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Connected health to monitor and treat concussion
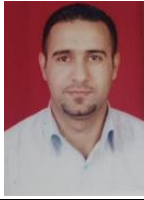
Abstract:

Concussion is a serious condition that needs special attention to detect, diagnose, and manage. Early detection and good management of concussion is the backbone of mitigating the effect of it. Telehealth that is a mixture of technology and healthcare offers a solution to achieve that. It allows for early detection of concussion even at rural places by incorporating a sensor to sport tools which detects the impact that may cause concussion by measuring the linear and angular acceleration. Some companies offer gadgets that enable health professional to perform tests to diagnose the condition remotely without having to be at the same place. These gadgets also allow for better management of patients who suffer from concussion and help in adopting the return to play decision.In this article, I want to explore some recent sensors and devices that use the connected health solution to address the problems associated with this condition.

Keywords: Concussion, telehealth, connected health solution, continuous remote monitoring, linear and angular acceleration.

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Introduction:

Concussion is the most common injury among athletes from different types of sport such as football, basketball, and cricket (Veena et al., 2014). It affects also part of the community who experience vehicle or bike accidents. Young children especially who are involved in sport activities have the highest concussion rate among all age groups, because their heads are disproportionately large compared to the rest of their body(The concussion place, 2013). In addition to that, high percentage of people with concussion do not experience any symptoms and do not recognize the incidence of concussion (FIT force impact technologies, 2015). This makes concussion a serious condition that needs special attention to detect, diagnose, and manage it correctly. Telehealth which incorporates the technology into the healthcare system offers some promising solutions to early detect the incidence of injury. As well as that, it also allows for better diagnosis and management of patient who suffer from concussion. In this article, I want to explore some recent sensors and devices that use the connected health solution to address the problems associated with this condition.

Definition and overview of concussion:

A concussion is a traumatic brain injury with temporary loss of brain function, typically induced by either direct blow to the head, or when the head and upper body are violently shaken due to falls, motor vehicle accidents, sporting accidents and wrongful firearms discharges,usually causing a temporary neurological impairment which lead to physical (e.g., headaches, nausea), emotional (e.g., irritability, sadness), cognitive (e.g., difficulty with concentration or memory), and maintenance (e.g., sleep disturbances, changes in appetite or energy levels) symptoms.Human brain is surrounded by cerebrospinal fluid, cushioning the brain within the skull and serving as a shock absorber for minor impacts. However, a sudden acceleration or deceleration of the head causes a brain injury. The impact rapidly accelerates the head, making the brain bump into the interior of the skullat the point of impact(i.e., the coup). When the head decelerates and stops its motion, the brain then strikes the opposite side of the inner wall of the skull (i.e., the contrecoup). Moreover, the rotational movements of the brain inside the calvaria, causing shearing and straining of brain tissues, is another scenario that can lead to a concussion (Scientific American, 1999).

Concussion causes temporary symptoms including headaches, dizziness, confusion, vomiting, depression, disturbed sleep, moodiness, and amnesia. However, it is recently revealed that a concussion is associated with long term effects lasting decades, especially in those who experienced a second concussion before signs and symptoms of a first concussion have resolved. A recent study showed that athletes who experienced head trauma 30 years ago had symptoms similar to those of earlyParkinson's disease - as well as memory and attention deficits in comparison to healthy athletes of the same age (MNT, 2013).

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High percentage of Hospital admissions together with lost work time and early retirement due to concussion lead to an estimated economic cost of more than \$12 billion per year worldwide. The economic burden of concussion increases when it causes long term effects lasting decades especially among young children who are the leaders of the future. Young children have the highest concussion rate among all age groups, because their heads are disproportionately large compared to the rest of their body. The second leading cause of concussion among those young children is sport, resulting in recognizing sport-related concussion as a major public health concern in the United States and worldwide. Of all sports, football has the highest absolute number of concussions each year because of the large volume of participants at the high school and collegiate levels (The concussion place, 2013).

Required patient data to detect/diagnose/manage concussion:

Patient's Historyand baseline: concussion management requires considering patient's past concussion exposure, medical history and family history to create a more complete picture of his health. In addition, a baseline concussion test by measuring reaction Time, memory Capacity, speed of mental processing, and executive functioning of the brain prior to a sport season is an important piece to concussion management. This test is repeated In the event of a concussion is received during the season,yielding comparative scores from before and after the injury. This test is important because each concussion is uniqueand it is important to treat individuals on a case-by-case basis (Sports concussion institute, 2008).

Neurological examination: The application of neurological (NP) testing in concussion has been shown to be of clinical value and contributes significant information in concussion evaluation(McCrory et al., 2013). Atypical neurological exam involves assessment of the cranial nerves, the nerves that exit directly from the brain and brain stem. This includes visual acuity screening, muscle strength assessment, sensory exam performed on the face and all 4 extremities, upper and lower body reflexes and tests of balance/coordination.Visual screening includes checking the responsiveness of the pupils, peripheral vision, and eye movements to reveal any abnormal pupillary response and sudden unexplained change in visual fields caused by concussive injury (Concussion connection, 2014).

Fourthconsensus statement on concussionin sport and recent studies considered balance testing a useful tool for objectively assessing neurological functioning and a validand reliable addition to the assessment of athletes with concussive injury, especially where signs orsymptoms indicate a balance disorders (McCrory et al., 2013) (McCrea et al., 2013).Balance error scoring system (BESS) is the most commonlow-technology balance assessment which can be performed easily using a piece of foam. However, a computerized dynamic posturography is needed to perform the Sensory Organization Test (SOT), which is the most commonly used high-technology balance assessment. It measure how much a person sways when standing in certain position on a

force plate. Measurable balance disorders can be detected up to 3 days after injury using BESS and 30 days after injury using SOT (Furmanet al., 2013). Testing of hearing, smell or asking patient to whistle, smile and clench his teeth are other neurological tests that can add significant information in concussion evaluation (Concussion connection, 2014).

Cognitive testing: several cognitive tests such as Wechsler Digit Span, Stroop Color Word Test, and Wechsler Letter Number Sequencing Test are required to identify cognitive deficits resultingfrom concussion. They are designed to assess various domains of cognitive functioning including working memory, short-term memory, concentration, attention and reaction time (Straus, 2015). Imaging tests by using a series of X-rays to obtain cross-sectional images of patient skull and brain (CT scan) or using a powerful magnets and radio waves to produce detailed images of the brain (MRI imaging) may be recommended to assess the brain right after injury and to diagnose complications that may occur after a concussion (Mayo clinic, 2014).

Commercial systems on the market for concussion management:

Shockbox sport Helmet sensors: the system is composed of a sensor attached to player's helmet. When a player experience a significant head impact above a preselected magnitude that may lead to a concussion, the sensor will immediately transfer impact data using wireless Bluetooth technology to Apple, Android, or Blackberry smartphone which is held by coach or Athletic Trainers located within up to 100 meter distance away from player. This smartphone has an application that allows for recording player history, player's baseline data, setting sensor setting and impact thresholds, and forwarding data as Excel file via email or SMS. The application also contains a player assessment module in a form of questionnaireand checklist to help coach or parents to record player signs and symptoms (Shockbox sport helmet sensors, 2015).
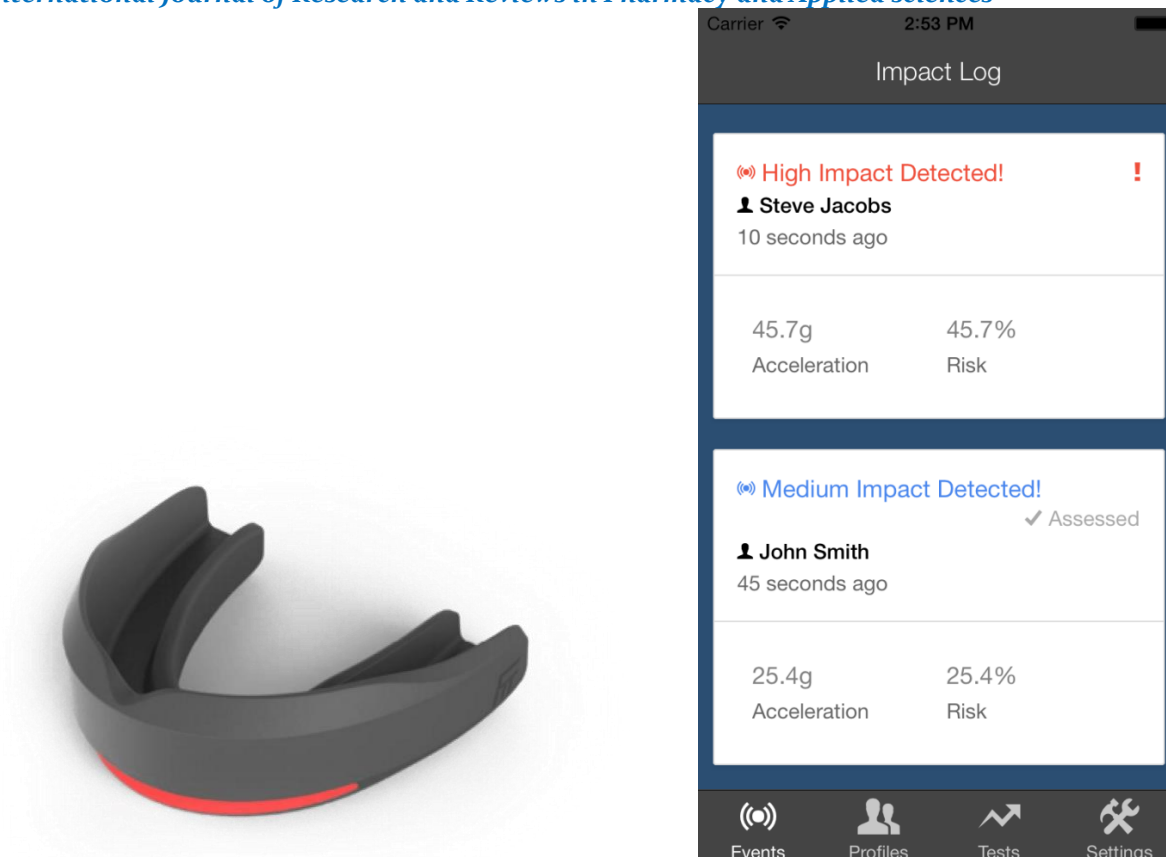
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Figure 1: a) FITGuard mouthgaurd b) Mobile application for detection and management of COPD (FIT force impact technologies, 2015).

FITGuard mouthguard: some clinical studies have revealed that concussion prediction based on measurement of both linear and angular acceleration together is more accurate in than that based on one of the measurements independent of the other (Yoganandan et al., 2005). Other studies have shown the superiority of positioning of accelerator sensor in mouthguard to positioning on a helmet or a chinstrap (Camarillo et al., 2013). Force Impact Technology, the leader of the emerging 'Athletic-wearable technology' sector, exploits these findings to introduce FITGuard mouthguard, shown in figure 1a, that has a built in accelerometer and gyroscope to measure both linear and angular acceleration required to detect the impact that may cause concussion. Figure 1b show that the measured linear and angular acceleration as well as the duration of the impact are transmitted to smartphonevia Bluetooth technology and then to a centralized database (FIT force impact technologies, 2015).

X2ICE Integrated concussion examination: As displayed in figure 2, it is a tablet that incorporate iOS and windows application to examine and manage athletes who are susceptible to concussion by integrating their baseline and post-injury assessments. This system allow for registering players' historical and current examination information. Furthermore it incorporates several

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exam modules including cognitive performance, short term memory, durable memory, balance and coordination, situational orientation, baseline comparison, and other modules that act as integral

Figure2: X2-ICE Integrated Concussion Examination(X2 biosystems, 2013).

unit to monitor player's neurological and cognitive data progressively to evaluate him and document any warning signs of concussion. As well as that, it is cloud based, "Anytime Anywhere" Access to data system that transmits data wirelessly using X2Net wireless protocol (X2 biosystems, 2013).

Ongoing research on devices:

Stanford researchers are examining mouthguard device that was previously developed by X2 Biosystem to allow for better understanding of the force imparted on the head during an impact. 500 impact events were recorded using mouthguard during regular sporting event, two of them was diagnosed as concussion. Preliminary data analysis revealed that concussion prediction is correlated more with rotational acceleration than linear acceleration. It is also showed that measurement recorded with six degree of freedom was more predictive to concussion than those with three degree of freedom. Further research is needed for full understanding the combination of accelerations by using large size sample. (Stanford news, 2015).

University of Miami Miller School of medicine and medical equipment manufacturer Neuro Kinetics Inc. are granted $500,000 by the National football League to evaluate the efficacy of a novel diagnostic device for early and accurate detection of concussion. This device is portable, allowing for easily using outside hospitals such as at a sport site. In addition, it incorporate eye tracking and stimulus display to assess some of the more common symptoms of concussion

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including dizziness and balance problems. This initiative aims to have a diagnostic tool with the ability to accelerate concussion detection and diagnosis at a sport avenue (University of Miami health system, 2015).

Regulations and guidelines of sport related concussion:

The combined effect of several years of research in clinical medicine, athletic training, sport medicine, and sports science has led to developing strategies, policies, regulations, and laws intended to guarantee the prevention and optimal management of the condition.Most of these laws and regulations revolve around achieving three action steps:

1. Raising the awareness and knowledge of Athletes, coaches and guardiansregarding several aspects including the definition of the condition, its signs and symptoms that differentiate it from other conditions, proactive steps to prevent it, and the required on field actionsto protect patient with suspected concussion and allow for a quick and full recovery. Using information sheets as well as trainingand educational programs, the involved people will be able to recognize all these aspects. Information sheets that is customized for athletes, coaches, parents, and school professionals can result in an appreciable value. Moreover, other recourses such as online training courses, Facebook pages, videos and podcasts can play part in achieving this goal (Centers for disease control and prevention, 2015).

2. Coaches' formal concussion training is imposed by common law or statute in most countries at specific time intervals. In addition, parents are entitled to sign a form admitting the receipt of information regarding concussion (Graham et al., 2014).Based on the gained knowledge about concussion discussed earlier, it is required to take any athlete with suspected concussion out of the game. It is worth mentioning also that changing the games rules is required to prevent penalizing the player's team if one has a suspected concussion (McCrory et al., 2013).

3. Return to play decision must be taken by a licensed health care professional guided by a group of experts in sport medicine and neuropsychology, but not before a duration of at least 24 hours. According to the 3rd International Conference on Concussion in Sport held in Zurich, November 2008, it is recommended to follow a protocol of several steps before returning to play. First and foremost, cognitive and physical rest is needed to allow for recovery. Following that, a step up increase in the physical activity starting with light exercises and slowly progress to the intermediate and then to full contact practice should be followed until enabling the athlete to regain his functional skills. Finally, a return to play permission should be supported by medical clearance (McCrory et al., 2013).

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Aside from sport laws adopted by some countries to prevent, manage, and early detect and diagnose players with suspected concussion, some schools and sport league embrace additional strategies and policies including: (a) readiness for emergency cases by establishing a plan containing information required to contact emergency medical responders and centers, and to follow several steps in case of emergency.(b) Promoting player's safety by trying to reduce contact between players if possible, changing play rules to guarantee a play free of injuries, and ensuring the safety and propriety of sport equipment according to company recommendations. (c) Building scientific approach in dealing with incidence of concussion by reporting the case to study the reasons behind it and know the number of occurrences (Graham et al., 2014).

Connected health for management of concussion:

The management of people who suffer from concussion or at high susceptibility to future concussion encounters several problems that need to be addressed. One problem is that health care facilities distributed throughout any country lack consulting specialists who can deal with such condition, as well as that it is impractical to enroll such experts in each medical facility. Another problem is the inability of people in some rural or geographically isolated places to access health care resources. Addressing these problems is possible with the contribution of connected health solutions that we are about to examine briefly in this section.

First and foremost, educational applications can offer invaluable resources for patients, couches, guardians, and medical practitioners. These educational mobile applications can be in the form of head up brochures that educate the involved people about the concussion, its signs and symptoms, and contact information necessary to acquire the required help. Theyprovides educational materials accessible even by a non-medical personnel to reduce the gap in concussion education. It also allows involved people to record data on concussion incident by answering several questions such as asking about the strength of the blow, the place and cause of the blow, and noticed signs and symptoms. Following that, if concussion is suspected, the mobile application will prompt the involved person whether a couch or guardian about the condition, asking him to follow some recommendations and advices such as asking to remove the athlete from the play, instructing user about how to order an ambulance in case of emergency, learning the user about how to observe and monitor the player during the next 24 hours of blow, etc. to protect the player (Lench, 2013).

Some applications allow the user to contact a practitioner or licensed medical specialist who can assess the player situation based on acquired data and give them required instructions and recommendations step by step to improve the quality of dealing with this medical case. Educational mobile application can benefit practitioner by keeping them up to date with the latest medical information, guidance, and findings regarding concussion. Rural practitioner can also

contact medical specialist for consultation in diagnosis and management of the condition (Lench, 2013).

Remote medical sensors and devices are beneficial in detecting, diagnosis, and management of concussion. Since high percentage of athletes (47%) proceed playing without recognizing the incidence of concussion, it is necessary that the player wears protective equipment supplied with sensors to allow for early detection of concussion (Yoganandan et al., 2005).

One example of these remote detection equipment is mouthgaurd. It includes a sensor that detect the both linear and angular acceleration. When a predetermined threshold value of acceleration, which is related to the likelihood of concussion incidence, is exceeded, the LEDs of the mouthgaurd will change colors. This visual display alongside with alarming signal transmitted wirelessly via Bluetooth technology to smartphone alert the couch or guardian of possible head injury. All data about the impact is transferred via Bluetooth to nearby smartphone which includes an application that automatically detect the possible injury and transmits patient data to a centralized database. This allows clinician or medical specialist to interpret patient data including patient history, severity of injury, signs and symptoms, etc. this medical expert can also contact the patient remotely to ask him several diagnosing questions or ask him to perform several medical tests such as balance test, visual test, hearing test, memory test or other tests in any nearby medical facility to enable the medical expert to diagnose the patient correctly and proceed to the required treatment (FIT force impact technologies, 2015).

The same principle of connected health solution discussed earlier can be applied using sport helmet that contains acceleration sensor and connected wirelessly with smartphone of couches or parents. Another example of connected health solution to concussion is the using of an integrated system of concussion examination by means of tablet device. This device are designed to accommodate players' history and baseline data. In addition, it include modules to perform several tests needed for assessing athlete with suspected concussion including cognitive performance test, short term memory, durable memory, balance/coordination, and situational orientation tests. Furthermore, it contains features that allow for return to play management. This system is connected wirelessly to a centralized database to make all data accessible by medical staff in different health care facilities. This enables medical specialist to effectively access all needed information for a better assessing and treatment of the patient (X2 biosystems, 2013).

Challenges with concussion connected health solution:

There are several concerns and challenges regarding using the connected health in the management of concussion. These challenges are not far away from the challenges of using connected health in any medical field. Firstly, breaching the confidentiality that arises from using the internet for transferring patient data. Secondly, training of concerned people and medical staff is a serious concern, because it require an expensive and time consuming procedure.

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Finally, there is some concerns about the lack of research regarding the efficacy, reliability, and validity of such solutions in mitigating the risk of concussion. These and other challenges poses a serious risk that should be treated correctly to avoid it.

Conclusion:

Overall, early detection and good management of concussion is the backbone of mitigating the effect of it. Telehealth that is a mixture of technology and healthcare offers a solution to achieve that. It allows for early detection of concussion even at rural places by incorporating a sensor to sport tools which detects the impact that may cause concussion by measuring the linear and angular acceleration. Some companies offer gadgets that enable health professional to perform tests to diagnose the condition remotely without having to be at the same place. These gadgets also allow for better management of patients who suffer from concussion and help in adopting the return to play decision.

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