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The Effectiveness Obstructive Sleep Apnea Monitoring Using Telemedicine Smartphone System (TmSS)

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Abstract. Data at the world health organization shows that around more than 100 million people worldwide suffer from Obstructive Sleep Apnea (OSA) and most sufferers go undetected. The purpose of this study is to develop an apnea monitor that can detect the symptoms of Obstructive Sleep Apnea using the Telemedicine Smartphone System (TmSS). The contribution of this study is the generation of telemedicine systems in sleep apnea monitoring devices. So that the monitoring tools can be effective and efficient when used, then the Obstructive Sleep Apnea monitoring tool is made with the TmSS system that can transmit data values wirelessly and in real-time. This tool uses a flex sensor to detect patient breathing. The output generated by the sensor is then conditioned on an analog signal conditioner (PSA) circuit. The signal output from the PSA is processed on the ATMega 328 microcontroller to get the respiration value which is then sent via Bluetooth HC-05 and displayed on an android smartphone device which will also display a warning notification in the event of stopping breathing (apnea). Based on the results of the measurement of respiration values compared with standard equipment produces the highest error value of 6.98% and the lowest of 0.00%. The tool can send data respiration values using the TmSS system properly. This tool can be implemented to detect the symptoms of Obstructive Sleep Apnea.

Introduction

According to the World Health Organization, around 100 million people worldwide suffer from Obstructive Sleep Apnea (OSA). Obstructive Sleep Apnea (OSA) is a type of sleep apnea event. Sleep apnea is a sleep disorder characterized by reduced airflow during sleep, which in turn causes pauses and decreased breathing. This recurring disorder due to sleep due to airway obstruction causes fragmented sleep patterns and causes activation of the body's sympathetic nervous system [1]. Apnea is defined as the duration of time when there is a complete blockage of airflow for 10 seconds or more and is measured in the apnea-hypopnoea (AHI) index [2]. Some of the symptoms that are usually manifested by sufferers of sleep apnea include snoring, stopping breathing during sleep, choking or panting following breathing disorders, daytime sleepiness while doing routine tasks, headaches, dryness of the throat in the morning, lack of ability to concentrate, urinating at night, depression and irritability, and obesity [3]. In the United States, OSA is estimated to affect 1 in 4 men and 1 in 9 women; it also affects 23 million working adults. About 4% of men and 2% of women over the age of 35 have moderate or severe OSA symptoms, affecting around 12 million people in the United States. It is estimated that less than 25% of people with OSA have been diagnosed [3][4]. The diagnosis of OSA can be done through various tests and techniques. However, the symptoms of OSA disorders are not very specific and can sometimes be caused by factors other than sleep apnea such as alcohol intake, lack of sleep, and stress [5]. Therefore, sleep specialists need to do the right tests to rule out and differentiate these symptoms. If these results indicate sleep apnea, then further diagnostic tests need to be performed, which include medical, physical, and sleep history examinations [6]. After the OSA probability is determined to be high from the tests carried out, polysomnography is usually done. Polysomnography is the most common sleep study conducted overnight and measures the patient's brain activity along with several other measurements. It electronically monitors sleep stages, measures eye movements, brain waves, airflow, and respiratory effort, respiratory changes, blood oxygen levels, and heart rate [6]. The doctor will then measure the amount of apnea that occurs and which lasts more than 10 seconds [7][8]. Significant apnea is diagnosed if more than 5 episodes of apnea occur for one hour. Unlike existing applications that only consider some of the signs of sleep apnea, the proposed application approach is to use built-in sensors to collect data that represent important parameters for proper initial diagnosis. By using built-in sensors, this application seeks to collect representative data sets which, once analyzed, will help identify, with a high degree of certainty, whether there are symptoms of sleep apnea or not. In premature babies, apnea occurs because the immature respiratory system is called apnea of prematurity (AOP) [9]. Other things that can cause apnea are unstable temperatures, pneumonia, asphyxia, and anemia. All infants were born less than 34 weeks must be monitored or monitored at least the first week or until no apnea episodes occur in more premature babies [10]. Therefore, it is necessary to make a tool to detect the incidence of sleep apnea so that it can reduce people suffering from Obstructive Sleep Apnea (OSA) [11]. Today, technology is developing so fast both in the economic, industrial, and not in the world of health. The tools used to diagnose a disease already use a microprocessor so that the medical devices produced are smaller and easier to use [12]. Medical devices, especially diagnoses, have also been developed with telemedicine or remote monitoring systems so that doctors can monitor patients' conditions over long distances.

In 2016, Monitoring of Obstructive Sleep Apnea Using a Mobile Phone was made by Nilam Maske and A.N.Gaikwad. This tool functions to monitor the body temperature, heart rate, and breathing rate of the patient. This tool uses an oral sensor and a nasal thermistor that is placed at the bottom of the nose and above the mouth to detect breathing through the flow of air produced while breathing[13]. This tool can monitor these three parameters remotely using a wireless system (antenna). In his journal, it is said that the manufacturing of the tools does not require much cost / is very cheap [14]. This tool is also equipped with GPS tracking to track the current position of patients sent using the GSM module. However, the use of nasal and oral sensors to detect breathing that is used on this device is not effective so it makes the patient feel uncomfortable. This tool also does not provide a warning alarm or indicator if the patient is experiencing a stop breathing (apnea). In the same year a tool called Thermistor based Apnoea Monitor was made by Namrata Dhumal, et al. This tool also uses a temperature sensor to detect patient breathing, the temperature sensor used is LM35 which is placed on the face mask so that LM35 will detect changes in temperature that occur when the patient breathes. This tool uses a PIC 16F877A microcontroller, this microcontroller serves to process data on the value of LM35 temperature changes into respiration values. Respiration values per minute are then displayed on the LCD display so that the patient's respiratory condition is normal, too fast, or too slow [15]. This tool is also equipped with an alarm in the form of a piezoelectric buzzer to provide a warning in the event of abnormal conditions in breathing or the patient experiences stopping breathing (apnea). However, this tool still has shortcomings namely the tool still uses an adapter for the power supply so that the tool cannot be portable. Then in the same year, Ranjitha BS made a Non-Invasive Sleep Apnea Detection and Monitoring System, this tool serves to measure the body temperature and the respiratory rate of patients. The sensor used to detect the patient's respiratory rate in this device is a NTC type thermistor then the sensor output is processed on the Arduino board microcontroller. This tool uses an Arduino Board integrated with IC ATMega 328 (Arduino UNO) because this IC has 6 Analog to Digital Converter (ADC) input pins on pins A0 - A5. ATMega 328 IC is an 8-bit microcontroller that is capable of executing several commands in one time loop, and this microcontroller consumes very low power. Output data that has been processed on this Arduino microcontroller is in the form of respiration value per minute which is then displayed on the LCD 2 X 16. On this LCD serves to display respiration value, body temperature, and also displays a warning when abnormal conditions occur, namely stop breathing (apnea). This tool also sends the patient's condition in the form of sms to the doctor's cell phone using the help of GSM SIM 900 module [16]. This tool also uses a battery so that it can be carried everywhere (portable). Even so, this tool has shortcomings in the sensor used, the use of thermistor sensors to detect patient breathing is ineffective because patients will feel uncomfortable when used. This tool is also not equipped with a warning alarm in the event of stopping breathing (apnea) only a warning is displayed on the LCD display so that nurses/people who are around the patient must see and examine the patient's condition closely. in the same year, an apnea monitor was developed by Kumari Sneha with the title Detection of Sleep Apnea using a Pressure Sensor different from the tools made previously, this tool uses a pressure sensor type MPX 100DP to detect patient breathing. This tool uses Arduino UNO to process the signal generated by the pressure sensor which was also previously processed in the signal conditioning circuit. The processed signal on Arduino is then sent via the Bluetooth HC-05 module on a computer device which is then processed again in the MATLAB application [17]. This tool can monitor the incidence of sleep apnea wirelessly and then analyze it in the MATLAB application, but this tool has the disadvantage of placing a pressure sensor on the nostrils making patients who use this tool less comfortable, especially during sleep, cannot be portable because of the appearance of the device on a computer device.

Based on the literature search above, the development of apnea monitor needs to be done including sensors that are used to detect patient breathing, display of the results of measurement of respiration values, and data delivery system of respiration values [6][18]. Therefore, in this study an Obstructive Sleep Apnea Monitoring tool using Telemedicine Smartphone System (TmSS) aims to improve usability/feature of respiration monitoring when used by patients, sending respiration values using the Telemedicine system that enables remote monitoring, display devices using an android smartphone so that effective and add a warning if the patient has a stop breathing (apnea) so that treatment can be quickly carried out [19][20].

The remainder of this paper is organized as follows. Part II contains the tools and materials and methods used in this study. Part III is the result of the research conducted. Part IV contains a discussion of the results obtained in this study. And part V contains conclusions obtained from this study.

Materials and Methods

Experimental Setup. This study used men and women as subjects aged 20-25 years and infants under 3 weeks old. Sampling is done randomly by taking data 5 times with a total of 10 samples. Tests conducted in this study did not meet the ethical test, however, testing of respondents in this study had received prior permission from the respondent and the respondent's parents for the baby respondent.

Materials and Device. This study uses a flex sensor (Spectra Symbol, China) as the detection of patient breathing. Using an LM358 operating amplifier IC (Texas Instrument, China) for analog signal conditioning circuit. Using a microcontroller IC AT-Mega328P (Atmel, China) as data processing. The processed data is then sent to an Android-based smartphone (Version 6.0.1, USA) using an application that has been formed with the MIT App software (Inventor, Version 2.58A) via a Bluetooth network with HC-05 module (V2.0 + EDR, China).

Experiment. In this study, measurements were made of two patients as follows:

Measurement of Respiratory Signal Amplitude. This measurement is done by placing the flex sensor at 2 different points, namely on the right umbilical region and the left umbilical region [21]. Then the respiratory signal output is measured using an oscilloscope so that the amplitude of the signal formed during respiration can be known.

Measurement of Respiration Values. Respiration value data collection was carried out on 10 respondents with each respondent as much as 5 times compared to standard tools. At the time of measurement, the respondent is in a sleeping position.

The Diagram Block. In this research, flexible sensors were used to identify the swelling and deflection of the abdomen of the patient during breathing as seen in Fig 1. The output sensor that is still in the form of resistance will enter the analog signal conditioning circuit so that it can be processed by the microcontroller.

While the breathing detected, the microcontroller will send data for respiration value counters to android via Bluetooth. When sleep apnea occurs, the module will activate the alarm on the device and also on android. On the Android display, there is also a patient's respiration value in the form of plotting the graph of respiration value.

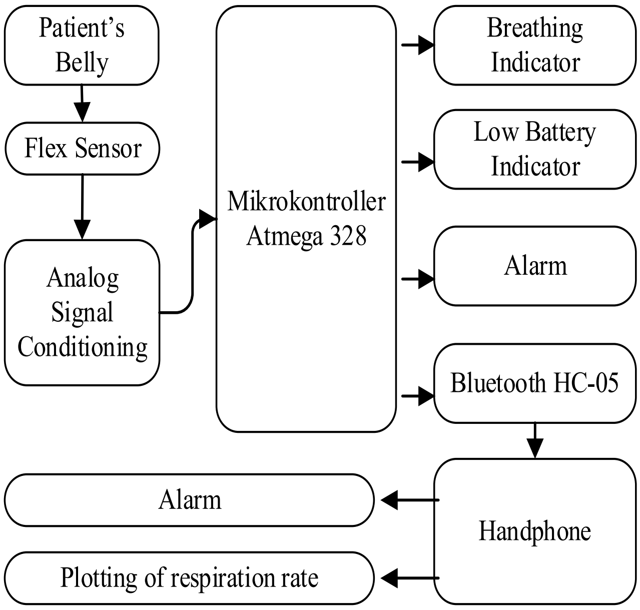

Fig. 1. Apnea Monitor Block Diagram

The Flowchart. The flow diagram of the apnea monitor microcontroller program is shown in Fig. 2 and the flow chart on an android smartphone device is shown in Fig. 3.

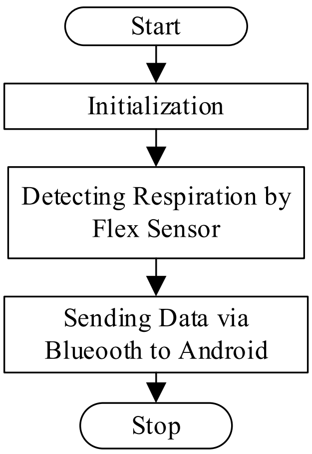

Fig. 2. The Flowchart Microcontroller

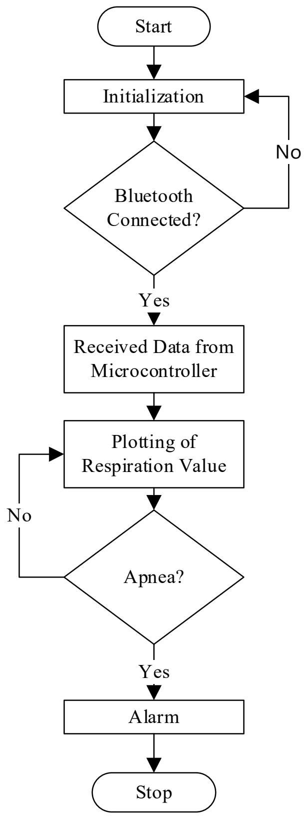

Fig. 3. The Flowchart Android

The Arduino program is based on the flowchart in Fig. 2. After initializing the microcontroller will detect changes in input voltage produced by the flex sensor. Furthermore, this data will be sent via

Bluetooth to Android. The Android program flowchart can be seen in Fig Fig.3, where after initializing, the operator needs to connect Android to Bluetooth from the device. When breathing occurs, the value of the patient's respiration will appear, and when it's one minute there will be an update to plot the graph of respiration value on the android display.

Result

Module Design. The mechanical diagram of the tool is shown in Fig 4. On the front of the apnea monitor, it has 3 indicator LEDs, namely the ON indicator that will light up when the device is turned on, the breathing indicator that will light up when a patient's breath is detected, and the low battery indicator that will light up when the battery is in the device will run out. This tool transmits respiration value data via a Bluetooth network which is then displayed on an android using the MIT App [22].

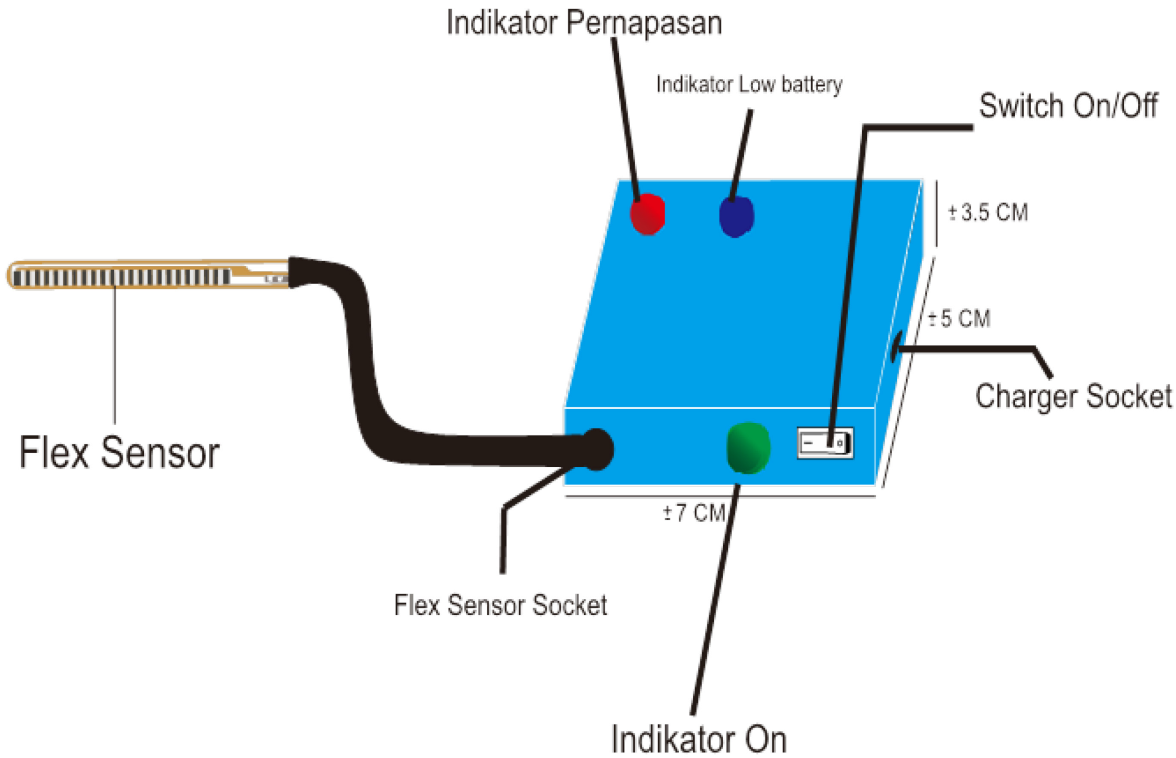

Fig. 4. Apnea Monitor Monitoring System Overview

Sensor Placement. In this study conducted direct testing on respondents. Data transmission on the apnea monitor uses a TmSS (Telemedicine Smartphone System) system. Respiration values generated by the device are then compared with a comparator / standard device using a digital counter. In Fig. 5 below shows the flex sensor placed at the top of the umbilical area and the device is next to the respondent with an Android smartphone display device.

Fig. 5. Sensor Placement

Results of Measurement amplitude of the Respiratory Signal. Respiration signals are measured twice with two different points from the placement of the first flex sensor point to the right of the umbilical region and the second point to the left of the umbilical region. Respiratory signal measurements using a digital oscilloscope so that the amplitude of the signal produced at the time of respiration can be known. The results of the measurement of the amplitude of the respiratory signal to 10 respondents with two different points are then averaged so that it is known which point produces a signal with a higher amplitude as shown in Table 1.

Table 1. The Amplitude of The Respiration Signal

Respondent	Right Side (Volt)	Left Side (Volt)
1	2.56	2.16
2	1.92	1.16
3	2.4	2.24
4	3.24	2.36
5	2.88	1.64
6	1.60	0.76
7	1.80	1.44
8	3.04	2.24
9	3.60	2.88
10	2.16	1.24
Average	2.52	1.812

Based on data from the measurement of respiration signals, the greatest signal amplitude is obtained by placing the flex sensor on the right side of the umbilical region with an average amplitude of 2.52 Volts.

Results of Measurement Respiration Rates. A comparison of the results of measurements of respiration rate carried out in a manner like Fig 4. compared with a standard tool in the form of a digital counter obtained the results in Table II below.

Table 1. The Error of Respiration Rate on Design

No.	Device	Average	STDEV	Ua	Error
1	Standard	11.2	0.45	0.20	3.57%
	Design	10.8	0.84	0.37	
2	Standard	19.6	0.89	0.40	5.10%
	Design	18.6	2.07	0.93	
3	Standard	12.6	0.89	0.40	4.76%
	Design	12.0	1.00	0.45	
4	Standard	17.2	1.30	0.58	6.98%
	Design	16.0	2.35	1.05	
5	Standard	13.0	2.00	0.89	3.08%
	Design	12.6	1.95	0.87	
6	Standard	18.8	2.17	0.97	2.13%
	Design	18.4	2.88	1.29	
7	Standard	15.0	2.00	0.89	1.33%
	Design	14.8	2.17	0.97	
8	Standard	23.4	2.30	1.03	5.98%
	Design	22.0	2.55	1.14	
9	Standard	18.8	1.48	0.66	3,.19%
	Design	18.2	1.92	0.86	
10	Standard	19.0	1.41	0.63	0.00%
	Design	19.0	1.41	0.63	

From the results of a comparison using a standard tool in the form of a digital counter, the greatest error was 6.98% and the smallest was 0.00%. The uncertainty of measurement is obtained from external factors such as the accuracy of the observer to determine the counters at the time of respiration using digital counters, Bluetooth networks, and etc. The greatest uncertainty value is 1.29 and the smallest is 0.37.

ROC Curve TmSS of Respiration Rates. The ROC TmSS curve was taken from respiration rate data of respondents with a range of 19-25 years of age and then performed calculations to obtain the ROC curve as in Fig. 6.

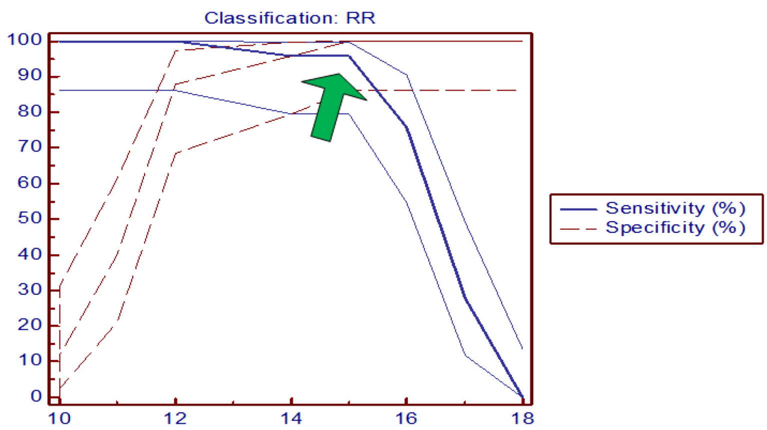

Fig. 6. Respiration Rate ROC Curve in TMSS for Respondents with Different Ages

The ROC curve in Fig. 6 shows the value that the respiration rate of respondents in the age range of 19-25 years is 0.997 which means that the Telemedicine Smartphone system on RR data can detect the Respiration Rate (RR) value using the flex sensor.

Discussion

After measuring the respiration signal to 10 respondents by placing the flex sensor at two different points shown in table 1, the highest amplitude of the respiration signal is obtained by placing the flex sensor on the right side of the umbilical region with an average amplitude of 2.52 Volts. Measurement of respiration value to respondents was also done by comparing the measurement results using a standard in the form of a digital counter in table II, the highest error value was 6.98% and the smallest error value was 0.00%. This apnea monitor uses a flex sensor that has a relatively small physical size that makes it comfortable when used by patients. This tool also uses the Telemedicine Smartphone System (TmSS) which can monitor the respiration rate of patients in a longer distance because sending data using a Bluetooth network with a display on an android smartphone device.

This is a development of tools made previously in terms of the sensors used, the display of the measurement results of the tools, and the sending of data used. The sensors used are still inefficient and lack comfort when used by patients. Respiratory rate measurement results are still displayed on the 2X16 character LCD so nurses must monitor the routine display of the device to know the patient's breathing rate [16]. As for devices made previously by Namrata Dhumal, et al who sent data on respiration values still use antennas so that the size of the device is relatively larger [15].

The use of flex sensors on this device is very influential on the level of comfort when the tool is used by patients. The size of the apnea monitor in this study is much smaller than the previous research because the circuit used is not much and the results of the measurement of respiration value are not on the device but on Android smartphone devices that are currently widely used.

Even so, the results of the measurement of respiration value are also influenced by factors such as sensor placement, the Bluetooth connection network used, and the distance between the device and the display in the form of an android smartphone.

Conclusion

The purpose of this research is to make a tool to detect the symptoms of sleep apnea by measuring the respiratory rate of patients that can be monitored remotely and increasing the comfort level of the tool when used by developing the sensors used. This research has shown that an apnea monitor can be made with the Telemedicine Smartphone System (TmSS) so that it can transmit data from respiratory rate measurements in real-time and can be monitored remotely. This tool can also provide a warning when there is a stop breathing (apnea) by sending a notification on an android smartphone device as a display so that it can be done quickly to the patient. Further research on tools to detect the symptoms of sleep apnea needs to be done to improve weaknesses in the placement of sensors to detect breathing, data transmission systems, and sensors used to further enhance comfort when used.

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