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QUANTITATIVELY EVALUATING THE RELIABILITY OF WEARABLE SENSORS INDIAGNOSIS, TREATMENT AND RECOVERY FROM COVID-19

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Abstract

Due to elevating incidents of SARS-CoV 2 (engendered by the causative agent COVID-19), the world has seen a greater reliance on wearable sensors like pulse oximeters, pyrometers/ thermometers for the diagnostic, treatment and recuperation stages of the disease. The purpose of this study is to assess the precision, accuracy and viability of these wearable sensors through trials and a survey, and measured these results against similar studies. Wearable sensors were found to play an important role in initiating diagnosis and in recovery.
Keywords: SARS-CoV 2; reliability of wearable sensors; diagnosis, treatment, recuperation

Introduction

More than two years since the beginning of the COVID-19 pandemic, countries are still combating the different variants of the virus. As of 13th April 2022, there have been 499,119,316 confirmed cases, and 6,185,242 deaths from COVID-19 as reported by national governments [1]. Early diagnosis continues to offer high cure rates and yields more effective treatment routes. Reverse Transcription- Polymerase Chain Reaction (RT-PCR) tests are considered to be confirmatory teststo detect the presence of COVID-19. A recent study by the CDC suggests that only about 1 in 4 casesof COVID-19 are reported and only about 1 in 1.32 deaths related to COVID-19 were reported [2]. This large number of actual cases in comparison to the true load of cases, translates to a requirement of a more efficient system for diagnosis of the disease and monitoring the health standards of the patient. An accurate and widely available method is the use of wearable sensors.

Wearable sensors are those devices which can be applied onto articles of clothing or directly onto the skin to measure and interpret biophysiological data. They are used in several medical specialities including dermatology, and electrophysiology etc. Wearable sensors, commonly used for Covid-19, include pulse oximeters and thermometer/pyrometers. The purpose of this research paper is to quantitatively evaluate the reliability of these wearable sensors. This study defines reliability as the accuracy, precision and validity, which is the degree to which a measurement is close to a true value,the closeness between successive measures and the extent to which the data measures what was intended to measure, respectively [3].

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Theory

Wearable sensors include a wide range of different sensor types including piezoelectric sensors, electrical sensors, optical sensors, etc. Of particular importance to diagnosis of Covid-19 are optical sensors and pyroelectric sensors.

Optical sensors are widely used in pulse oximeters, which are used to measure pulse rate (bpm) and blood oxygen concentration (spO2): two key vital signs which change upon contracting Covid-19. Optical sensors work on the principle of detecting scattered light which is reflected from internal body structures. The light is introduced artificially by a light emitting source which is positioned in close proximity to the sensor. [4] Pulse oximeters make use of the varied optical properties of haemoglobin and oxyhaemoglobin. When light of 650 nm is introduced, absorbance of haemoglobin and oxyhaemoglobin varies by 414220 cm-1/M. Oximeters exploit this characteristic to determine the patient's spO2. [5] Photoplethysmography in pulse oximeter machines can be used to determine the pulse rate.

Fever is another symptom commonly experienced when a person has contracted COVID-19. Body temperature can be measured using pyroelectric sensors in pyrometers. Pyroelectric sensors are constructed using a combination of gel and crystalline solution. When these substances are exposed to IR Radiation, their ability to carry electrical charge changes. This change in current can be measured using a sensitive transistor. [6] Digital thermometers work on the principle of changing resistance of metals as temperature changes. A metal probe measures the voltage and a microchip converts it to an understandable reading.

Experimental

1. Survey

A survey was conducted to assess the viability of wearable sensors for diagnosis and treatment of Covid-19. Participants were asked to enter their age and sex, after which they were asked a series of Boolean, multiple choice and Likert scale questions.

Link of survey: https://forms.gle/VGi4vQvueyySRiW97

2. Field experiment

Field experiments were conducted to determine the accuracy and precision of pulse oximeter and pyrometers. 10 pulse oximeters were used 5 times each, and the spO2 and BPM were tabulated. The mean and standard deviation of the results was calculated to determine the precision of the oximeters. The same procedure was carried out for 10 pyrometers to determine its precision. The results of the same data were then compared with a 'gold standard' thermometer and oximeter.

To ensure fairness of the results, the following variables were held constant: the same individual (and thus same age and sex) tested all the devices; all the devices were tested under the same conditions, and the volunteer had the same amount of activity before testing (resting).

Results

Following is the result of the survey:

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Pulse Oximeter

Serial No	spO2									
	1	2	3	4	5	6	7	8	9	10
1	98	98	97	98	99	98	99	98	98	97
2	98	97	97	98	97	98	98	99	97	98
3	99	98	98	99	98	98	96	98	97	98
4	98	98	98	97	98	98	99	98	98	98
5	97	97	98	97	98	96	97	98	98	99
$\sum x$	490	488	488	489	490	488	489	491	488	490
n	5	5	5	5	5	5	5	5	5	5
$\bar{x}$	98	97.6	97.6	97.8	98	97.6	97.8	98.2	97.6	98
$\sum x^2$	48022	47630	47630	47827	48022	47632	47831	48217	47630	48022
σ	0.632456	0.489898	0.489898	0.748331	0.632456	0.8	1.16619	0.4	0.489898	0.632456
	Average standard deviation=			0.648158						

Pyrometer

Serial No	Body temperature/ °F									
	1	2	3	4	5	6	7	8	9	10
1	97.3	95	97.5	96.6	97	98.3	98.1	96.8	98.4	98.1
2	97	97.3	97	97.3	95	97.2	98.4	97	98.2	97.5
3	96.4	97.4	98.2	97	96.3	98	97.3	97	97.1	96.8
4	97.4	98	97.1	98.3	96.3	96.2	98.1	97.6	96.5	98.2
5	98	96	96.8	96.5	97	97	96.9	96.9	97.7	97.4
$\sum x$	486.1	483.7	486.6	485.7	481.6	486.7	488.8	485.3	487.9	488
n	5	5	5	5	5	5	5	5	5	5
$\bar{x}$	97.22	96.74	97.32	97.14	96.32	97.34	97.76	97.06	97.58	97.6
$\sum x^2$	47260.01	46799.05	47357.14	47182.99	46390.38	47378.17	47786.68	47103.61	47611.75	47630.1
σ	0.584808	1.21573	0.554076	0.723187	0.816701	0.835464	0.630872	0.31305	0.785493	0.570088
		average standard deviation =			0.702947					

spO2 on 'gold standard' oximeter= 98; bpm on 'gold standard' oximeter= 91; temperature on 'gold standard' thermometer= 97.3

Discussion

The following observations were made from the experiments (survey and field experiment):

1. Diagnosis: Fig 1a suggests that almost three quarters of all the people who have ever taken an RT-PCR test have used wearable sensors to measure their symptoms before taking a confirmatory test. Furthermore, Fig 1b suggests that 52% of people were compelled to some or complete extent to take an RT-PCR test from their sensor readings. On the contrary, 31.2% of people were not at all compelled to take the test. These statistics suggest that a majority of people rely on wearable sensors to measure their symptoms but only about half the people rely on sensor data to the extent that they get a confirmatory test. Fig 1c is indicative of the fact that in only 45.5% of the cases, a fever/low oxygen concentration resulted in a positive RT-PCR test. This is, however, due to the fact that the symptoms experienced by Covid-19 patients are very similar to other commonly occurring diseases such as influenza.
2. Recovery: Fig 2a demonstrates that 67.5% of all Covid-19 patients measured their vital signs using wearable sensors frequently or very frequently. On the other hand, only 25.7% of people reported that they measured their vital signs infrequently or never. Fig 2b suggests that 67.1% of people reported their vital signs to their family physicians. This insinuates the fact that almost 7 out of 10 patients depended on wearable sensors to measure the severity of their symptoms and also reported them to their primary care doctors. This is more than the percentage of people who were convinced to take an RT-PCR test when experiencing symptoms- indicating that reliance on wearable sensors increases upon getting a positive result for the confirmatory test. Fig 2c suggests that only 44.4% of people solely relied on normal vital signs from these wearable sensors to end their two week quarantine period. Greater reliance was shown for negative RT-

PCR test, suggesting decreased credence on sensors.

3. Treatment and prognosis: Fig 2d is indicative that 58.9% of physicians asked their patients to send them their vital signs as measured by these wearable sensors. They take this into account in order to determine the severity of viral load and thus accordingly prescribe dosageand type of medicine. About 35.6% patients did not send their vital signs to their doctors- maybe due to being asymptomatic or experiencing very mild symptoms. Similar statistics arereinforced by fig 3a in which 54.5% of healthcare staff reported basing their route of treatment partly or completely on sensor data.

Similar results to the field experiment were obtained by previous studies such as those by Dukinget al. (2018) [7] and Dong et al. (2019) [8].

Conclusion

From the results of the field experiment, the precision of pulse oximeters for spO2 and pyrometers for temperature is quite high. Digital thermometers are likely to have an even higher degree of precision. BPM measured using oximeters is less precise and has a larger standard deviation. The accuracy of oximeters for measuring spO2 is quite high when compared to the 'gold standard' machine. The accuracy of oximeters measuring BPM is a little inadequate. The accuracy of pyrometers is also high, but digital thermometers are likely to have higher accuracy. From the surveyit can be deduced that wearable sensors are quite viable for diagnosis, treatment (prognosis) and recovery.

The limitations of this research are that only the wealthy can afford wearable sensors and the survey sample size may not be representative of the entire Indian population since it is challenging to make the survey accessible to all sects of the society. Furthermore, it is challenging to measure utility on a Likert scale and satisfaction differs for each individual.

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