REVIEW OF HEAD IMPACT SENSOR ON BIOMECHANICS JOURNAL OF FOOTBALL HEADING

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ABSTRACT

Heading skills put football players at risk of head injury. Such impacts can cause fractures, eye injuries or concussions. Measuring head impact in sports can help athletes understand the biomechanics of brain injury & prevent occurring of concussions. The use of head impact sensor is as an alternative in measuring head impact exposure. This research purpose was reviewed the use of head impact sensors in the biomechanics journal of football headings. Research was used a systematic review to perform data searches through electronic databases such as google scholar and science direct. The search was carried out by writing the keywords "head football", " biomechanics heading football", "head impact sensor" from 2016-2021. The review results stated that 12 journals (60%) used the X2 Biosystems XPatch & 8 journals (40%) used the Triax Smart Impact Monitor. The availability of head impact sensor data used to measure head impact during football heading activities is the X2 Biosystems XPatch or Triax Smart Impact Monitor. The device using because the placement for football players is more suitable to use a head impact sensor without being mounted on a helmet.

Keywords: Review, Head Impact Sensor, Biomechanics

INTRODUCTION

Exercise and sport were considered as healthy activities, both of which can lead to physical injury. The athlete's severe physical injury is head injury because the brain controls mental and physical performance. Head injuries can occur as a result of falling or hitting players against each other or by the ground or by an obstacle such as a goal. The incidence of injury can occur in the football. Football is considered a contact sport and is like an impact sport which has consequences through both greater skill levels and physical demands during training and matches (Mainer, Lozano, Duarte, Llorente & Moliner, 2021). Football is most popular sport in the world, and is referred to as a contact sport in which football players are very vulnerable to various types of head and neck injuries to concussion injuries (Cassoudesalle, Bildet, Petit & Dehail, 2020). Injuries in football including of body contact with players, wrong basic technique, excessive training load, fatigue, lack of warm-up or cool-down, and improper sports equipment. Injury is damage to the body produced by the exchange of energy which has a relatively sudden and visible effect. An injury is a bruise or wound, or a dislocation of a muscle, joint or bone caused by an accident, impact or excessive movement, so that the muscle, bone, or joint cannot bear the load or perform its job. Sports injury is damage that occurs to the body that is sustained from participation in sports (Reiner, 2020). Injuries in the sports are damage to tissues (soft or hard), whether muscles, bones, or joints caused by technical errors, collisions, or activities that exceed the training load limit which can cause pain or soreness and/or the result of overtraining in providing loads are too heavy, so that the muscles, bones, or joints are no longer in an anatomical state or position.

The injury locations in football are head/face, shoulder/clavicle, elbow, hand/wrist, abdomen, chest, cervical spine, dorsal spine, lumbar spine, groynes, quadriceps, hamstring,

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knee, calf, ankle, and foot (Sghir et al., 2021). Football is a unique sport where players are allowed to use all parts of the body except their hands to control and pass the ball to teammates. The head is also used during passes and even for scoring goals, this is called a heading. Heading skills put football players at risk of head injury. Unintentional heading, which causes the highest heading acceleration and the result of collisions with balls that were not anticipated or contact player-to-player or player-to-land, which carries the greatest risk potential (Becker et al., 2021). Such impacts can cause fractures, eye injuries or concussions.

Heading is one of the basic techniques in the football. Heading can be a way to score goals against goal which is quite difficult for a goalkeeper to catch. Heading technique in football is a technique that uses the head to pass the ball to a teammate or score a goal by heading the ball into the opponent's goal. There are several principles of heading techniques that need to be considered by every football player, where one of them is doing a heading using the forehead and keeping the eyes open, not using the crown. To perform a hard heading, the head can be pulled back before doing the heading. During the straight-on header, the trunk is first hyperextended and the chin is directed towards the chest, then the athlete comes to make contact with the ball, the trunk is moved into flexion (Caccese & Kaminski, 2016). Higher neck strength is a key factor in reducing the severity of head impact because it can decrease linear and rotational acceleration during football headings (Peek, Elliott & Orr, 2020). This means emphasizing the importance of contracting the neck muscles to stabilize the head while doing football headings. If the head is not ready, it will increase the mass of ball contact and increase the risk of injury due to the force of the ball hitting the head (Worsey et al., 2020).

Advances in technology, make it easier for someone to access various kinds of information through electronic devices. The development and advancement of sports technology is indispensable for the advancement of sports achievement. Technological progress is in accordance with advances in science. Every innovation is created to provide positive benefits for sports players, provide many conveniences, and as a new way of doing activities. The development of sensor technology provides strong support for the coach's decision to develop an exercise program so that it can improve athlete movement, effectively reduce injuries, and increase sports competitiveness (Zhao & Chen, 2020). Measuring of head impact in sports can help sports players understand the biomechanics of brain injury and as a prevention of concussions. Several researchers have used sensor systems to measure exposure to head impact and concussions. A wearable sensor system has been developed to record motion with a precise time stamp for synchronizing multiple time series data. Movement in sports action is a very fast and high impact (Ishida, 2020). The sensor system for the head is called a head impact sensor. The head impact sensor is basically an inertia measurement unit, sensitive to linear acceleration and rotation. Linear acceleration is the rate of change in the velocity of an object moving in a straight line. Rotational acceleration is the rate of change in angular velocity at which the rotational speed of an object changes across a certain angle of rotation. Measurements were carried out by testing the impact of eight sensors (Cue Sport Sensor, GForce Tracker, Prevent boll-and-bite mouthguard, Prvent custom mouthguard, Shockbox, SIM-G, Vector MouthGuard, and XPatch) in the laboratory on artificial head shapes with various impact severities and in the field through video validation. Eight sensors were assessed in the first stage, but only four sensors were assessed in the second stage. Sensor accuracy is varies widely. CCC (concordance correlation coefficient) of the first stage between from 0:13 to 0.97, with an average value of 0.72. Overall, the four devices that are implemented in the field has a PPV (positive predictive value) are between from 16.3 to 91.2%, with an average value of 60.8%. Performance in the laboratory does not always indicate the performance of the device in the field (Kieffer, Begonia, Tyson & Rowson, 2020). Mathematical calculations such as speed, acceleration, force, and energy in the sensor system determine the degree of head injury. In addition, the incidence of head injury is not seen from the magnitude of the linear or rotational acceleration but also the time interval in which the acceleration occurs affects the pathological outcome.

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LITERATURE REVIEW

Heading Biomechanics

Biomechanics is the study of the structure and function of mechanical aspects from biological systems at the level of all organisms to organs, cells and cell organelles, using mechanical methods. Mechanics refers to the study of mechanical principle of the organism being living mainly movements and their structure. In mechanics, there are 2 sub-fields of study, namely statistics and dynamics. Statics is studying systems that are in constant motion, either at rest or moving at a constant speed. Whereas dynamics is the study of systems in motion where there is acceleration which involves kinematics (the study of the motion of objects with respect to time, displacement, and movement speed both straight and rotation direction) and kinetics (study of forces related to motion including forces that cause motion and force resulting from movement). Kinematics research plays a particular role in the analysis and diagnosis of motion technology. While kinetic plays a role in force studies to evaluate certain characteristics of motion technology and the effects of these motion techniques (Huifeng, Shankar & Vivekananda, 2020).

Biomechanics is one of several sub-disciplines in the field of sport, kinesiology, or exercise science, which involves the amalgamation of human anatomy and Newtonian mechanics (Wallace, Knudson & Gheidi, 2020). Sports biomechanics is a quantitative based study and analysis on professional athletes and sports activities in general. It is described as the physics of the sport being applied in order to gain an understanding of movement performance through mathematics, computer simulation, and measurement. These technological developments have contributed to improve monitoring of sports training and competition performance from a sports biomechanics perspective. Sports biomechanics experts help a person to find movements with optimal muscle performance. Biomechanics can identify high risks by observing errors in motion. This activity is carried out by measuring and characterizing human movement during sports activities, this is important for a coaching program in improving techniques and preventing injuries (Taborri et al., 2020).

Football is a sport that requires a variety of basic technical movements. The efficiency of motion will increase the maximum ability in basic technical movements. One of the basic techniques of football is headings. The study of heading movements can be carried out in the field of sports biomechanics. Guidelines on heading techniques aim to improve player skills, in addition to observing the response of the head to ball impact and potential injury. Biomechanical studies can help identify a better understanding of the physiological parameters related to the response of the head to the effects of a violent head impact, causes and contributing factors to head movement, as a preventive measure to reduce head injury. Biomechanical heading calculated the linear and rotation acceleration of the head impact. Head acceleration resulting from impact is, in general, associated with the risk of a concussion diagnosis (Cecchi, Monroe, Moscoso, Hicks & Reinkensmeyer, 2020).

Head Impact Sensor

Head impact exposure is a common occurrence in football and has been linked to headings in some cases. In this modern era the use of a head impact sensor has made it possible to measure force while heading the ball. Each type of head impact sensor has a difference in components but their use is almost the same with regard to the tri axial accelerometer and the triaxial gyroscope. An accelerometer measures linear acceleration, while a gyroscope measures rotational speed which is converted into rotational acceleration. Each head impact sensor in football is used differently, some are used by attaching it to the skin (behind the ear) or a headband. There are several types of head impact sensors that can be used to measure head impact in football, including:

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X2 Biosystems XPatch

The X Patch (X2 Biosystems, Seattle, WA) is a skin-mounted sensor consisting of three linear accelerometers and three angular velocity sensors. XPatch measures the frequency and magnitude of head impact experienced during sports activities (Saunders, Le, Breedlove, Bradney, & Bowman, 2020).

FIGURE 1
(A) X2 BIOSYSTEMS; (B) X2 BIOSYSTEMS APPLICATION (Saunders et al., 2020)

Triax Smart Impact Monitor

The Triax Smart Impact Monitor (Triax Technologies, Norwalk, CT) is a sensor mounted in a headband consist of three-axial linear accelerometer and three-axial gyroscope. The Triax Smart Impact Monitor helps to improve concussion safety and alertness in athletes. The sensors monitor the physical strength applied to the athlete whenever there is contact or collision on the playing field.

FIGURE 2
TRIAX SMART IMPACT MONITOR & TRIAX SMART IMPACT MONITOR APPLICATION

(Caccese, Lamond, Buckley & Kaminski, 2016)

METHODOLOGY/ MATERIALS

The study used a systematic review where the identification of articles was carried out by screening for the presence of inclusion and exclusion criteria (Piedade, Hutchinson, Ferreira, Cristante & Maffulli, 2021). Systematic review is a study method for identifying, evaluating and interpreting all relevant research results related to certain research questions, certain topics, or phenomena of concern. Systematic reviews will be very useful for synthesizing various relevant

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studies so that the facts presented are more comprehensive and balanced. The research was conducted by searching for data from the football heading biomechanics journal through an electronic database, namely Google Scholar and Science Direct. The search was carried out by writing the keywords “head football”, “ biomechanics heading football“, “head impact sensor” from 2016-2021. The journal inclusion criteria are (1) The journal discusses the head impact sensor on football heading biomechanics; (2) The journal must have been published in English. Meanwhile, we exclude journals that do not discuss the use of head impact sensors on football headings biomechanics. From the search results, and after adjusting the criteria journal in a review, produced 20 journal conducted the review. The analysis was carried out by descriptive percentages by comparing the use of the head impact sensor used in journals.

RESULTS AND FINDINGS

Based on the 20 journals reviewed, there were 2 head impact sensors used by researchers in researching football heading biomechanics.

Table 1
THE USE OF HEAD IMPACT SENSOR IN FOOTBALL HEADING BIOMECHANICS JOURNAL

Publication Year	X2 Biosystems XPatch	Triax Smart Impact Monitor
2016	6	2
2017	1	
2018	1	3
2019		1
2020	4	1
2021		1
Total	12	8

Table 1 shown the use of a head impact sensor in the biomechanics journal of football headings. Table 1 shown that there are 12 journals (60 %) that use the X2 Biosystems XPatch and 8 journals (40 %) use the Triax Smart Impact Monitor.

DISCUSSION

The football is played by two opposing groups who each struggle to get the ball into the opponent’s goal. The mutual struggle that allows each group to come into physical contact. In playing football, players are provided with good basic techniques. This technique can use the feet or head. The use of the head to pass or enter the ball into the opponent’s goal is called heading. The ball floating in the air is received by the head and then directed at a teammate or into the opponent’s goal. The head-ball interaction is an important mechanism for understanding how much energy transfer is in the implementation of football headings (Dunn, Davies & Hart, 2020). Execution of the football heading can cause head injury such as concussion. The relation of football headings with concussions explained the mechanism of injury and exposure to head impact has been studied in biomechanics studies. The two most common mechanisms of injury that can cause a concussion are head contact injuries and head movements due to impact to several other parts of the body (O'Day et al., 2017). Identify the mechanism of injury as a determinant of the time resolution of concussion symptoms. The results shown that the determinants of football are related to the concussions (Chandran, Elmi, Young & DiPietro, 2020).

Concussions caused by biomechanical forces can be caused by a direct impact on the head or on the body resulting in an impulsive force being transmitted to the head. Evaluation in the context of biomechanical loads comes from the contact of the head with the ball, goal, and

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the surface of the playing field (Chandran, Barron, Westerman & DiPietro, 2017). Technological developments made it possible with Computed Tomography (CT-Scan) and Magnetic Resonance Imaging (MRI) to study the linear and angular effects of accelerations on the brain. The physiological mechanisms of head injury will predict the impact on primary head injury. The main components include the strength of the injury (contact or force), the type of injury (rotational, translational, or angular), and the size and duration of the impact. The force of contact occurs when the head moves after a force, whereas the inertia force occurs in the acceleration or deceleration of the head, so the differential motion of the brain relative to the skull.

The physiological mechanisms that cause head injuries are head collisions with solid objects at sufficient speed, impulsive loads producing sudden head motion without significant physical contact, and static compression loads or quasi-compression heads with gradual force. Brain injury can result from the acceleration of the skull that is fast, leading to deformity of brain tissue and the extension (elongation) fiber axons (Knutsen et al., 2020). The force of contact usually results in injuries such as bruises and skull fractures. Inertia forces, especially translational, result in injuries such as contusions and sabdural hematomas, whereas acceleration and deceleration rotational injuries are more likely to result in diffuse injuries starting from concussion. Rotational injuries typically cause injury to cortical surfaces and inner brain structures. Angular acceleration, a combination of translational and rotational acceleration, is the most common form of inertia injury. Due to the biomechanical properties of the head and neck, head injuries often result in deflection of the mid-head and neck or lower cervical spine (as the center of movement).

Biomechanical detection using sensor systems plays an important role in measuring human movement through motion capture systems. In heading biomechanics, head impact has been studied using a sensor system device, as in research of (O'Sullivan, Kwak, Kim & Jeong, 2020) stated that a total of 501 head impacts in 10 football matches were measured. The results showed that there were significant differences between athletes, especially in terms of rotational acceleration, meanwhile there were significant differences in linear and rotation based on variables in each football match. Although most impact below 39 m/s^2, there are 2 potential impact that dangerous above 69 m/s^2. Advances in technology allow extensive field measurements and data collection in a fast time. Advances in technology also allow athletes and coaches to track functional movement, biomechanics and workload by utilizing wearable devices to maximize performance and minimize potential injury through the physiological data provided (Seshadri et al., 2019). The head impact sensor is a wearable device. Wearable devices are sensors and devices attached to the body where their use refers to electronic or computer technology. Wearable device technology has major implications for health and exercise such as monitoring and measuring biophysical or biochemical signals to help researchers develop further understanding of human health and the correlation between human performance and disease. A head impact sensor is a head impact sensor in which an inertia sensor (accelerometer and/or gyroscope) is attached to measure linear and rotational movements of the head during impact, which are factors related with head injuries. The way the head impact sensor works starts from the signal sent by a tracker that the athlete wears when doing the heading, then the signal is captured by a portable computer which will analyze the data obtained before finally being sent to the iPad. In order to understand the frequency, magnitude, and direction of head impact experienced by athletes, various sensors have been developed to collect head impact biomechanical data.

Given the wide variety of devices used to measure head kinematics including head impact (including helmet-mounted, skull-cap, headband, skin-patch, and mouthpiece sensors), various factors such as location, suitability, sensor attachment, and hair/skin characteristics will be affected sensor coupling and measurement accuracy(Miller et al., 2018). The use of helmet-mounted sensors is very limited as they can only be combined with certain helmets and headgear. The results of a review in the journal biomechanics of heading football states that

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there are 12 journals (60%) are using the X2 Biosystems XPatch and 8 journals (40%) use the Triax Smart Impact Monitor. The reasons for this use depend on the researchers such as ease of device placement, measurement capability, hardware or software linkages, and calculation filters. X2 Biosystems XPatch is skin patch impact sensors mounted on the process us mastoid behind the ear with an adhesive strip (Greybe, Jones, Brown & Williams, 2020). XPatch sensor measuring the time of impact, the location of head impact, and linear and rotational acceleration above 10 m/s 2 threshold at 1 kHz and 800 Hz. Impacts below 10 m/s^2 are not recorded as an impact that is most likely due to day-to-day activities and is considered not to be associated with head injury(Smirl et al., 2020). XPatch record all the head impact and the data then collected through technology Bluetooth that will be stored and analyzed in X2 Biosystems Impact Management System App. App (application) can be accessed on Tablets, Smartphones, and desktop computers. Meanwhile, the accelerometer unit that is attached to the footballer's head using a headband is called the Triax Smart Impact Monitor (Kalichová & Lukášek, 2019). The Triax fitting is positioned just above the greater occipital protuberance. Triax Smart Impact Monitor is a device consisting of a triaxial gyroscope, to measure angular velocity, and high and low triaxial accelerometer, to measure linear acceleration with measurements between 3 to 150 m/s^2 and trigger a threshold of 16 m/s^2. For each impact, the sensor records linear acceleration and angular velocity at 1000 Hz in all 3 axes and store data time series of 10 ms preimpact to 52 ms after impact (Patton et al., 2020). Triax Smart Impact Monitor is basically a real-time monitor that plays a role in conjunction with the proprietary Triax app (currently involving iOS, with the Android version almost ready). Connected through Bluetooth, the SIM-P sensor sends data to the iDevice, where the app sends alerts to the sidelines whenever the player has a head impact. The team can remove the player immediately for the necessary checks and treatment.

CONCLUSION

The availability of head impact sensor data used to measure head impact during football heading activities is the X2 Biosystems XPatch or Triax Smart Impact Monitor. The use of this device because the device placement for football players is more suitable to use a head impact sensor without being mounted on a helmet.

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