Journal of Engineering Technology Vol. 10(1): 38-42, 2022
ISSN 2231-8798© 2013 UniKL BMI

Primary Monitoring Device for Epilepsy in Pediatric Patients

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Abstract: Most commercially available devices on detection of epilepsy in seizure patients are meant for adult and it's not suitable to be used by a pediatric patient. This prototype devices have the capability to detect seizure episode on pediatric patient with epilepsy during their sleep. This product detect seizure through two parameters which are the heart pulse rate and wrist acceleration. A photoplethysmography pulse rate sensor is used to detect the heart pulse rate while a three-axis accelerometer is used to detect the wrist acceleration. When an episode of seizure is detected, this device will send notification to parent's or guardian's phone to warn and notify them as well a buzzer will also turn on that will allow first-aid help to the patients by the people surrounding them.

Keywords: Epilepsy, Seizure, NodeMCU, Monitoring Device, Pediatric

1.0 INTRODUCTION

Good sleep habits are essential to wellness and mental health where as a bad sleep habits will risk one's professional and personal life. A good sleep habits are not only meant for human being but it's equally important to every living creature. As stated in the Al-Quran "And He it is Who made the night for you as clothing and sleep [a means for] rest and He made the day a resurrection." (Al-Quran 25:47). It is norm that human sleep at night and wake up energetic in the morning in order to be able to carry out activities during the day [1][2]. In [3] has defined a good sleep habits that can be categorized into two: 1) Objective sleep quality refers to how peaceful a person can be without any interruption during their sleep and 2) subjective sleep quality refers to how refresh a person can be after awaking from sleep.

A good sleep habits is essential to the development of wellness and mental health and it is critical to development of brain especially for baby as well as children [4]. Unfortunately, during this resting period, sometime people will experience very unpleasant episode of seizure which is called nocturnal seizure. The nocturnal seizure is a major concern especially for children since nocturnal seizure can cause some bad impacts on a children's development including speech impairment[5][6]. Worse still if the nocturnal seizure happens that will cause distress to parents since they will be in constant worry for their children wellbeing.

If the seizures repeated that can lead a person to epilepsy disorder. Therefore, it is important to seek medical attention after experiencing one or more nocturnal seizure which are potentially life-threatening especially when it happens to a baby or children.

Epilepsy is a neurological disorder which caused by unusual nerve cell activity in the brain[7]. Seizure usually just happens once while epilepsy is a condition when there is two or more unprovoked seizure occurrence. When it comes to pediatric patients, 1 out of 150 is diagnosed with epilepsy on the first 10 years of their life[8].

Electroencephalogram (EEG) is widely known method for detecting brain abnormalities including epileptic seizures. The EEG is a noninvasive, effective tool for decoding the electrical activity of the brain in clinical research. In order to identify a seizure occurrence, expert neurologists must visually check EEG for seizure identification, which is a time-consuming and arduous operation[9].

In this prototype product development known as the Primary Monitoring Device for Epilepsy in Pediatric Patients is designed to detect seizure based on the pediatric patient's heart rate and wrist acceleration. When seizure occur, this device will then alert the children's parents by sending notifications on their smart phone and the device

will buzzer to alert surrounding people to provide emergency first aid help.

2.0 PERVIUOS WORKS

The heart rate data of the epilepsy patient can be used as an indicator of seizure occurrences[10]. Most seizures occurrences are accompanied by a heart rate reading of more than 100 bpm[11][12]. The development of tachyarrhythmia is one of the possible factors that lead to sudden unexpected death in epilepsy patients (SUDEP)[13].

M. Zijlmans et. al. study on heart rate changes and Electrocardiogram (ECG) abnormalities during epileptic seizure. EEG is used to determine the occurrence time of the seizure and then it is compared to the graph obtained from ECG. It was found that 147 seizures in 62 patients shows heart rate reading of more than 100 beats/minute where 13 patients experience 22 seizures with heart rate higher than 150 bpm which indicates tachycardia [14].

W. Chen et. al. did this research on heart rate changes in partial seizures by observing the frequency of heart rate changes and its relation to seizure. Video-EEG and ECG records were used in this research and are attached to 81 patients. The increase of heart rate of more than 100 bpm can be seen from between 10 seconds preictal and ictal onset. The research finding where 83.98% seizures from 74 patients accompanied by tachycardia, 1 patient experienced bradycardia and 1 patient experience both tachycardia and bradycardia. The result recorded shows rapid increase of heart rate within 10 seconds before seizure onset and most recorded seizure occur when patients are asleep[15].

Seizures that are accompanied by a clear manifestation of convulsion can be detected by referring to the wrist acceleration data of an epilepsy patient[16]. An accelerometer is an excellent device to be used in order to detect the acceleration during convulsion with a very low false detection rate [17].

In 2013 where S. Beniczky et. al. investigates how reliable a wireless wrist accelerometer in detecting generalized tonic-clonic seizure (GTCS). The three-axis acceleration transducer sensor is used where the setting for peak acceleration is set when it reaches higher than $2g/ms^2$ and decrease lower than $-2.5g/ms^2$. The device managed to detect 89.7% seizure occurrences correctly. The seizures that are not detected involves seizure without convulsion movement which is simple partial, complex partial, focal tonic, hypermotor, absence, myoclonus and psychogenic nonepileptic seizure[18].

Johan B. A. M. Arends did the study on movement-based seizure detection in 2018. It was done to measure the accuracy of movement detection in epileptic seizures. Two sensors were used in this research which is the accelerometer sensor and the piezoelectric bed sensor. Seven patients were asked to wear an accelerometer sensor on their wrist while four patients have piezoelectric bed sensor attached to their bed. Both sensors detect seizure based on the same parameter which is acceleration. The difference between these two sensors is the placement of the sensor. It was found that both accelerometer and piezoelectric sensors produce high positive predictive value[19].

3.0 THE PROTOTYPE

In this study two parameters are used to detect seizure in pediatric patients which are the heart pulse rate and the wrist acceleration. To detect the heart plus rate the MAX30102 high sensitivity pulse oximeter and heart rate sensor is used. This sensor is used to measure heart pulse rate in BPM and blood oxygen concentration (SpO2). However, in this prototype the MAX30102 sensor will be a single used that to measure the heart pulse rate. For wrist acceleration, ADXL335 accelerometer sensor is used. Acceleration is a process in which velocity is changed with respect to time, speed and direction. This sensor has a complete 3-axis acceleration measurement system. In the case of this prototype the ADXL 335 accelerometer is used to detect the wrist movement of a pediatric patients when seizure occurs. Figure 1 shows the flowchart for processes of the proposed prototype device. Pulse sensor will detect the heart pulse rate of the patients while the accelerometer will detect the wrist acceleration of patients.

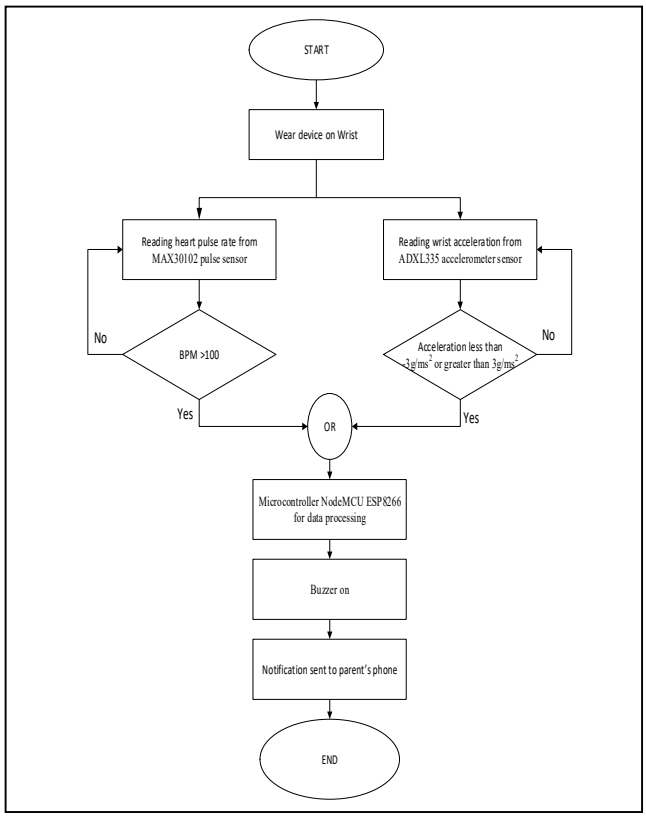

Figure 1: Flowchart of Primary Monitoring Device for Epilepsy in Pediatric Patients

Any one of these parameters exceeded the minimum setting indicate seizure is detected the data will be sent to the microcontroller NodeMCU ESP8266 will then turn the buzzer on as well will send a notification to the patient's parents to notify them on the seizure episode that is currently occurring to their children.

If both the pulse rate and acceleration did not meet neither of the minimum setting, it shows that no episode of seizure is occurring. Therefore, the device will not produce any output to trigger the microcontroller. However, the device will continuously take the reading of patient's pulse rate and wrist acceleration as long as the device is power on.

4.0 RESULTS

The device will detect two parameters which are the pulse rate and the wrist acceleration. Hence, it should be worn on the patient wrist, the best position to detect the pulse rate and the wrist acceleration. The pulse rate sensor is set at minimum 100bpm and the accelerometer sensor is set at decreases lesser than -3g/ms^2 exceeds 3g/ ms^2 that will indicate occurrence of seizure.

When seizure is detected, this device will automatically turn the buzzer on to blare a loud sound to alert their parents and the device will send a warning to the parent's phone to notify them that seizure is currently attacking to their children. This dual alarming system will ensure that the parent's will not missed the notification when seizure episode that is currently occurring to their child. Table 1 shows the result based on pulse rate and wrist acceleration of the proposed prototype device.

Table 1: Input and output of the Primary Monitoring Device for Epilepsy in Pediatric Patients

Pulse rate (bpm)	Wrist acceleration (gm/s^2)	Buzzer	Phone notification
<100	-2.99<y<2.99	X	X
	y≥3	Y	Y
	y≤-3	Y	Y
≥100	-2.99<y<2.99	Y	Y
	y≥3	Y	Y
	y≤-3	Y	Y

When the pulse rate sensor detected is less than 100bpm and the wrist accelerometer sensor exceeds more than -3g/ms^2 lesser than 3g/ms^2 the device does not buzzer and no notification will send to the parent's phone. It's assumed the patient condition is in normal state or it shows that no episode of seizure is occurring. However, when one of the conditions is met (pulse rate or wrist acceleration), this device will buzzer and phone notification will send the parent's phone. These are shown in Figure 2.

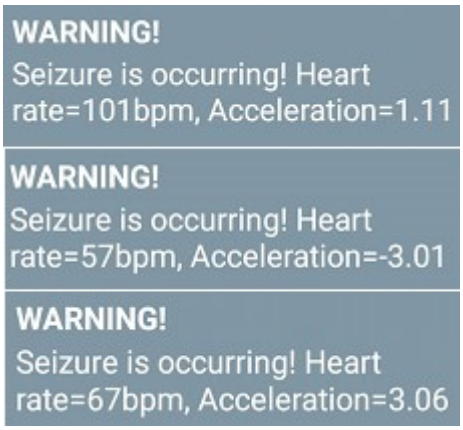

Figure 2: Notification shown on Parent's Phone.

The second results tabulated on Table 2 it is the time taken for the prototype device to notified their parent's handphone when a seizure occurs. Ten test samples were done when an episode of seizure took place. From the results the average time taken to receive notification is 2.8 seconds. Therefore, parents or guardian will receive a notification fast regarding any seizure occurrence on their children. This can help them to take further action to ensure the wellbeing of their children.

Table 2: Time taken to receive notification.

No. of test	Time taken to receive notification (s)
1	3
2	2
3	2
4	4
5	3
6	2
7	2
8	3
9	4
10	3

Table 3 tabulated the testing of accuracy the MAX30102 sensor for pulse rate. The pulse oximeter will be used as a reference reading. The MAX30102 sensor will located on finger and on wrist. Twelve samples were taken.

Table 3: Pulse oximeter and pulse sensor readings.

MEDISANA Pulse Oximeter (bpm)	Pulse Sensor MAX30102	
	On finger (bpm)	On wrist (bpm)
64	64	59
65	65	23
67	63	19
67	63	28
68	66	26

68	66	31
68	65	7
70	69	43
72	70	56
94	94	21
98	97	10
120	113	67

Average reading for Pulse Oximeter is about 77bpm, the MAX30102 located at finger the average reading is 75bpm however when MAX30102 is located at wrist the average reading is 33bpm. It can be seen that the average reading for MAX30102 when it is used on finger the percentage error is about 2.6%. However, when MAX30102 is located at wrist the percentage of error is huge at 57.14%. The cause of this very high percentage of error is due to the diverse skin condition[20]. In this case, the diversity is in the thickness of epidermis layer. The thickness of epidermis layer of finger and wrist are different from one another[21]. The reflection of light from the transmitter to the receiver become unstable due to the skin inhomogeneity to the morphology of photoplethysmography (PPG) waveform which effect the light penetration depth[22]. This high percentage error become a major limitation on this prototype

5.0 CONCLUSION

The detection of seizure via the Primary Monitoring Device for Epilepsy in Pediatric Patients can bring a lot of benefits. This includes making parents with epilepsy children to feel less anxious since they will be notified of any seizure occurrence so they can proceed in taking the next step like contacting their children's nanny to ensure their child is well attained. This can also allow early detection of seizure episode since this device will produce sound to attract the attention of nearby people. Therefore, the nearby people can help the child while they are having an episode of seizure like containing the patient if they are having seizure that includes convulsion to avoid them from hurting themselves. An early detection of seizure can also decrease the risk of SUDEP.

However, some limitations must be overcome to improve the performance of this device. For future improvement, a pulse heart rate sensor that is design for thicker epidermis layer should be considered. The design of the device must consist of a very optimized contact pressure between the sensor and the wrist to avoid any unnecessary resistance in the pulse rate reading.

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