International Journal of Multidisciplinary Research and Publications
ISSN (Online): 2581-6187

Application of Sensors in Sports

Dr. Kishore Mukhopadhyay
Associate Professor in Physical Education, Union Christian Training College, Berhampore, Murshidabad, West Bengal
Email address: kishore.km2007 @ gmail.com

***Abstract*—** *Technological advancement is a natural process, and with the introduction of the game, athletes simply "get better". Sports technology is man-made methods designed to achieve a person's interests or objectives or related to a particular sport. Sports technology is a technology approach where athletes try to improve their training and competitive environment in order to improve their athletic performance. Putting the sensors in the athletes who wear them while training, can balance not only the heartbeat and breathing but also the performance of muscles and muscles. With this knowledge, runners and coaches can identify areas that need improvement. The nerves are worn and not worn. The current article talked about exploring the diversity and use of sensors in sports*.

***Keywords*—** *Sensors, technology and Sports industry*.

I. INTRODUCTION

In the field of sports, day-to-day research has been done to discover such new things so that one can meet one's needs, gain experience or prove it through new community development strategies. In the field of sports and innovation, the researcher, scientist and partner in sports are trying to achieve some new ways of demanding the participation of sports people and spectators. Artificial intelligence is among such things, ingenuity or strategies for international use also (1). Sports technology today is a fast-growing field. The desire to speed up, recover quickly and stay longer, has led to an increase in sports technology. The most common fields of modern research and high-tech products are textiles, material science and electronics. With better nutrition and better training, today's athletes are faster and stronger. Old records are always broken, and new ones are set. While many of these achievements may be due to atheism, advances in sports technology have also played a significant role (2). New sports equipment has become particularly relevant in rowing, cycling, swimming, tennis and other public and team routes, providing not only new records, but also the way the game is played.

Technology is not just here on earth, it is just inside us. Indeed, every day our hemorrhage carries the residues of ibuprofen and multivitamins, that many people work with, or undertaken, by artificial heart, contact lenses, and other medical procedures. Technology is defined as any material, intangible or modern sports and exercise science that aims to continue (3-5). The flexible definition allows everything from the development of running shoes and eyewear to a variety of body imagery such as technology. In previous years, the use of technology in sports had a strong focus on athletic testing (diagnostics); develop sports equipment with better engineering and technical skills, and is widely used in competitions. Thus, the earliest examples of sports technology were the abolition of images (1888), body scanners (1920's), a quick screen replay screen (1955) and the first use of electronic timing touch swimming pads (1957) (6).

In a highly competitive sports world, only a fraction of a second is all lying between the champion and their competition. Every athlete wants to have a high level of strength and self-discipline. They train for years - some train most of their lives - to get the chance to be selected as the best.

Today however by taking advantage of the advancements in microelectronics and other micro technologies it is possible to build instrumentation that is small enough to be unobtrusive for a number of sporting and clinical applications (7). One such technology that has seen rapid development in recent years is in the area of inertial sensors. These sensors respond to minute changes in inertia in the linear and radial directions. These are known as accelerometers and rate gyroscopes respectively. Accelerometers have in recent years shrunk dramatically in size as well as in cost. This has been due chiefly to the adoption by industries such as the automobile industry where they are deployed in airbag systems to detect crashes. Micro 2 Daniel A. James electromechanical systems (MEMS) based accelerometers like the ADXLxxx series from Analog Devices (8) are today widely available at low cost. The use of accelerometers to measure activity levels for sporting (8), health and for gait analysis (9) is emerging as a popular method of biomechanical quantification of health and sporting activity and set to become more so with the availability of portable computing, storage and battery power available due to the development of consumer products like cell phones, portable music players etc.

We live in a world of nerves. There are various types of sensors in homes, offices, cars etc. that work to make life easier by turning on the lights by finding presence, adjusting room temperature, getting smoke or fire, making delicious coffee, opening garage doors as soon as the car is near the door and many other activities.

All of these and many other changing functions occur as a result of Sensors. Before going into the details of what Sensor is, there are a variety of sensors and applications for these different types of sensors, especially in the field of sports and games training, monitoring, performance tracking and many more. We are now moving into a modern sports arena.

This work will focus on the use of a variety of sensors and their use in the sports industry and resilience to achieve greater market penetration, increase availability and lower costs, device size and efficiency.

Dr. Kishore Mukhopadhyay, "Application of Sensors in Sports," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 4, Issue 1, pp. 103-108, 2021.

II. Background: (Industrial Transformation)

Smart Sensor plays a very important role in Smart Factory of Industry 4.0 which is considered to be the fourth revolution in the manufacturing industry.

The First Revolution has brought us a water-powered machine (1765)

Second Revolution introduced mass production using electricity (1870)

The Third Revolution introduced automated production processes using computers and robots (1969)

And now the Fourth Revolution has introduced the Internet of Things (IoT) and the Smart Factory (2000).

The basic sensor is a device that senses something. For many years we have been able to see, hear, hear, smell, and even taste.

In the world of instrument control and process control, we define a sensor as a device that detects changes in body structures and produces an electrical effect to respond to that change (10).

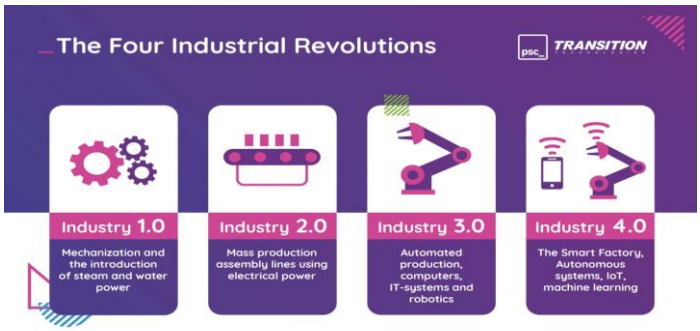

Fig. 1. 4 Industrial Revolution (11)

Figure -1 represents the technological change in chronological order. There are two images that come to mind representing the need to think about where education is in order to go beyond where it should be. The second image is courtesy of the future Gerd Leonhard. This picture is a simple, yet powerful reminder of the important role of soft skills and immeasurable qualities with traditional metrics that will play a role in preparing students for success over time.

III. Definition of Sensor

The sensor can be defined as an input device that provides output (signal) in relation to a specific body value (input).

The term "input" in the Sensu definition means that it is part of a larger system that provides input to a larger control system (such as a Processor or Microcontroller).

Another unique definition of Sensor is as follows: It is a device that changes the signals from one energy domain to an Electric domain. The meaning of the Sensor can be better understood if we take the example into consideration (12).

Smart sensor functions include:

• Compensation for error and audible and reliable sensory signals
• Advanced diagnostics and monitoring with individually identifiable devices
• Predictable detection mechanisms for immediate commission
• Advanced adjustment for reliable acquisition
• Personal adaptation of acquisition parameters for individual system solutions
• Auto adaption to adjust the parameter change automatically as the signal drops over time until the alarm limit is reached
• Effective sensor insertion and alignment assistance.

We will also gain new insights from the data available in these sensory systems. New details and details of how our equipment, processes and systems work and how they work will provide an opportunity for further development (13).

In simplified form, in a single module, there is a total sensory detection of sensory values. These signals are designed electronically and are processed (by microcontrollers and / or microprocessors). Thereafter, the communication section is responsible for data transmission, using a variety of methods (cable, wireless, Bluetooth®, Xbee®) to a network with other sensors in the transmitter and data analysis (14).).

The main uses of smart sensors are: agriculture, environmental monitoring, transport and transportation, operational, industrial, hospitals, lighting, space, energy conservation, automotive and communications (14-17). Among these various areas, applications to health care and sports performance are also associated with greater emphasis (18-19).

Because of the similarities between these technologies, and between the analytical areas suggested in this review, this work is organized into three application categories: sports, background and history.

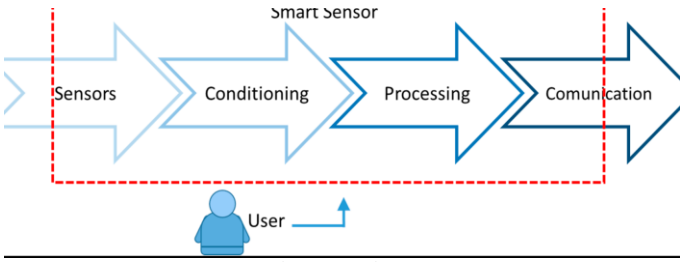

Fig. 2. Summary flow chart for intelligent sensor.

IV. Classification of Sensors

Sensors can be categorized in different ways, the most common categories are included below (12):

A. In the first stage of the senses, they are divided into Active and Passive. Active sensors are those that require an external entertainment signal or energy signal. Passive Sensors, on the other hand, do not require any external power signal and directly produce an output response.

B. The second type of separation is based on the detection methods used by the sensor. Some of the ways to find Electric, Biological, Chemical, Radioactive etc.

C. The third type of category is based on the nature of the modification, namely, input and output. Some of the most common modifications are Photoelectric, Thermoelectric, Electrochemical, Electromagnetic, Thermooptic, etc.

D. The final separation of the nerves is the Analog and Digital sensors. Analog sensors produce analog output i.e., continuous output signal and, digital sensors, unlike analog sensors,

Dr. Kishore Mukhopadhyay, "Application of Sensors in Sports," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 4, Issue 1, pp. 103-108, 2021.

operate with different or digital data. The information in digital sensors, used for conversion and transmission, is digital in nature.

V. TYPE OF SENSORS

In everyday life applications, commercial and industrial devices, educational projects, various types of sensors are used in a specific role. The most common type of sensor is listed here (20),

1. Heat Weight

The thermal sensor uses it to detect heat energy and heat and converts it into an electrical signal (in the form of an electric current or current). Eg Thermometer, Thermocouple, Resistance Temperature Detector etc.,

2. Pressure Sensor

Pressure Sensor is called a Pressure Transducer or Pressure Transmitter or Piezometer. The pressure sensor detects the pressure of air, gas, water and provides an electrical signal to the controller.

3. Touch Sensor

The touch sensor is called a Tactile sensor. It is an electronic sensor used to detect and record physical touches. The powerful touch sensor, the opposing touch sensor is an excellent example of the touch sensor.

4. Image Sensor

Image sensor is an electronic tool used to detect image pixels and provide information to display devices. In digital camera, closed television (CCTV), medical imaging equipment, thermal imaging devices, radar, sonar, etc.

5. Motion Sensor

Motion sensor measures and records body functions or movements. It is divided into different types.
• Active movement sensor
• Unusual motion indicator
• Tomographic motion sensor
• Touch movement sensor

The motion sensor is used for home safety, automatic door operation, microwaves, robots, ultrasonic waves, action detector, etc.

6. Light Sensor

A light sensor is a photoelectric device. This sensor detects and converts light or light lumoncence or photon into an electrical signal.

7. Vibration Sensor

At one time, the vibrating sensor was known as the Piezoelectric Sensor. The vibrating sensor detects and records any movements or activities. It also provides information or signals on connected devices or systems.

8. Moisture Sensor

The moisture sensor is also known as Hygrometer. To find moisture in the air and soil, a moisture sensor is very important. Mostly, it is used in the Air Conditioner (AC) system.

9. Proximity Sensor

The proximity sensor can easily detect nearby objects without any physical contact. Divided into different types such as
• Capacitive Proximity Sensor
• Incoming Circuit Sensor

It is widely used on smartphones, tablet computers, machines, robotic systems, roller coasters, etc.

10. Color Sensor

Color sensor is a type of photoelectric sensor.

It helps to feel the color of the object and recognize the color of the object. This sensor uses an RGB color scale (red, green, and blue).

11. Radiation Sensor

Radiation sensor is an electronic device that senses and measures radiation particles such as alpha, beta, gamma, neutron, X-ray.

12. Level Sensor

The key role of the sensory level is to measure the level or height of various substances such as solids, liquids, and gases. It is divided into different parts.

- Laser Level Sensor
- Floating Sensor
- Performance Sensor
- Resistance Level Sensor
- Ultrasonic Level Sensor
- Hydrostatic Level Sensor
- Optical Level Sensor
- Electromagnetic Level Sensor

13. Position Sensor

The position sensor determines the movement and location (such as rotation and rotation).
Basically, a standing sensor available in a variety of forms.
• Visual Position Sensor
• Linear Position Sensor
Circuit Position sensor
• Incoming Position Sensor
• Powerful Position Sensor
• Fiber-Optic Position Sensor
• Ultrasonic Position Sensor

14. Gas or Smoke Sensor

A gas sensor is used to detect various types of breathing, toxic or explosive breaths, smoke in the air. Some of these sensors are capable of measuring gas congestion.

15. Flame Sensor

The flame sensor easily detects flames or flames of nearby objects. These detected signals are transmitted to connected control devices.

Dr. Kishore Mukhopadhyay, "Application of Sensors in Sports," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 4, Issue 1, pp. 103-108, 2021.

16. Leak Sensor

A leak sensor is used in a closed container or in an injection to detect water leaks, water leaks, air leaks, etc.

17. Accelerometer

Accelerometer is a tool that measures movement speed or speed.

18. Tilt Sensor

The slope sensor detects and varies with angular movement, angular slope, angular movement, axis of the reference plane.

19. Mark Sensor

Mark's sensor acts as a kind of photoelectric sensor. It is used to sense colour mark on presence of an objects.

20. Flow Sensor or Float Sensor

The level of sensory flow detects almost any liquid process. This acquired data will be delivered to the control system. The use of sensors in sports and sports development is not new, following sensors used to monitor, evaluate, train and aim to revitalize sport and sport (21),

VI. Application of Sensors in Sports

Application of sensors for the development of sports and games are not new, following sensors are used for the monitoring, evaluation, training and rehabilitation purpose in sports and games (21),

1. WIRE ENCODER or POTENTIOMETER for measurement, speed and acceleration measurements.
2. LIGHT LIMIT of Speed
3. LASER / DOPPLER VELOCIMETER for position and speed
4.ACCELEROMETER Position, Speed, Speed, Load and Full angle.
5. INCLINOMETER for Absolute and relative angle, angular velocity, and angular acceleration.
6. GONIOMETER of parallel angle, angular velocity, and angular velocity.
7. Absolute GYRO with corresponding angle, angular velocity, angular acceleration and time.
8. Inertial Motion Unit (IMU) speed, acceleration, perfect and related angle, angular velocity, angular velocity, load and second.
9. LOW the cell (Uniaxial / Multiaxial) load.
10. TORSIOMETER [Nm] for a while
11. THE FIRST MEANING OF CENTER load and second
12. One pressure sensor (Localized Force Sensor) for load and pressure.
13. Pressure compression (Matrix of pressure sensors) load and pressure
14. Pressing Mat or Insole (Matrix or local device) loading and pressure
15. Image sensor for measuring temperature, Light intensity.
16. Thermo sensor for measuring temperature

Fig. 3. Smart Protective Sensors (30).

Most impact monitoring systems in the game are made up of inertial smart sensors that can transmit the following values: impact speed, impact time, local impact (head or body part), impact direction, and number of effects respectively (if more than one) (22-29). Since the main goal of the course is the impact on the head, the most protective equipment, the idea of protecting the helmet can also be applied to the boxer's watch.

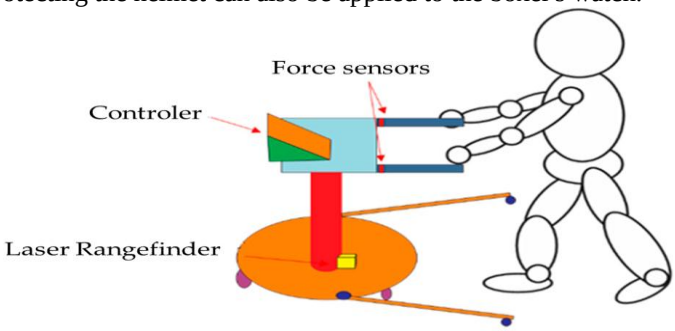

Fig. 4. A mobile help robot that highlights energy sensors, laser indicator, and controller. (30)

VII. Classification of Sensors Depended Upon Sports

Sensors can be classified according to the type of sports equipment, (31).

1. Field distance estimates:

The laser sensor saw field events of major sporting events such as shot put, discus, javelin, hammer, measuring the competitive results of these entrants, with its high accuracy, high stability, efficiency, proved the birth of competitive medals.

Dr. Kishore Mukhopadhyay, "Application of Sensors in Sports," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 4, Issue 1, pp. 103-108, 2021.

2. Follow the Time Sensor:

Currently the default timetable for results is available in the second century accurately to the second millennium.

3. Boxing sensor

Boxing, in order to determine if a player's shoulder is touching the ground, the referee needs to lie down a deep vision of the runner in everything he does.

4. Game Environmental Sensors

An ultrasonic anemometer can be used in fast-changing air conditions, and accurately measure the airspeed ratio. Impact of wind on track and field competition, where wind speed exceeds the limit of track area and field, the created results will not be accepted. Outdoor regatta racing, rowing competitions are required an ultrasonic anemometer to measure air speed.

5. Weight Training Equipment Used in Activity:

Existing weight training equipment for training, speed, weight sensor, real-time weight training data and diagnostic system to monitor training process, strength, speed, strength and other parameters, and responding to real-time user results, thus recognizing eight intelligence and visual and safety training training.

6. Motion Detection sensor

In intensive training projects, detecting bone fatigue in athletes is important in improving the athlete's body and protecting the athlete's safety, uncontrolled discovery is a method that uses ultrasonic Lamb wave propagating to the bone. Bone Young's modulus is like a simulation. When bone loss, Young modulus descended to change the distribution curve. Phase speed is used to reshape the Youth module to identify bone fatigue in order to achieve accurate and non-invasive testing.

7. Force Transducer

To test whether the beat goes to the effective parts of the other player and the magnitude of the applied force imparted by the opponent.

8. Flexible Pressure Array Sensor

All martial arts running events, such as martial arts, boxing, fencing, etc. It can be used on the same training equipment.

9. Stadium construction sensor

Using photovoltaic sound technology, solar panels are installed on the roof of a training hall.

National Stadium, the roof of the competition hall and south of the glass curtain wall.

10. Electricity reduction

The field of organic electronics in recent years has seen an increase in publishing, in terms of semiconductors used in electronics and optoelectronic devices, including light-emitting diodes, photovoltaic cells, and thin-film transistors (32) Advantages of -organic electronics incorporate the stability of their electronic devices through chemical integration and compliance with roll-to-roll manufacturing, which can result in the production of much lower costs. Emerging focus in the field includes the use of biological devices such as transducers in chemical and biological sensors (33-35).

11. Ionogels & OECTS: The future of biosensing:

Significant contributions to current research conducted in the area of complete lab-on-a-chip analysis systems can be made by combining OECT and Ionogels. Many OECT / Ionogel sensor applications may involve disposable devices, cheaper processing and therefore enzyme stability is very important. OECT devices are naturally low in power and easy to build (36).

12. Wearable sensors

Sensors are continuously manufactured and integrated with the latest wearables for approval wise decisions and healthy lives. The TE (TE) connection continues with various sponsorships applications with new product development and the creation of smaller, more accurate sensors.

In addition to the aforementioned sensors there are various sensors for analyzing body and human applications such as vo2 max estimator, body fat analyzers, EMG monitor, electric pedometer and more.

VIII. CONCLUSION

By placing small sensors, which are not visible to the athletes who wear them during training, he can measure not only the heartbeat and breathing but also the performance of muscles and muscles. With this knowledge, runners and coaches can identify areas that need improvement. For example, changes in altitude can have a significant impact on aerobic capacity. Targeted training focused on increasing lung capacity can help reduce the height of the impact it will have. The soft, comfortable sensors embedded in the athlete's singlet torso can measure an athlete's VO2 (oxygen volume) levels and measure elevation as a result of proper training. Accelerometers and props attached to compression shirts and shorts can also measure posture and provide real-time feedback to athletes so that they can improve their form. It is one thing for a coach to give a verbal response to a runner, it is quite another thing for a runner to see himself appear in real-time against the ideal silhouette that performs the same action. In these and many other ways, adding sensors to the sports field will further change the way athletes train and compete. The current article discussed an examination of the various types of nerves and their use in the field of sports and games.

REFERENCES

[1] "Artificial Intelligence in the Field of Physical Education and Sports", International Journal of Scientific Research & Development, 8, 9, 2020, P-252.

[2] Exploratorium, 2012, "The Science of Cycling: Aerodynamics & Drafting." Available at http://www. exploratorium.edu/cycling/aerodynamics1.html (15 October 2012).

[3] Feenberg, A. (1999). Questioning technology. New York. NY: Routledge.

Dr. Kishore Mukhopadhyay, "Application of Sensors in Sports," *International Journal of Multidisciplinary Research and Publications (IJMRAP)*, Volume 4, Issue 1, pp. 103-108, 2021.

[4] Feenberg, A. (2003). Questioning technology. New York. NY: Routledge.
[5] Miah, A. (2004). Genetically modified athletes: Biomedical ethics, gene doping and sport. London, UK: Routledge
[6] Omoregie , Osamende Philip , 2016, The impact of technology on sport performance, Proceedings of INCEDI 2016 Conference, 29th-31st August 2016, Accra, Ghana,
[7] James, D.A, Davey, N. And Rice, T.(2004), An Accelerometer Based Sensor Platform For Insitu Elite Athlete Performance Analysis, IEEE, Sensors, Vienna
[8] Weinberg, H. (1999). Dual Axis, Low g, Fully Integrated Accelerometers, Analogue Dialogue 33, Analogue Devices (publisher).
[9] Moe-Nilssen, R., and Helbostad, J. L.,(2004), Estimation of gait cycle characteristics by trunk accelerometry, J Biomech, 37(1), 121-126
[10] https://ttpsc.com/en/blog/the-fourth-industrial-revolution/
[11] http://esheninger.blogspot.com/2018/04/preparing-learners-for-fourth.html
[12] https://www.electronicshub.org/different-types-sensors/
[13] https://www.rs-online.com/designspark/smart-sensors-and-io-link-delivers-industry-40
[14] Chaudhari, M.; Draravath, S. Study of Smart Sensors and their Applications. Int. J. Adv. Res. Comput.Commun. Eng. 2014, 3, 5031–5034.
[15] . Yurish, S.Y. Smart sensors for electrical and non-electrical, physical and chemical variables: State of the art. In Smart Sensors and MEMS; Yurish, S.Y., Gomes, M.T.S.R., Eds.; Kluwer Academic Publishers: Houten, The Netherlands, 2003; pp. 1–50.
[16] . Frank, R. Understanding Smart Sensors, 2nd ed.; Artech House: Norwood, MA, USA, 2000; pp. 1–16.
[17] . Singh, V.R. Smart sensors: Physics, technology and applications. Indian J. Pure Appl. Phys. 2005, 43, 7–16.
[18] . Magno, M.; Benini, L.; Gaggero, L.; La Torre Aro, J.P.; Popovici, E. A versatile biomedical wireless sensor node with novel drysurface sensors and energy efficient power management. In Proceedings of the 5th IEEE International Workshop on Advances in Sensors and Interfaces, Bari, Italy, 13–14 June 2013; pp. 217–222.
[19] . Harms, H.; Amft, O.; Winkler, R.; Schumm, J.; Kusserow, M.; Troester, G. ETHOS: Miniature orientation sensor for wearable human motion analysis. In Proceedings of the 2010 IEEE Sensors, Hona, HI, USA, 1–4 November 2010; pp. 1037–1042.
[20] https://dipslab.com/sensor-types/#What_are_the_different_types_of_Sensors
[21] Daniel Arthur James on 18 August 2016., Sensors and wearable technologies in Sport: Technologies, trends and approaches for implementation, https://www.researchgate.net/publication/306259444
[22] Crisco, J.J.; Fiore, R.; Beckwith, J.G.; Chu, J.J.; Brolinson, P.G.; Duma, S.; McAllister, T.W.; Duhaime, A.C.; Greenwald, R.W. Frequency and location of head impact exposures in individual collegiate football players. J. Athl. Train. 2010, 45, 549–559. [CrossRef] [PubMed]
[23] Mihalik, J.P.; Guskiewicz, K.M.; Marshall, S.W.; Blackburn, J.T.; Cantu, R.C.; Greenwald, R.W. Head impact biomechanics in youth hockey: Comparisons across playing position, event types, and impact locations.Ann. Biomed. Eng. 2012, 40, 141–149. [CrossRef] [PubMed]
[24] . Crisco, J.J.; Wilcox, B.J.; Beckwith, J.G.; Chu, J.J.; Duhaime, A.C.; Maerlender, A.C.; McAllister, T.W.; Greenwald, R.M. Head impact exposure in collegiate football players. J. Biomech. 2011, 44, 2673–2678.[CrossRef] [PubMed]
[25] Wilcox, B.J.; Beckwith, J.G.; Greenwald, R.W.; Chu, J.J.; McAllister, T.W.; Flashman, L.A.; Maerlender, A.C.; Duhaime, A.C.; Crisco, J.J. Head impact exposure in male and female collegiate ice hockey players. J. Biomech. 2013, 47, 109–114. [CrossRef] [PubMed]
[26] Beckwith, J.G.; Greenwald, R.M.; Chu, J.J.; Crisco, J.J.; Rowson, S.; Duma, S.M.; Broglio, S.P.; McAllister, T.W.; Guskiewicz, K.M.; Mihalik, J.P.; et al. Head Impact Exposure Sustained by Football Players on Days of Diagnosed Concussion. Sports Exerc. 2013, 45, 737–746. [CrossRef] [PubMed]
[27] Daniel, R.W.; Rowson, S.; Duma, S.M. Head Impact Exposure in Youth Football. Ann. Biomed. Eng. 2012,40, 976–981. [CrossRef] [PubMed]
[28] Greenwald, R.M.; Gwin, J.T.; Chu, J.J.; Crisco, J.J. Head impact severity measures for evaluating mild traumatic brain injury risk exposure. Neurosurgery 2008, 62, 789–798. [CrossRef] [PubMed]
[29] Crisco, J.J.;Wilcox, B.J.; Machan, J.T.; McAllister, T.W.; Duhaime, A.C.; Duma, S.M.; Rowson, S.; Beckwith, J.G.; Chu, J.J.; Greenwald, R.M. Magnitude of Head Impact Exposures in Individual Collegiate Football Players.J. Appl. Biomechan. 2012, 28, 174–183.
[30] José Jair Alves Mendes Jr., Mário Elias Marinho Vieira , Marcelo Bissi Pires and Sergio Luiz Stevan Jr. 2016, Sensor Fusion and Smart Sensor in Sports and Biomedical Applications, www.mdpi.com/journal/sensors, doi:10.3390/s16101569
[31] Jin-wei WANG, (2013), Applications and Prospects of Sensor in the field of Sports, Published by Atlantis Press, Paris, France.
[32] D. A. Bernards, D. J. Macaya, M. Nikolou, J. A. DeFranco, S. Takamatsu and G. G. Malliaras, "Enzymatic sensing with organic electrochemical transistors" J. Mater. Chem., 18, 116-120 (2008).
[33] L. Wang, D. Fine, D. Sharma, L. Torsi and A. Dodabalapur, "Nanoscale organic and polymeric field-effect transistors as chemical sensors" Analytical and Bioanalytical Chemistry, 384, 310-321 (2006).
[34] J. Locklin and Z. Bao, "Effect of morphology on organic thin film transistor sensors" Analytical and Bioanalytical Chemistry, 384, 336-342 (2006).
[35] J. Mabeck and G. Malliaras, "Chemical and biological sensors based on organic thin-film transistors" Analytical and Bioanalytical Chemistry, 384, 343-353 (2006).
[36] Nilsson, T. Kugler, P.-O. Svensson and M. Berggren, "An all-organic sensor-transistor based on a novel electrochemical transducer concept printed electrochemical sensors on paper" Sensors and Actuators B: Chemical, 86, 193-197 (2002).