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Wearable Detection Systems for Epileptic Seizure: A review

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Abstract

The seizure epilepsy is risky because it happens randomly and leads to death in some cases. The standard epileptic seizures monitoring system involves video/EEG (electro-encephalography), which bothers the patient, as EEG electrodes are attached to the patient's head.

Seriously, helping or alerting the patient before the seizure is one of the issue that attracts the researchers and designers attention. So that there are spectrums of portable seizure detection systems available in markets which are based on non-EEG signal.

The aim of this article is to provide a literature survey for the latest articles that cover many issues in the field of designing portable real-time seizure detection that includes the use of multiple body signals, new algorithm methods, and detection devices that are commercially available.

As a result, the reviewing process shows that there are many research articles that have covered wearable seizure detection systems that based on body signals. The more effective monitoring and detection seizure system is the system that uses multi-body signals, is highly comfortable and has low power consumption.

Keywords: *Biosensors, Wearable sensors, Epilepsy, Seizures, Non-EEG, EMG.*

1. Introduction

Since the 70's, medical specialists have envisioned intelligent, implantable devices for predicting seizures and triggering abortive treatment to aid many people all over the world who have medically intractable epilepsy. Most of the researcher used the seizure detection method based on the EEG –recordings that require, either an invasive recording (intra-cranial electrodes) or placing numerous scalp electrodes, which are less stable over time. Moreover, the patient can get uncomfortable wearing electrodes on their scalp, due to the fact that they are very obvious for others. Despite the EEG approach being the standard; it does not necessarily seem as the optimal choice for a seizure alarm outside the hospital, so other researches tried to find a new different method to predict the seizure [1-3].

The research presented a review of researches that used non-EEG signals, such as electromyography (EMG), heart rate (HR), oxygen level (SpO2), accelerometer (ACM), and body temperature. It also prepared a list of latest of available commercial devices for epileptic detection. The aim of this work is to present useful information to assisted researchers in the field.

2. Epilepsy

Epilepsy can be defined as a brain disorder identified via an enduring pre-disposition for the generation of epileptic seizures and via the physiological, neuro-biological, cognitive, and social results of this disorder. Defining epilepsy needs the occurrence of a minimum of one epileptic seizure [4].

This condition is the 4th most common neurologic disorder affecting people of different ages [5]. There are about 65 million people affected all around the world, with a high and dramatic impact not only on the patient's quality of life, but also on the professional development and social behavior; the health system budget is highly affected as well [6].

Epilepsy may have an effect on people of any age but it is most widespread among children and the elderly. A few kinds of epilepsy are inherited and are caused by genetic factors. Other probable epilepsy causes involve brain injuries because of oxygen deprivation at birth or head traumas. In several of the situations, the reason behind epilepsy is simply not known [7].

3. Seizure

A seizure is an unusual behavior (with symptoms or signs) that results from unusual discharges of cortical neurons. This phenomenon, which is observable, is finite in time. Epilepsy is a definition of a chronic state which is defined by repeated occurrences of seizures. A syndrome is a set of symptoms and signs occurring together, however, unlike disease, have no single known cause or pathology [8].

Seizures occur, in the majority of the patients, suddenly with no external symptoms. The sudden occurrences of those seizure pose a serious concern and accounts for mortality in patients that have uncontrolled epilepsy. Thus, timely predicting seizures provides a sufficient time for reducing risks of seizures and thereby improve the quality of life for the affected [9].

A seizure could seem to happen in a spontaneous way, with no external cause, even though in a great deal of patients a cause like a flashing light, redundant sounds or stressful cases are easily characterized as triggers of seizure. While seizures often happen during sleep, a seizure during the waking time could be a cause for the patient to harm themselves when they suddenly lose consciousness. The danger that this poses to the epileptic patient and others is obvious. They could fall and harm their head, fall into moving machinery or lose control of a car.

4. Seizure Types

Until the past few years, seizures were categorized based on the international classification of seizures, which has been suggested by the "International League against Epilepsy (ILAE) [10]. In 2017, ILAE announced a new classification of seizures according to the onset of the seizure (i.e. focal or generalized), the state of consciousness at the time of seizure (complete or impaired awareness), and on the symptoms that occur at the time (motor or otherwise) [11].

- Focal onset seizures (or partial seizures).This type of are more widespread than generalized seizures and happen in one or more certain locations in the brain. In some of the situations, they could spread to wider areas in the brain. They typically happen as a result of some injuries, but in the majority of the cases the specific origins are not known (idiopathic).
- Generalized onset seizures.

This type usually occurs in each of the brain sides. Those seizures are combined with loss of consciousness. Many types of those seizures are genetically based. People typically have normal neurologic functions between episodes.

- Unknown onset seizures.

In some of the cases, the seizure onset happens unobserved and it is difficult to determine if it started out as focal or generalized.

5. Seizure Detection Using Wearable Biosensors

In a clinical setting, Electro-Encephalo-Graphy (EEG) in combination with video monitoring is the optimal standard for detecting and diagnosing different neuro-logical cases including epilepsy. The capability for the automatic detection of seizures is crucial for different diagnostic, safety, and treatment causes. For example, the diagnosis of a patient that has epilepsy needs capturing ictal episodes with the use multi-channel EEG. Which could be time consuming and costly at the same time, and requires either a clinic stay or wearing ambulatory devices for a number of days [12].

With the continuous need from the patients to have a normal life while being observed for their physiological activities, wearable biomedical sensors are playing a significant part. To achieve this, new adhesive tape type wearable sensors enable sensor integrations [13].

There are several devices on the market which are designed for the detection of convulsive seizures with the use of extra-cerebral (non-EEG) signals. The majority of those devices use motion sensors due to the fact that convulsive movement is identical amongst patients, and therefore readily identifiable. On the other hand, there are no any wearable devices available for the detection of complicated partial seizures (CPS), as they are non-convulsive [14].

Designing and developing of wearable bio-sensor systems for monitoring health has captured a great deal of focus in the industry as well as in scientific association in the past few years. Primarily motivated by the increase in health-care expenses and powered by recent improvements in the technology of miniature bio-sensing devices. Such as wireless communications, smart textiles, and micro-electronics. The constant development concerning wearable sensor-based schemes will have a great potential in transforming the future of health-care by allowing ubiquitous monitoring of a patient's' health and permitting proactive management for personal health. Those systems may include different kinds of small physiologic sensors, transmission modules, and processing abilities, and therefore is capable of facilitating wearable low-cost unobtrusive results for constant day-round and anyplace health, also monitoring activity and mental status wearable-systems for the purpose of monitoring health could include different kinds of little sensors, implantable or wearable. Those bio-sensors can measure important physiologic parameters such as hearts rate, oxygen saturation, blood pressure, the temperature of body and skin, rate of respiration, electrocardiogram, and others. The measurements that were gained are being communicated by a wired or wireless linked to the centralized node, for instance, a personal digital assistant that is abbreviated as (PDA) or a micro-controller board that can afterward display the associated data on the user interface or transfers aggregated important signs to the health center. The previous depicts that a wearable system could include many different components such as: wireless communication modules and links, user interface, smart textiles, power supplies, sensors, wearable materials, software, control and processing units, decision-making algorithms and advanced data extraction [15].

In most countries in the Middle East, epileptic patients are feared to be known by the community because of their stigma because of social stigmatization. Therefore, it is necessary to find a way to detect cases of epilepsy before using modern technology [16].

6. Technologies Review

6.1 Researches Based on ECG

Most of epilepsy patients severed a Sudden Unexpected Death (SUD) due to neurogenic cardiac arrhythmias, for that one study suggest using Electrocardiograms (ECG) to monitor implantable loop recorder [17-18]. The method showed effective automatic detection of bradycardia and tachycardia.

Van Elmpt et al. (2006) [19] held an investigation which developed an algorithm based on the analysis of heart rate pattern by using ECG. This method can determine the heart rate patterns for the automatic detection of seizures in epilepsy patients.

Malarvili et al. (2009) [20] applied a method that contains a sequence of processes to monitor the epilepsy patients and used a supervised statistical classifier for HRV classification. The suggested method showed the sensitivity of HRV to the changes in the cardio regulatory system of the heart, which helped detecting seizures in patients with epilepsy.

Recent development in miniaturizing ultra-low power elements offer more intelligent wearable health monitors. The evolvement and evaluation of a wireless wearable electrocardiogram (ECG) monitor for the detection of epileptic seizures from variations in the cardiac rhythm is described. The ECG data is analyzed with the use of embedded algorithms: a robust beat-detection algorithm in combination with a real-time epileptic seizure detector [21].

An investigation has been held to test the ability of algorithm based on Electrocardiographic (EKG) - based seizure detection [22]. The results of EKG obtained a good quality that reached (91%), which was acceptable and promising using these for further analysis.

Behbahani et al. (2016) [23] also developed an algorithm based on heart rate analysis (HRV) analysis by predicting when the seizures may occur according to dynamical variations of ECG during the pre-ictal period. The presented method showed a potential for monitoring epileptic patients and improving their life quality. The general efficiency of the algorithm is an important step for clinical implementations.

The study of Shamim et al. (2016) [24] showed that using electrocardiogram (ECG) is one of the best ways for detecting epilepsy seizures, because it is comparatively easier compared to EEG. The results showed that the proposed algorithm detected epileptic seizures efficiently and compared to other models, it has been found to be more effective.

6.2. Researches based on ACM

Whereas, Nijsen et al. (2005) [25] used the visual analysis of 3-D accelerometer (ACM) and video/EEG recordings to predict epilepsy. The study results showed good results, 91% of the seizure with motor phenomena have been detected by using recorded data with these sensors and considered feasible for detecting seizures.

Cuppens et al. (2009) [2] suggested another detection systems applied with accelerometers ACM that are attached to wrists and ankles. This system used the development of an automatic detection algorithm. A detection system can solve the unsuitable use problem of EEG in the daily lives of patients, by using the development of an automatic detection algorithm. This resulted in an algorithm of sensitivity of up to 91.67% and accuracy of up to83.92%.

Another study used ACM with a different algorithm based on a Bayesian approach and found that the patient in standing up status promotes a good detection close to 90% of seizures and 25% of false alarms [26].

Schulc et al. (2011) [27] used a Wii Remote (R) which encased an accumulator and Bluetooth antenna and by using this device achieved 100% temporary sensitivity and specificity of over 88% while a positive predictive value ≥75% of false alarm ratio.

Another study used wireless ACM sensor with some physiological parameters, the false alarms were reduced with realizing a high level of detection [28].

Borujeny et al.(2013) [29] revealed the benefit of Wireless Sensor Networks (WSN) in the application of health monitoring to detect epilepsy seizures. This application can be used in a clinical environment or at the patient’s home. They used ACM in the portable device. This study obtained 85% sensitivity with 3FP, while another study got a high sensitivity of up to 90% and a low rate of false alarms (0.2/day) which used the same device with a different algorithm [30].

The study of Gheryani et al. (2017) [31] examined the Wireless Body Area Network (WBAN) to detect and identify seizures by the armband via a portable unit. The study used an inertial measurement unit and muscular activity acquisition sensors and these signals were transmitted from the used device.

Helmy & Helmy, (2015) [32] created the first mobile application which was called Seizario, This app offered a set of useful properties that help to provide assistance to epilepsy patients. Seizario app. are introduced a new accelerometer-based learning algorithms with elaborate finite-state-machines for the automatic detecting of grand mal seizures and harmful falls. Seizario’s detecting algorithms were designed to operate efficiently on mobiles and showed great potential with more than 95% detection rate for each of seizures and falls, with a minimum number of false alarms.

Whilst Ribeiro et al. (2016) [33] used the wearable device from ACM and embedded sensors by applying machine learning algorithms obtained KNN 99% and C4.5 & PART 98% and there was no valuable variation at the results between KNN, PART, and C4.5… An experiment showed that the user of wearable accelerometer sensor was found very efficiently with a limited number of false alarms (Tonpe et al., 2017) [34]. Also Kusmakar et al. (2017) [35] used wearable ACM sensors and their results showed that the sensitivity was 23% with 0:72=24h.

6.3. Researches based on mixed sensors (e.g. EDA, ACM, ECG, EMG, SpO2 video, audio skin, temperature and BR)

Poh M . (2011) [36] proposed an approach to monitor sympathetic nervous system activity during epileptic seizures with the use of a wearable sensor measuring electro-dermal activity (EDA) and ACM. The sensitivity of the method reached 94% tonic-clonic seizures with low rate of false alarms (<;1 per 24h).

Another study used a method to distinguish between ordinary movement and hyper motor seizures [37]. The ACM was applied in both wrist and ankle to get the dataset with synchronized video, audio, EEG, ECG, upper arm EMG and ACM data. The results were achieved 100% sensitivity and Positive Predictive Values PPV which ranged from 34.91% to 100%.

Other researchers monitored the human health by observing some physiological signals such as electrocardiogram (ECG), respiration and electromyography (EMG) signals. (Altini et al., 2011) [38] promised to use these findings to monitor the epilepsy seizure. Becq et al. (2011) [39] used motogrogram to detect different types of epilepsy seizures. by collecting data from triaxis accelerometers and magnetometers.

Conradsen et al. (2012) [30] applied an automatic multi-modal intelligent seizure acquisition (MISA) system to detect motor seizures from electromyography data. Their results showed that the MISA system has highly sensitive short detection latency and a low rate of false detection. Moreover, the results have shown that the multimodal detecting system is superior when compared with a uni-modal system. The proposed system has a potential to detect seizures according to multi-modal data.

A group of researchers developed a small medallion which is attached to the patient's neck with the use of a necklace type grip that consists of combining the spectral analysis method of anomalous currents with modern processors and mobile communications technology such as GPS and Bluetooth [40]. The device disassembles and amplifies only the primary brain currents, the ones of epileptic seizures, and warns the patient of possible danger The voice warning is used to connect the mobile to the patient with the use of a specified program, and to send an emergency text that the seizure reports are imminent and the current location with the use of GPS system for the emergency service, the doctor, and the National Center for Epilepsy Monitoring and Communication in advance.

In the recent years, cloud computing in the area of health-care started gaining importance. Pandey et al. (2012) [41] presented a model for on-line monitoring of the patient’s health with the use of cloud computing technology. Also, Internet of Healthcare Things (IoHT) became very essential in field healthcare. Abdulaziz A. Albesher (2019) [42] provides an overview of different aspects of IoT in healthcare.

Forkan et al. (2014) [43] presented a model which is based on a service-oriented model enabling real-time aided living services. It offers a flexible middle-ware layer hiding the complexity in managing sensor data from various types of sensors and contextual information as well.

Fortino et al. (2014) [44] presented a model which is based on combining the utilization of BSNs and cloud computing. It performs monitoring of assisted living by wearable sensors which transmit data to the cloud using a mobile.

A study presented a method which considered the first step in the direction of a reliable ambulatory monitoring system for epileptic seizures with or without motor activities (Helderg et al., 2015) [45]. A hierarchical classification method has been implemented for the detection of various types of epileptic seizures utilizing data from wearable sensors (EDA and ACM). They obtained a general sensitivity of up to 89.1% and a general accuracy of up to 93.1% was obtained with motor activity By using a k-nearest neighbor (KNN). Whereas with no motor activity the sensitivity reached a percentage of 97.1% and the accuracy reached 92.9%

Single seizure detecting methods have the problem of high false positive rate Cogan et al,.2015) [46]. A group of signals that may be easily monitored by a wrist -worn device have been found and which produced a distinctive pattern during the time of seizures for patients in epilepsy monitoring unit (EMU) A group of five bio-signals have been chosen, which may be monitored at the wrist and are known or believed to be affected by seizures they are: heart rate (HR), arterial oxygenation (SpO2), accelero-metry (ACC), electrodermal activity (EDA) and temperature (TEMP). Several researchers have notices great HR changes at the beginning of some kinds of seizures; they needed to collect more data from epileptic patients in a day by day basis, in addition to EMU settings prior to being confident of having found a seizure detection method beneficial for a wide range of people. Data collection is continuing, so we will have opportunity to further evaluate our findings. We expect that more sophisticated methodologies mentioned in Subsection.

Sasikala et al. 2016 [47] proposed the design, development and validation of a wrist-based wearable device that can not only detect seizures efficiently, but over time can also predict a seizure before the actual onset. The results concluded that seizure detection would primarily involve the measurement of the following parameters: (i) motion , (ii) electro-dermal activity (EDA), (iii) skin temperature, and (iv) heart rate.

A new multi criteria decision system (MCDS) was proposed by Ahmed et al. (2017) [48], they obtained a precision of 96% with 90% recall over the synthetic data. In this study, they used the parameters of Electro-cardiograph (ECG), electrodermal activity (EDA), body motion and breathing rate (BR).

Different physical factors were applied to transmit the signals of seizures to a cell phone device Ramirez-Alaminos et al. (2017) [49], these physical factors are temperature, heart rate, and extreme motion. The authors examined different temperature values, heartbeats and tested the battery life of the used system.

Audio identification was applied on a group of epilepsy patient in the Netherlands (De Bruijine at al., 2009) [50]. The used system was comprised of three stages; this system depended on a theory of Bayesian to classify the characteristics vector.

A proposal of a non-intrusive video analysis system for the patient's body parts movement analysis in Epilepsy Monitoring Unit is present by (Mandal et al.2012) [51]. The system utilized skin colour modeling, head/face posture template matching and facial detection for the analysis and quantification of the head motions. Epileptic patients' heads have been analyzed in a holistic way for inferring seizures and usual arbitrary motions. The patient is not required to wear any specific clothes, markers or sensors, therefore it is entirely non-intrusive.

Saleh M. Gaber et al. (2017) [52] depended on the EEG Network on Chip (NoC) concept to display and predict unstable brain waves. This prevents the risks of seizure during the driving and childhood stage.

Table 1 provided a comprehensive summary of the state-of-the-art literature on epileptic seizure detection including the methods and algorithms used and the results obtained.

Table 1.1,
The review of different method, Algorithm and results for the detection of seizures. ECG= Electrocardiography , EEG= Electroencephalography , HRV=Heart Rate Viability, ACM= Accelerometer , KNN= K-Near Neighbors, EDA= Electro-dermal activity, EMG= Electromyography, SpO2=Arterial Oxygenation , TEMP= Temperature, NoC=Network on Chip , FAR=False Alarm Rate , FDR= False Discovery Rate, FP= False Positive, PPV= Positive Predictive Value, SNE= Sensitivity, SVDD=support vector data description , SVDD=support vector data description, PPV= postivie predictive value , FDR= false detection rate , H= hours , Avg= Average, FPR= false

No.	Article	method	Algorithm	Results
1	Rugg-Gunn et al. (2004)[16]	ECG	Device implantable loop recorders	Detected the beat per min of HR in seizure patients
2	Nijsen et al. (2005)[25]	ACM & video/EEG	Visual inspection of the data	48% of seizures were detected by ACM. 91% of the seizures with motor phenomena were detected
3	Van Elmpt et al. (2006)[19]	ECG	Two Algorithm were used: i. Curve-fitting used to characterize the HR patterns. ii. A moving median filter to detect the change of HR	More than 10seizures of 2 patients out of 3 showed a sensitivity 90%
No.	**Article**	**method**	**Algorithm**	**Results**
4	De Bruijne et al. (2009)[50]	audio signals	Bayesian decision theory	The sensitivity 95 to 98% and specificity 72 to 97% , depending on sound type PPV 2-40%
5	Malarvili et al. (2009)[20]	ECG	Used the Heart rate viability (HRV) to detect newborn seizures	The Sensitivity 85.7% and 84.6% specificity
6	Cuppens et al. (2009)[2]	ACM	development of an **automatic detection algorithm**	Sensitivity of 91.67% and a specificity of 83.92%.
7	Poh M et al. (2010)[53]	EDA	Novel method for monitoring sympathetic nervous system	
8	Jallon (2010)[26]	ACM	based on a Bayesian approach using hidden Markov models	Able to find out 90% of seizures when FAR are 25% of alarms.
9	Poh, M. (2011)[36]	ACM & EDA	Monitoring sympathetic nervous system activity	The sensitivity of the method reached 94% tonic-clonic seizures with low rate of false alarms (<;1 per 24h).
10	Van de Vel et al. (2011)[37]	ACM	Work on algorithm for distinguishing between normal movement and hypermotor seizures	The results were achieved 100% sensitivity and Positive Predictive Values PPV ranged from 34.91% to 100%.

11	Schulc et al. (2011)[27]	(ACM)-based	Dives Wii Remote®	Achieved 100% temporary sensitivity and specificity of over 88% while a positive predictive value ≥75% of false alarm ratio.
12	Becq et al. (2011)[39]	ACM & magnetometers	Artificial neural networks.	Sensitivity 90%, FDR per night 0.7
13	Altini et al. (2011)[38]	ECG , respiration and EMG signals	Low-power, multi-modal, wearable sensor platform	The author promised to use these finding to monitor the epilepsy seizure
14	Conradsen et al. (2012)[30]	EMG , ACM & gyro	Automatic multi-modal intelligent seizure acquisition (MISA)	Sensitive short detection latency and low rate of false detection. A 100% sensitivity was observed with FDR per 0h and mean response 0.7s
15	Mandal et al. (2012)[51]	Video	The system utilized skin colour modeling, by using SMV to classify the seizure and normal movement	This method limited use in hospital to monitor the statues of the epilepsy patients
16	Popescu et al. (2013)[40]	Small medallion which is attached to the patient's neck with the use of a necklace type grip	Method of spectral analysis of abnormal cerebral currents with modern microprocessors and mobile telecommunication technologies	-
17	Conradsen et al. (2012)[30]	ACM		High sensitivity of up to 90% and a low rate of false alarms (0.2/day)
18	Borujeny et al. (2013)[29]	ACM	Artificial Neural Network and K Nearest-Neighbor	Sensitivity85%,3FP
19	Massé et al. (2013)[21]	ECG	A robust beat-detection algorithm in combination with a real-time epileptic seizure detector	The system obtained 75% of sensitivity and 70.4%specificity.
20	Osorio et al. (2014)[22]	EKG-based	Threshold	EKG obtained a good quality that reached (91%) a total of 241 out of 266 clinical seizures.
21	Salem et al. (2014)[28]	ACM	We use the exponentially weighted moving average algorithm	Highly level detection accuracy in against temporal variation.
22	Helmy et al. (2015)[32]	ACM	Seizario app depending on ACM in smartphone	more than 95% detection rate for each of seizures and falls, with a minimum number of false alarms

No.	Article	method	Algorithm	Results
23	Helderg et al. (2015)[45]	EDA and ACC	A hierarchical classification method has been implemented, by using a k-nearest neighbor (kNN) classified.	obtained a general sensitivity with **Motor activity** : up to 89.1% and a general accuracy of up to 93.1% was obtained .Whereas with **No-motor activity** : the sensitivity reached 97.1% and the accuracy reached 92.9%
24	Cogan et al. (2015)[14]	Temp, HR, ACM, SpO2 & EDA	Versatile bio-signal activity recognition algorithm in which the physician received the seizure response time electronically	observed the change in HR↑ ⇒ SpO2 ↓ ⇒ EDA↑ by special algorithm in six out of 10 patients
25	Shamim et al. (2016)[24]	ECG	by setting threshold and by using linear support vector machine	Obtained Accuracy 94.2%, SNE 84.1% and specificity 94.5%

26	Behbahani et al. (2016)[23]	ECG	The algorithm based on heart rate Analysis (HRV) analysis by prediction the occurrence of seizures based on dynamic changes of ECG	Result showed an AVG SNE of 78.59% and AVG FPR of 0.21/h false prediction rate
27	Sasikala et al. (2016)[47]	ACM ,EDA, HR & skin temperature	The paper proposes to design	/
28	Ribeiro et al. (2016)[33]	ACM and embedded sensors	Machine Learning	obtained kNN 99% and C4.5 & PART 98% and there was no valuable variation at the results between kNN, PART, and C4.5
29	Kusmakar et al. (2017)[35]	ACM	Using machine learning approach kernelized support vector data description (SVDD)	results showed that the sensitivity 95:23% with 0:72=24h.
30	Ahmed et al. (2017)[49]	ECG , EDA & BR	A multi criteria decision system (MCDS)	obtained a precision 96% with 90% recall over the synthetic data
31	Gheryani et al. (2017)[31]	ACM, angular velocity (Gyro) and EMGgyroscope	Approach starts with Derivation of the root mean square for ACM and Gyro, followed by the normalization of whole signals in the same range and aggregation to a signal.	The result showed 100% of sensitivity with 5% of FAR
32	Mohammad Saleh et al. (2017)[52]	Network on Chip (NoC) ECG		the result present the EEG of NoC chip depends on the design of network , WLAN protocols , number of sensors and the packet size over the network
33	Ramirez-Alaminos et al. (2017)[49]	Temp , HR and vibration sensor	By using device has Bluetooth module to connected wireless with smart phone	depending on the parameter that used in the device give sign when it get over the threshold and its depended on the epilepsy type
34	Onorati et al. (2017)[54]	ACM and EDA	Used 3 different data of wristbands and test two new machine learning classifiers	Results of classifier(III) showed that the sensitivity 94.55% and FAR 0.2 events/day
35	Fürbass et al. (2017)[55]	EEG ,ECG and EMG	Automatic multimodal detection	Obtained **86%** sensitivity with Avg of false detection 12.8 in 24h
36	Sopic et al. (2018)[56]	ECG	**E-Glass** using 4 EEG electrodes	The Sensitivity 93.80% and 93.37% specificity
37	Elger et al. (2018)[57]	Heart Rate	Low Complex Novelty classifier detection	Results showed that sensitivity **77.6 %** and Avg of FAR **2.56** false alarms per night
38	Geertsema et al. (2018)[58]	Video	Analyzing of Oscillatory motion pattern and set threshold	Obtained **97%** sensitivity with median of false alarms **0.78 per night**

6.4 Commercial Devices

There are different technologies developed for tracking seizure information. The developed devices and mobile applications will becomes a tool to help patients, families, and clinicians capture seizure data**.** The table 1.2 shows the commercial device with their details.

Table 1.2
Review of different commercial devices

Commercial device	Used apparatus	Detection Method	Website
Advance Brain Monitoring	EEG with different NO. of channels	Wireless EEG	www.advancebrainmonitring.com
Emfit	ACM, bed motion sensor	Wireless transmission	www.emfit.com
Affectiva	Wrist-band	Bio-sensor for measuring EDA ,ACM and body TEMP	www.affectiva.com
EpDetect	Mobile Application (base on ACM of mobile)	Wireless transmission : sending SMS ,movement detection and GPS position location	www.epdetect.com
Smart belt	Chest-belt ,wearable	Respiration sensor and EDA sensor	.
Movisens	Electrodes	Raw signal of EDA , ACM TEMP and air pressure	www.movisens.com
Epi Watcher	ACM , bed motion sensor	Wireless alarm bell, wired version integrated and message to responsible person	www.vahlkamp.nl
Mio Alpha Streapless	Watch	Heart rate monitor	www.alphaheartrate.com
ADLX330	Wrist-band	ACM	www.sparkfun.com
Pulseguard	Wrist-band	Heart rate changing	www.pulseguard.org
SensAlert200	Bed motion sensor	Detecting unusual movement	www.sensorium.co.uk
SAMI-sleep activity monitor	Video-Camera Night vision monitoring	Detecting unusual movement and send alarms and video records	www.samialert.com
Baby-Ping	Video-Camera Night vision monitoring with voice	Wi-Fi connection	www.babyping.com

7. Discussion

The epilepsy seizure detection and alert system is very important and urgent for saving the patient's life. Many social organizations encourage researchers to design such a system to make a penitent's life more safer and prevent case of Sudden Unexpected Death in Epilepsy (SUDEP).

This review paper gives a useful overview of the spectrum of non-EEG body signals which are related to seizures. The review shows that these body signals (such as Electromyography (EMG), Heart rate (HR), oxygen level (SpO2), accelerometer (ACM) and eta) individually fail to detect seizures, so the effective seizure system is based on multi-body signals.

In spite of if seizure alerts happen or not, these systems enhances the patient monitoring process by collecting the statistical date about the number of seizures during the period of time and the time between seizures. This information is very important for the diagnosti purpose. Finally, the paper gives an up to date list of some available seizures detection commercial devices.

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استعراض أنظمة الكشف القابلة للارتداء لنوبات الصرع

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الخلاصة

يعرف نوبة الصرع بأنه محفوف بالمخاطر بسبب حدوث عشوائي وقد يؤدي إلى الوفاة في بعض الحالات. يتضمن نظام نوبات الصرع التقليدي للمراقبة باستخدام فيديو / تخطيط الدماغ (EEG) ، وهو أمر مزعج بالنسبة للمريض ، حيث يتم ربط أقطاب EEG برأس المريض. ومن الضرورة مساعدة المريض وتنبيهه قبل حدوث النوبة وهي أحد المشكلات التي يلفت انتباه الباحثين والمصممين. يتوفر طيف واسع من أنظمة الكشف عن النوبات المحمولة المتاحة في الأسواق والتي تستند في تصميمها إلى إشارات غير إشارة .EEG
الهدف من هذه المقالة هو توفير دراسة لاستعراض المقالات الأخيرة التي تغطي العديد من القضايا في مجال تصميم جهاز الكشف عن نوبة في الوقت الحقيقي المحمولة مثل إشارات الجسم التي يمكن قياسها ، وأساليب الخوارزمية ، ونظام كشف جيد متاح تجارياً.
نتيجة لذلك ، توضح عملية الأستعراض أن هناك العديد من المقالات البحثية التي تغطي أنظمة اكتشاف نوبات يمكن ارتداؤها والتي تستند إلى إشارات الجسم. أكثر أنظمة المراقبة والاكتشاف فعالية هي النظام الذي يستخدم إشارات متعددة الأجسام ، مريحة ، منخفضة الطاقة.