PROSPECTS OF FACE SHIELD WITH WIRELESS MONITORING OF TEMPERATURE AND RESPIRATION FOR FRONT LINE HEALTH WORKERS & COVID-19 PATIENTS

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ABSTRACT: The virus (COVID-19) originated from Wuhan has infected millions of peoples from all over the world. It spreads through contact contamination and respiratory droplets. The death rate in this pandemic is increasing day by day. The requirement to use the personal protective equipment (PPE) has increased worldwide especially for medical services. Due to this pandemic, the screening of common vital symptoms has become important for any emergency conditions. To form a smart Face Shield that aims to provide more protection than a mask to humans against contagious viruses especially Covid-19, the suggested design refers to the attachment of Temperature and Pulse Oximeter sensors at face shield to monitor the disease with the continuous display of parameters on a mobile application. From statistics of Literature Review it is found evident that from last decade the use of face shields for protection from COVID-19 has increased but according to studies more improvement in this setup is required for better protection that shall minimize the Burdon from hospitals Our suggested design of shield will be an innovation in the field of medical and electronics because it provides facial protection from viruses along with that monitor vital signs of Temperature and Oxygen Saturation and reduces hospital visits for follow ups. It will serve society with an improved quality of PPE.

Key Words: Covid-19, Contamination, Electronic face shield, Personal Protective Equipment (PPE), Vital Signs

(Received 21.04.2021 Accepted 26.05.2021)

INTRODUCTION

Severe acute respiratory syndrome–coronavirus-2 (SARS-CoV-2) has been separated from the epithelial cells of human airways in December 2019 from a bunch of people suffering from obscure pneumonia in Wuhan (China). It infected more than 1.5 million people from all over the world and that 40% of the medical staff have been removed from their workplace because they have been infected by this virus (Armijo *et al.*, 2020) Coronavirus affect more than 210 countries, it propagates through contact contamination, respiratory droplets (Chaturved., 2020) and by touching eyes, mouth, or facial area from contaminated hands (Lemarteleur., 2020). The total no. of confirmed cases till December 27th, 2020 are 80,794,083 and the no. of death cases are 1,766,513 also the statistical analysis indicates that there is more male patient between 20-59 age group than women and there are 18.4% death rate between 50-59, 22.93% between 60-69 and 12.96% between 70-79 age group males (Fawad., 2021). COVID-19 is spreading through close contact therefore in order to stop traveling (Wang., 2020) many countries have suspended their borders also lockdown situations have occurred in many countries (Uddin., 2020). Surgical mask provide unsatisfactory protection against viral particles produces by infected person in form of respiratory droplets and aerosol particles (Brosseau., 2020). Antibody development and examination into clinical treatment for COVID-19 are in progress yet are numerous months away therefore, tension on the worldwide medical services keeps on increasing (Mostaghimi., 2020). Healthcare facilities and hospitals are under burden due to this rapid increase of SAR-COV-2 also the availability of required personal protective equipment (PPE) like mask, face shield, googles, gloves etc. has been hampered (Adams., 2020). There are some notable and serious side effects for COVID-19 include Fever (98%) (Wang., 2020), Shortness of breath (55%) and Cough (65%) (Jaeong., 2020). Those peoples with the symptoms of Covid-19 should be kept at 6 feet distance from other until they can be sent for isolation in separate room (Amin., 2020) or quarantine (Chan., 2021) with continuous monitoring of suspected symptoms (Jeong., 2020) for any emergency condition.

Many studies have reported that cost effective face shields are now developing locally by open source community as an effective solution for this pandemic (Chaturvedi., 2020). Single face shield provides extreme protection. In 2020, an inexpensive 3D printed face shields for health care workers are constructed which include 3D printed headband, elastic strap and a PVC sheet. By using PRUSA RC2 or PRUSA RC3 printers and polylactic acid (PLA) as a filament material, this 3D

printed face shields are made by using fused deposition modelling (FDM) technique. Disinfection of these face shields are performed by sodium hypochlorite solution before sent to hospitals. In total 5 days 10151 shields are produced. In order to reuse these shields, disinfect the face shield with sodium hypochlorite solution for 15 minutes (Lemarteleuer., 2020) also face shields can be made locally by using a plastic sheet, brow foam and elastic headband. These locally developed shields can be cleaned and disinfected by procedures recommended by Centre for Disease Control and Prevention (CDC) include sanitizing wipes. In order to access the functionality of face shield following test must be performed: 1) SPLASH RESISTANCE TEST: watery spray delivered at the center of the visor if the subject did not fell any droplets in his neck or face, the visor passed the test. 2) TESTING WEARABILITY: If the face shield does not fall by the motion of subject's head in all directions, the wearability test will be passed (Mostaghimi., 2020), CDC also recommend that visor should have sufficient width to touch the point of ear so that no splash could go inside from the face shield and for the purpose of improved infection control it should have the protection of chin and crown (Roberge., 2021). Another study has proposed the simplest way to prepare face shield which include a OHP sheet and a cotton thread. Cotton thread passes through the holes made by punching machine to bind around the head. These face shields can be sterilized by dipping in sodium hypochlorite solution for 10 min also by leaving it in sunlight then clean by using sanitizer whereas best sterilization is ethylene oxide sterilization (ETO) (Khan., 2020). Current Healthcare Infection Control Practices Advisory Committee (HICPAC) also recommend of wearing face shield during patient care for all illnesses (Garcia., 2020). According to another study face shields are printed using 3D printer in order to protect oral and maxillofacial surgeons (OMSs) from SAR-COV-2. They used 3D printer of MK3S PRUSA model and a Polylactic acid as filament material. They use Previously designed face shield file convert it into G-code then taken into digital SD card to transfer it into printer. Velcro strips, adhesive foam and transparent film are used in this 3-D printed face shield. All the parts are assembled to form complete face shield. Each part should be disinfected by using Sani-Cloth Germicidal Disposable Wipes. 100 face shields were printed for emergency department. This method is cost-effective and provides physical barrier from droplets (Amin., 2020) also face shield can be constructed using required materials include A4 generic acetate sheet, self-adhesive strip foam, elastic band, a piece of foam and cyanoacrylate glue. Fix all the parts properly then worn it (Skamnelos., 2020). There are five vital signs include spo2, heart rate, temperature, blood pressure and respiration rate that indicate the critical condition of the patient and need of medical treatment (Longmore., 2019). Currently no universal standards are there for face and eye protection. Recommendations vary widely for the use of face shield which indicate that there is a need of proper discussion for the usage of face and eye protection equipment for medical procedures (Roberge., 2021). More additional evidences are required for the individuals to make better facial protection in this pandemic for their safety (Gracia., 2020). For the production of PPE locally in pandemic situation there is no open source and clinically acceptable device and test policy (Mostaghimi., 2020) also there are no devices that eliminate fogging and improves ventilation (Chaturvedi., 2020). There should be proper feasibility, concern and advice for the family members of the health care workers or front-line caregiver in order to enhance workforce availability and confidence (Adams., 2020). Face shield is considered as personal protective equipment (PPE) that provide extreme protection (Celik., 2020). The arrangement to screen and distinguish COVID-19 symptoms continuously and non-intrusively for emergency clinic patients as well as for in-home settings are in incredible requests (Khan., 2020). Due to COVID-19, monitoring of temperature and spO2 has increased but there are no commercially available wearables to routinely measure these symptoms (Seshadri., 2020).

Objectives: The main aim of this research is to suggest the best design of a smart Face Shield that aims to provide protection against contagious viruses especially Covid-19, and also monitor the common vital parameters like temperature, heart rate and spO2 through sensors that directly relates to this disease with continuous display on a mobile application.

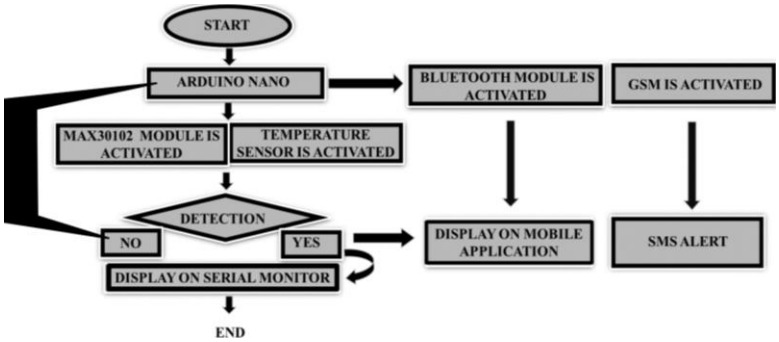

Figure 1 Block Diagram of suggested methodology

MATERIALS AND METHODS

The aim of this work is to make a Smart face shield that monitors temperature, heart rate and SpO_2 (common COVID-19 symptoms). Additionally, it aims to display the data continuously on a mobile application (ARDUTOOTH). Moreover, the component in this face shield includes, two sensors (DS18B20) and (MAX30102), a microcontroller (Arduino NANO), a Bluetooth module (HC-05), a GSM module (SIM 900A) and a lithium battery (3.7V) to power the Arduino. The mentioned components will be integrated on a single platform and interfaced using Arduino.

Face Shield: Face shield is recommended by WHO and other organizations as PPE because it provide protection to mucous membrane and facial area from the droplets and contamination (Chutarvedi *et al*; 2020). Current Healthcare Infection Control Practices Advisory Committee (HICPAC) recommend of wearing face shield during all patient care (Gracia *et al*; 2020).

Aurdino Nano: Arduino nano is one of the members of Arduino family. It is smaller in dimension (18mmX45mm) but its functionality remains same as Arduino UNO. It is suitable for the projects that require light weight microcontroller. It has 8 input/output analog pins and 22 digital pins. Signals from environment and body are taken in through analog pins and then its output are taken from digital pins. The weight of Arduino nano is 7g.

Temperature Sensor (DS18B20): is a waterproof digital thermometer. It has three terminals GND, DQ and VDD (3- 5.5V). When DQ terminal touches the skin measures the body temperature in degree centigrade. The operating and storage temperature range is 55°C to +125°C. It gives accuracy of ±0.5°C. The weight of DS18B20 is 60g.

Pulse Oximeter (MAX30102): is a spo2 and heart rate monitoring module, the IC in this module require typically 1.8V VDD. It has five terminals VDD (1.7-2.0V), GND, SCL (serial clock), SDA (serial data), and INT. SDA pin carries the data and SCL pin helps to transfer the data to devices. The weight of MAX30102 is 1.1g.

Bluetooth Module (HC-05): HC-05 is a 2-way wireless functionality module. It requires typically 5V VCC to perform its function. It has six terminals ENABLE, VCC (4-6V), GND, TX (transmit serial data), RX (receive serial data), STATE. The TX pin and RX pin are responsible for receiving and transmitting the data. Around 10 meter is the range limit for HC-05 module data transmission. The weight of HC-05 Bluetooth module is 3g.

GSM Module (SIM 900A): GSM module is used for mobile communication. It has capability of sending and receiving data via phone call or SMS. Arduino nano communicate with GSM module by using AT command. It is very useful for emergency alerts. The weight of GSM module is 3.4g.

Mobile Application (ARDUTOOTH): ARDUTOOTH is an android mobile application. It has capability to connect with Bluetooth by loading some code to Arduino board and display real time data continuously. The data of up to 10 sensors can be display easily and simultaneously.

Arduino Software (IDE): Arduino software use to write, upload and run Arduino program on a compatible Arduino board. C and C++ languages are supported by Arduino IDE. The window of Arduino IDE environment includes menu bar, serial monitor, text editor and output pane. Once the code is written it is verified using verify check mark, if any error then it will be displayed on output pane. After removing error click on the arrow key (upload) the code is uploaded on the Arduino board. Output can be seen using serial monitor.

The smart face shield will be formed using the hardware components mentioned above. Here Arduino is used as an open-source platform that control the whole circuitry part of the smart face shield. Here, Arduino will take the inputs and convert these inputs into an output. We will build and run our code on Arduino software (IDE) which tells the Arduino board what instructions will be followed. With Arduino board, DS18B20 (Temperature sensor), MAX30102 (Pulse oximeter), HC-05 (Bluetooth module) and SIM 900A (GSM module) will be connected. Once the code will run the entire circuit will be activated. The whole circuit will be fixed on the top portion of the face shield in a way that the temperature sensor and pulse oximeter will touch the forehead of the user. PPG devices are used in healthcare systems to monitor spo2 and heartrate in clinical settings also sensors are designed and utilized in foreheads, earlobe, toe etc. when finger-based sensing is not feasible. Forehead is considered as best anatomical location to measure heartrate and spo2 during all activities both at walking and rest. The overall median error is minimum about 2.4% for spo2 and 2.9 % for heart rate which is acceptable as compared to pulse oximeter that fix at finger (Longmore., 2019). Arduino will start its processing, both the sensor will be activated and start detecting the temperature, heart rate, and spO2, at the same time Bluetooth module and GSM module will also be activated. If the temperature sensor and pulse oximeter will fail to detect the temperature, spO2, and heart rate then they will send a signal back to Arduino to start its processing again to activate the sensor and module so that they will again start detection. If temperature, heart rate, and spO2 will be detected then

they will be sent to the serial monitor of Arduino software for display and also these data will be sent to the Bluetooth module. The mobile application will be connected from Bluetooth module wirelessly after that the real-time temperature, hear rate, and spO2 data of the user will be displayed on the mobile phone application continuously. GSM module will also be processed by Arduino nano and it will send SMS for emergency condition which will set through coding. If the temperature of user rises above 102°C, spO2 below 92% and heart rate above 120bpm and below 60bpm an emergency SMS will be sent by the sim card placed on GSM to the number set on the coding.

Best chosen designs of the reusable face shields were viewed physically and the face shield that can be worn comfortably by patient (Godoy., 2020) accommodate the circuit with ease should be chosen. Refer to the figure 1, The smart face shield must be constructed using multiple sensors and components attached to it. Initially, the sensors and modules can have tested one by one after interfacing them with a microcontroller so that a faulty component is replaced and the working of each component can be verified. After that, the entire circuit can be designed on a breadboard to see whether it is working properly. In the circuit of a smart face shield, microcontroller may take input signals from the sensors. By considering all the conditions and parameters, a code shall be designed. Additionally, with the help of interfacing accurate monitoring can be performed. When the code is designed, it has to execute to activate the entire circuitry of smart face shield. If any of these vital parameters are deteriorated, they serve as an indicator for subjects (Lynn *et al*; 2011) that are in immediate need of medical intervention (Kramar *et al*; 2017). After the verification of the circuit, all the components may be transformed in a solded form to become a part of face shield, forehead area. It important after this to test its functionality, accuracy and comfort by trying it on different subjects after taking ethical consent and disinfecting them carefully. By this suggested method any errors in the design and circuit may be corrected while maximum accuracy may also be attained.

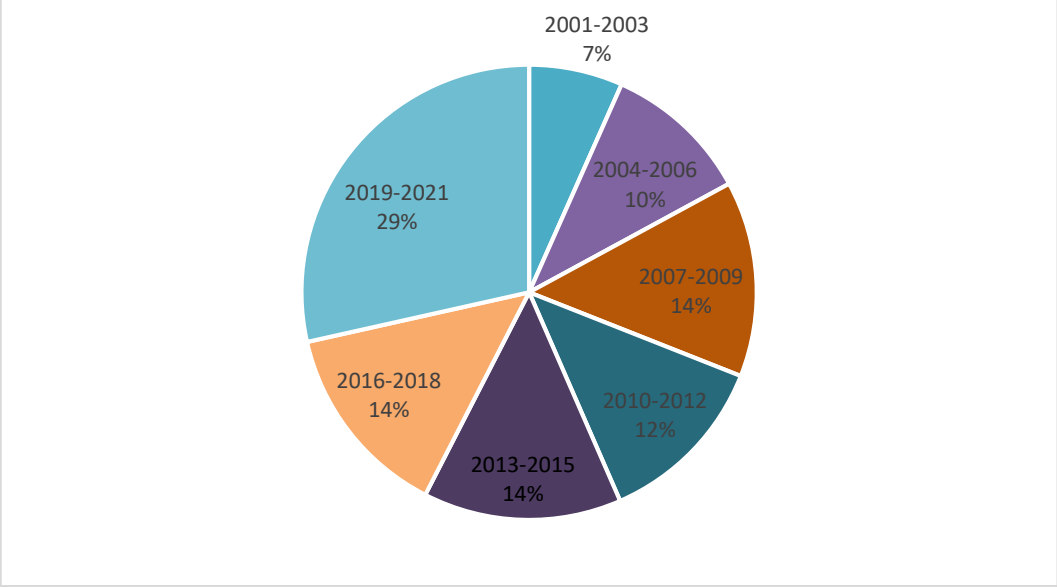

Figure 2 Construction of Various Face Shield from Year 2001 to Year 2021

OPINION BASED RESULTS

Table 1. Physiological Values of parameters for healthy Individuals.

S.no	Parameter	Value
1	Body Temperature	37 C
2	Oxygen Saturation	94% - 98%

The figure 2 indicates what has been done in various domains of this field. Until now, no significant approach in found in literature review to monitor the vital sign parameters that affect the condition of the patient due to their variation. From various potential databases, we found that face protection shield has been focused in scientific literature from year 2001-2021 but it attained highest peaks in the year 2019-2021, which means that working or research in face shield is increased in these three years, which may clearly be related with the current Pandemic of Covid 19.

As Temperature and Oxygen Saturation are highly considered parameters for monitoring of patient's health, there normal values as mentioned in table 1. A pulse oximeter reading of 92% or lower is one defining feature of sever disease in acute Covid-19 (Greenhalagh

et al; 2021), similarly body temperature above and below37C shows significant increase in mortality in duration of Covid- 19 (Tharkan *et al*; 2020), therefore a wearable can easily be designed with this information that reduce the risk of virus transmission and save resources of hospitals in mild cases by monitoring vitals from home are required (Seshadri., 2020).

DISCUSSION

This suggested project will offer the benefit of facial protection from viruses and other airborne particles that spread through the upper respiratory tract along with that it will continuously monitor the common COVID-19 symptoms (temperature, heart rate, and spO2) through the sensors and module and will display data on a mobile application. This face shield can act as small portable facial protection plus monitoring kit. While another special feature is the emergency alerts via a GSM module ensuring safety of a patient and society to a great extent. Most importantly it provides benefit to in-home patients specially COVID-19 in-home patients by allowing the family members to observe the monitoring of their patient symptoms from long distance through mobile application also an alert SMS will be sent to them in emergency condition. This smart face shield will provide extended protection to society by reducing the risk of virus transmission and in-home monitoring in mild cases save the resources of hospitals, Due to the severity of respiratory diseases, demand and shortage of PPE (Personal Protective Equipment) for facial protection increased which led to the quick development of 3D printed as well as disposable face shields apart from this continuous monitoring the disease symptoms also increased but there is no PPE yet that offer continuous monitoring from hospital to home with clinical-grade accuracy. This suggested design and setup of face protective shield can enhance the existing face shields by introducing some electronic components into it, in order to maximize their applications not only for protection of viruses but also for the monitoring of vital health indicators for better care and diagnosis. For these tasks there is a need of personal protective equipment that offers an extension of continuous monitoring from hospitals to home also to meet the problem of PPE shortages in the time of pandemics as well, thereby serving the society with an improved quality of PPE. Mobile phone users shall also be able to monitor their vital parameters on a mobile phone application so no other equipment is supposed to be bought to monitor these parameters. therefore, these all requirement can be fulfilled by this recommended shield More of it, this shield could be used under various health conditions to protect the Healthcare staff and the entire society.

REFERENCES

Adams and R. Walls, "Supporting the Health Care Workforce During the COVID-19 Global Epidemic", *JAMA*, vol. 323, no. 15, p. 1439, 2020.

Amin, N. Nguyen, S. Roser and S. Abramowicz, "3D Printing of Face Shields During COVID-19 Pandemic: A Technical Note", *Journal of Oral and Maxillofacial Surgery*, vol. 78, no. 8, pp. 1275-1278, 2020.

Armijo, N. Markin, S. Nguyen, D. Ho, T. Horseman, S. Lisco and A. Schiller, "3D printing of face shields to meet the immediate need for PPE in an anesthesiology department during the COVID-19 pandemic", *American Journal of Infection Control*, 2020.

Brosseau L, Sietsema M., "Commentary: Masks-for-all for COVID-19 not based on sound data" Accessed April 17, 2020

Celik, O. Kose, M. Ulmeanu, A. Rennie, T. Abram and I. Akinci, "Design and Additive Manufacturing of Medical Face Shield for Healthcare Workers Battling Coronavirus (COVID-19)", *International Journal of Bioprinting*, vol. 6, no. 4, 2020.

Chan, S. Yuan, K. Kok, K. To, H. Chu, J. Yang, F. Xing, J. Liu, C. Yip, R. Poon,

H. Tsoi, S. Lo, K. Chan, V. Poon, W. Chan, J. Ip, J. Cai, V. Cheng, H. Chen, C. Hui andK. Yuen, "A familial cluster of pneumonia associated with the 2019 novel coronavirus indicating person-to-person transmission: a study of a family cluster", 2021.

Chaturvedi, A. Gupta, V. Krishnan S and A. Bhat, "Design, usage and review of a cost effective and innovative face shield in a tertiary care teaching hospital during COVID-19 pandemic", *Journal of Orthopaedics*, vol. 21, pp. 331-336, 2020.

Fawad, S. Mubarik, S. Malik and J. Ren, "Statistical analysis of COVID-19 infection caused by environmental factors: Evidence from Pakistan", *Life Sciences*, vol. 269, p. 119093, 2021.

Godoy, A. Jones, T. Anderson, C. Fisher, K. Seeley, E. Beeson, H. Zane, J. Peterson and P. Sullivan, "Facial protection for healthcare workers during pandemics: a scoping review", *BMJ Global Health*, vol. 5, no. 5, p. e002553, 2020.

Jeong, J. Rogers and S. Xu, "Continuous on-body sensing for the COVID-19 pandemic: Gaps and opportunities", *Science Advances*, vol. 6, no. 36, p. eabd4794, 2020.

Kantor, "Behavioral considerations and impact on personal protective equipment use: Early lessons from the coronavirus (COVID-19) pandemic",

Journal of the American Academy of Dermatology, vol. 82, no. 5, pp. 1087-1088, 2020.

Khan and S. Parab, "Safety Guidelines for Sterility of Face Shields During COVID 19 Pandemic", *Indian Journal of Otolaryngology and Head & Neck Surgery*, 2020.

Kramer, A. Lobbestael, E. Barten, J. Eian and G. Rausch, "Wearable Pulse Oximetry Measurements on the Torso, Arms, and Legs: A Proof of Concept", *Military Medicine*, vol. 182, no. 1, pp. 92-98, 2017.

Lemarteleur, V. Fouquet, S. Le Goff, L. Tapie, P. Morenton, A. Benoit, E. Vennat, B. Zamansky, T. Guilbert, A. Depil-Duval, A. Gaultier, B. Tavitian, P. Plaisance, P. Tharaux, P. Ceccaldi, J. Attal and E. Dursun, "3D-printed protected face shields for health care workers in Covid-19 pandemic", *American Journal of Infection Control*, 2020.

Longmore, G. Lui, G. Naik, P. Breen, B. Jalaludin and G. Gargiulo, "A Comparison of Reflective Photoplethysmography for Detection of Heart Rate, Blood Oxygen Saturation, and Respiration Rate at Various Anatomical Locations", *Sensors*, vol. 19, no. 8, p. 1874, 2019.

Lynn and J. Curry, "Patterns of unexpected in-hospital deaths: a root cause analysis", *Patient Safety in Surgery*, vol. 5, no. 1, p. 3, 2011.

Mostaghimi, M. Antonini, D. Plana, P. Anderson, B. Beller, E. Boyer, A. Fannin, J. Freake, R. Oakley, M. Sinha, L. Smith, C. Van, H. Yang, P. Sorger, N. LeBoeuf and S. Yu, "Regulatory and Safety Considerations in Deploying a Locally Fabricated, Reusable Face Shield in a Hospital Responding to the COVID-19 Pandemic", *Med*, vol. 1, no. 1, pp. 139-151.e4, 2020.

Roberge, "Face shields for infection control: A review", 2021.

Seshadri, E. Davies, E. Harlow, J. Hsu, S. Knighton, T. Walker, J. Voos and C. Drummond, "Wearable Sensors for COVID-19: A Call to Action to Harness Our Digital Infrastructure for Remote Patient Monitoring and Virtual Assessments", *Frontiers in Digital Health*, vol. 2, 2020.

Skamnelos, A. Murino, N. Lazaridis, L. Cunado and E. Despott, "Endoscopy during the COVID-19 pandemic: simple construction of a single-use, disposable face shield using inexpensive and readily available materials", *VideoGIE*, vol. 5, no. 9, pp.399-401, 2020.

Uddin, S. Shah and M. Al-Khasawneh, "A Novel Deep Convolutional Neural Network Model to Monitor People following Guidelines to Avoid COVID-19", *Journal of Sensors*, vol. 2020, pp. 1-15, 2020.

Wang, B. Hu, C. Hu, F. Zhu, X. Liu, J. Zhang, B. Wang, H. Xiang, Z. Cheng,

Y. Xiong, Y. Zhao, Y. Li, X. Wang and Z. Peng, "Clinical Characteristics of 138 Hospitalized Patients with 2019 Novel Coronavirus–Infected Pneumonia in Wuhan, China", *JAMA*, vol. 323, no. 11, p. 1061, 2020

Greenhalgh, M. Knight, M.I.Kim, N. Fulop, J. Leach, " Remote Management of Covid-19 using home pulse oximetry and virtual ward support", bmj 2021;372:n677

Tharkan,K. Nomoto, S. Miyashita and K. Ishikawa, " Body temperature correlates with morality in Covid-19 patients", bmc 2020; 24:298.