system. They used 5G to transmit and receive information from wearables at first. The Flink data stream computation structure is then used to collect ECG data. Finally, they employed CNNs and lengthy poor memory networks to forecast COVID-19 patients' cardiovascular health. In **Figure 4**, we have discussed the architectural design of 5G-Enabled wearable sensors. Theoretical and experimental findings indicate that our solution may effectively address the above-mentioned issues and enhance cardiovascular disease prediction accuracy to 99.29 %. [2].

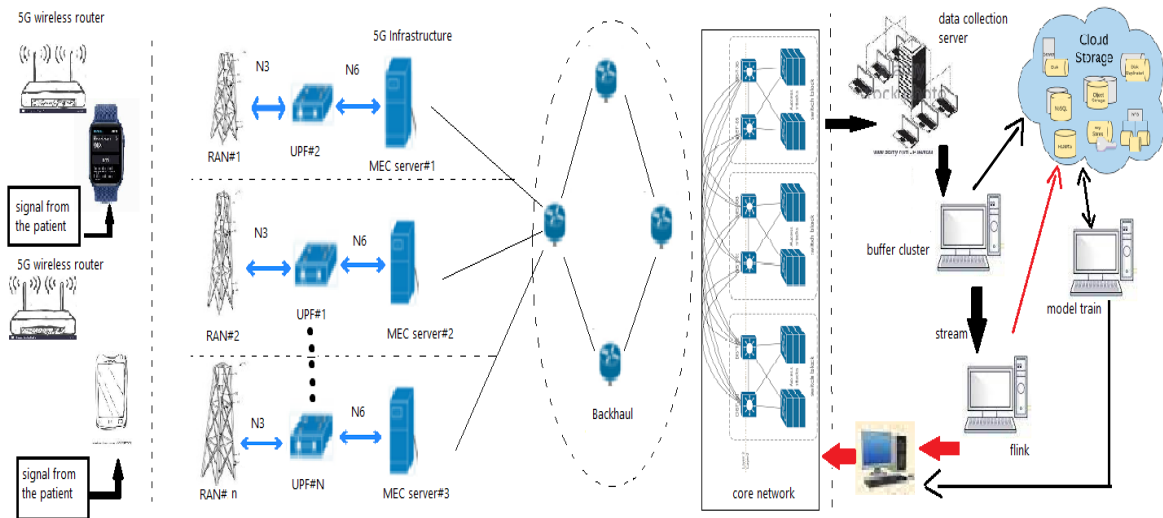


Figure:4 Cardiovascular Monitoring System Architecture Design for Patients of COVID-19

### 2.3.5 Ultrasound Sensor

Shahshahani et al. proposed a wearable device with an ultrasonic sensor for heart rate monitoring [17]. Dr. Dave Hughes proposed NoVo sound, a wearable lung device with an ultrasonic sensor that plays a vital part in the ongoing coronavirus pandemic. Ultrasound is not widely used in wearable devices right now, but it can detect a lot of things. It enables you to look inside the human body and examine structure, form, and mechanical properties like blood flow and tissue plumpness for hydration and dehydration monitoring. This wearable lung monitor would be placed on the patient's chest and this would send an ultrasound pulse through the lung wall, which would then bounce back to generate a measurement that would indicate whether the lung was healthy or whether there was any evidence of inflammation, fluid, or disease. Raw measurements are processed and interpreted to provide user-friendly data that may be examined at home by individuals or by healthcare professionals via remote continuous monitoring. The device provides a rapid measurement, enabling automated, continuous monitoring. The same device can also be used in ICU wards to track patient recovery during therapy, such as when evaluating the efficacy of a novel treatment [26].

### 2.3.6 Physiological Monitoring System

Thermal analysis is essential for COVID-19 identification, and many nations have used it as an immediate testing to measure whether visitors or citizens were infected. Song et al. presented a portable device that measures temperature of the body with extreme precision and a short response time, associated with different artificial neural networks. As part of a physiological monitoring system, Liu et al. presented a portable tool to monitor temperature of the body, Electrocardiography, blood sugar levels, hypertension, and other physiological functions. In **Figure 5**. We have discussed the placement of sensors for measuring various physiological functions. The system is compact and easy to use, simple to operate, and was designed specifically for COVID-19 patients to use at home. [23-25].

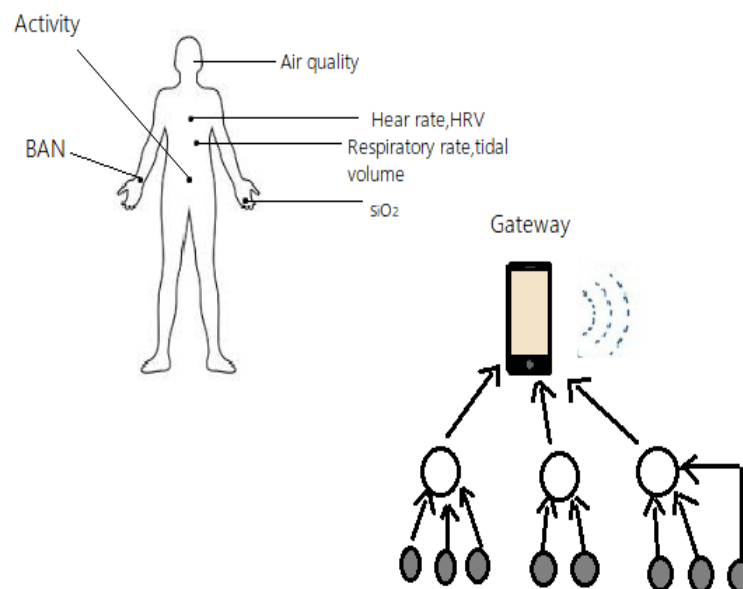


Figure:5 The placement of sensors for measuring various physiological parameters

**TABLE:1 Performance comparison based on sensors**

S.NO	Author	Sensor used	Pros	Cons
1.	Dai et al	Polyelectrolyte Humidity Sensor	High spatial response with simple construction.	High power consumption and lack of reproducibility.
2.	Charlton et al.	Electrocardiography (ECG)and Photoplethysmogram (PPG)	Low energy consumption	Low accuracy and dynamic range
3.	Quy et al.	Piezoresistive Sensor	High sensitivity and good data linearity at constant temperature	Requires significant amount of power.
4.	Shahshahani et al.	Ultrasonic Sensor	Fast and accurate response	Limited spatial resolution and low SNR

#### 4. Discussion

The unexpected severity and rapidity with which the COVID-19 disease outbreak is broadening between many people has caught modern health systems on the planet out of surprise. The disease outbreak might have brought to light the importance, innovation, resiliency, and self sacrifice of patient care and vital professionals all over the world. Moreover, health professionals were more subjected to or susceptible to coronavirus than all others, so as a result, also have some of the greatest effects. Wearable technologies, telemedicine functions, clinical autonomous systems, and screening and AI health monitoring are all needed more than ever in the battle against the coronavirus. We discussed about COVID-19 detection methods in this survey (Conventional methods, wearable sensors and models). The conventional methods include PCR-based and non-PCR-based procedures, as well as their different types. Accelerometric, triboelectric, piezoelectric, strain gauge, poly-electrolyte, electrocardiography and photoplethysmogram, ultrasound, and 5G-enabled sensors are the examples of wearable sensors. Smart wearable glasses, smart electronic devices, and wearable ECG sensors (zio patch, apple watch) are some of the wearable models. We also compared the methods using wearable sensors and models for detecting COVID-19 that are currently in use.

#### 5. Conclusion

In the short term, the current survey's results may provide insight into recognizing COVID-19 illness progression by physiological data monitoring and possible approaches to slow the disease's spread. We compared many wearable sensors, models, and the benefits of utilizing them during the COVID-19 pandemic in this survey. In the long term, the research could serve as a model for how wearable technologies can be implemented into existing medical services. Finally, the wearables focus on providing outcome, uninterrupted, real-world information which can be used to notify health - care workers about adherence to multiple levels of health care interventions, as well as focus on ensuring evidence - based decision and program management in epidemic isolation at either the domestic or cross-national stages. Heart rate, sleep duration, and behaviour patterns are presently available from smartwatches. This could be supplemented in the future with newer forms of wearables that track stress levels (electronic epidermal tattoos), biomarkers of inflammation and blood O<sub>2</sub> levels (microneedle patches), ambient temperature (electronic textiles), hypertension (smart rings), ionic strength (wristbands), and pressure inside the eye (smart contact lenses), the existence of airborne pathogens and breathing anomalies (face masks), and the strength of therapeutic drugs (on-teeth sensors). By monitoring both characteristic features and physiological factors, availability of low-price smart wearable

innovations can be helped to detect symptomatic and pre-symptomatic cases in upcoming outbreaks. These sensors might potentially be applied to track the progress of people's recovery stages or who are self-isolated at home.

## References

- [1] H.Mukhtar; S.Rubaiee; M.Krichen; R.Alroobaea, An IoT Framework for Screening of COVID-19 Using Real-Time Data from Wearable Sensors. *Int. J. Environ. Res. Public Health* 2021, vol 18, 4022. See also: <https://doi.org/10.3390/ijerph18084022>
- [2] L. Tan; K.Yu; AK.Bashir; X.Cheng; F.Ming; L.Zhao; X.Zhou; Toward real-time and efficient cardiovascular monitoring for COVID-19 patients by 5G-enabled wearable medical devices: a deep learning approach. *Neural Comput & Applic*,2021. See also: <https://doi.org/10.1007/s00521-021-06219-9>.
- [3] A.Caroline; M.Dittakavi et al., Monitoring Health Care Workers at Risk for COVID-19 Using Wearable Sensors and Smartphone Technology: Protocol for an Observational mHealth Study. *JMIR Res Protoc* ,2021, vol 10(5):e29562, See also: <https://www.researchprotocols.org/2021/5/e29562/>.
- [4] A.Kumar; K.Sharma; H.Singh; S.Naugriya et al., A drone-based networked system and methods for combating coronavirus disease (COVID-19) pandemic , *Future Generation Computer Systems*, Vol 115,2021,Pg 1-19,
- [5] H. Ceren Ates; Ali K. Yetisen; F.Güder; C.Dincer,. Wearable devices for the detection of COVID-19, *Nat Electron* Vol 4, Pg 13–14,2021. See also: <https://doi.org/10.1038/s41928-020-00533-1>
- [6] K.Raja; R.Kumar; S.Kirubakaran; J.Antony Marcin; Manikandan R;, COVID-19 prediction and symptom analysis using wearable sensors and IoT, *International Journal of Pervasive Computing and Communications*. See also: <https://doi.org/10.1108/IJPC-09-2020-0146>
- [7] L.Benjamin; K.Aschbacher; S.M. Fisher; A.Chowdhary et al., Feasibility of continuous fever monitoring using wearable devices. *Sci Rep*, 2020, vol 10, 21640. See also: <https://doi.org/10.1038/s41598-020-78355-6>.
- [8] M.Otoom; N.Otoom; Mohammad A. Alzubaidi, Y.Etoom; R.Banihani.,An IoT-based framework for early identification and monitoring of COVID-19 cases-,*Biomedical Signal Processing and Control*,2020,Vol 62, See also: <https://www.sciencedirect.com/science/article/abs/pii/S1746809420302949>.
- [9] L.Garibyan; N.Avashia,Polymerase Chain Reaction. *Journal of Investigative Dermatology*,2019, vol.133(3), pg- 1–4. See also: doi:10.1038/jid.2013.1.
- [10] <https://my.clevelandclinic.org/health/diagnostics/21462-covid-19-and-pcr-testing>.
- [11] N.Harish; P.Xu; V.Servellita; S.Miller; L.Liu; A.Gopez et al., Abate-Digital droplet PCR accurately quantifies SARS-CoV-2 viral load from crude lysate without nucleic acid purification. *Sci Rep*,2021, vol 11, 780. See also: <https://doi.org/10.1038/s41598-020-80715-1> .
- [12] R.C. She.;T.E. Schutzbank;E.M.Marlowe. *Non-PCR Amplification Techniques*. In: Tang YW., Stratton C. (eds) *Advanced Techniques in Diagnostic Microbiology*. Springer, Cham.,2018, [https://doi.org/10.1007/978-3-319-33900-9\\_17](https://doi.org/10.1007/978-3-319-33900-9_17)
- [13] Compton J., *Nucleic acid sequence-based amplification*. *Nature*. 1991 Mar 7; 350 (6313):91-2. See also: doi: 10.1038/350091a0.
- [14] World Health Organization. Laboratory Testing for Coronavirus Disease (COVID-19) in Suspected Human Cases: Interim Guidance; World Health Organization: Geneva, The Switzerland, 3 March 2020. <https://apps.who.int/iris/handle/10665/331329>.
- [15] M.Seki; P.E. Kilgore; EJ. Kim; M. Ohnishi et al.,Loop-Mediated Isothermal Amplification Methods for Diagnosis of Bacterial Meningitis See also: <https://doi.org/10.3389/fped.2018.00057> .
- [16] Md. Milon Islam; S.Mahmud; L. J. Muhammad; Md. Rabiul Islam et al, Wearable Technology to Assist the Patients Infected with Novel Coronavirus (COVID-19)-See also: <https://link.springer.com/article/10.1007/s10916-020-01697-1>.
- [17] J.C. Miller; D.Skoll; Leslie A, Saxon. Home Monitoring of Cardiac Devices in the Era of COVID-19. See also: <https://link.springer.com/article/10.1007/s11886-020-01431-w>

- [18] J.Dai; H.Zhao; X Lin; X Liu; S, Liu et al. Ultrafast response polyelectrolyte humidity sensor for respiration monitoring. *ACS Appl Mater Interfaces*. 2019; 11:6483–90. <https://doi.org/10.1021/acsami.8b18904>.
- [19] PH.Charlton; DA.Birrenkott; T.Bonnici; MAF.Pimentel et al., Breathing rate estimation from the electrocardiogram and photoplethysmogram: a review. *IEEE Rev Biomed Eng*. 2018; Vol 11, No 2–20. See also: <https://doi.org/10.1109/RBME.2017.2763681>.
- [20] VN Quy; DT.Xuan Duy; DT. Kien et al., *Wearable device for monitoring heart rate based on low-cost piezoresistive sensor*. In: 2019 8th International Conference on Modern Circuits and Systems Technologies (MOCASST). IEEE, pp. 1–4
- [21] C. Song; P.Zeng; Z.Wang; H.Zhao et al., *Wearable continuous body temperature measurement using multiple artificial neural networks*. *IEEE Trans Ind Inf*. 2018; Vol 14:4395–406- See also: <https://doi.org/10.1109/TII.2018.2793905>.
- [22] <https://www.apple.com/newsroom/2018/12/ecg-app-and-irregular-heart-rhythm-notification-available-today-on-apple-watch/>. Accessed 26 Feb 2020. *ECG app and irregular heart rhythm notification available today on Apple Watch*. Apple.-
- [23] B.Liu; Y.Zhang, *Wearable monitoring system with multiple physiological parameters*. In: 2008 5th International Summer School and Symposium on Medical Devices and Biosensors. IEEE, pp. 268–271.
- [24] <https://healthcare-in-europe.com/en/news/wearable-ultrasound-sensors-could-support-covid-19-fight>
- [25] RK.Mahendran; V.Parthasarathy et al., An efficient priority-based convolutional auto-encoder approach for electrocardiogram signal compression in Internet of Things based healthcare system, *Transactions on Emerging Telecommunications Technologies*, Vol 32, See also: <https://doi.org/10.1002/ett.4115>.
- [26] RK.Mahendran; Parthasarathy, A secure fuzzy extractor based biometric key authentication scheme for body sensor network in Internet of Medical Things, *Comput Commun*. 2020, vol153: no 545-552. See also: <https://doi.org/10.1016/j.comcom.2020.01.077>