

# The wearable and non-wearable sport electronic gadgets: structure, performance, and their roles in athletes training

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## Abstract

In recent decades, the growth of electronic technologies and their use in day-to-day life has increased dramatically. Electronic devices have also penetrated various fields of sports and physiotherapy in a way that their role in the sports industry has become irreplaceable. The purpose of using electronic gadgets in training is to observe, analyze, and improve the performance of players and prevent their injuries. Generally, the technology of these devices either can determine the intensity and type of exercise or allows the athletes to monitor their vital signs. The objective of this study is to investigate wearable and non-wearable electronic gadgets, introduce the parameters they provide and examine the technical specifications of their electronic circuits. Since the most substantial factor in analyzing the performance of athletes is measuring their movement characteristics, in the last section, we examine two principal movement-based sensors commonly used in gadgets.

*Keywords:* Electronic Gadgets, Sport, Wearable, Non-Wearable

## 1. Introduction

Recently, the use of electronic devices in all aspects of human life has increased widely. Most people, in their daily lives, carry electronics, including cell phones, tablets, smartwatches, and other similar devices, wherever they go [1]. The use of electronic gadgets in sports has also found a special place. Athletes and sports teams are always looking for ways to improve players' performance, enhance training conditions, prevent injuries, and optimize health and safety on the field [2]. On the other hand, advances in the technology of electronic devices manufacturing and miniaturization in the last two decades have paved the way for the introduction of electronics into sports. Therefore, Electronic systems have become an evolving trend in sport and are expected to become an integral element in many sports and related medical fields in the future.

Electronic gadgets used in sports fall into two general categories, wearable, and non-wearable. Wearable gadgets are the type of electronic devices that are placed in the user's clothing and user uses its integrated technology in the training sessions. Wearable gadgets in sports include wristbands, glasses, or similar products that can be purchased as a whole package or are devices that must be placed in shoes, shirts, or any clothing of the user in general. On the other hand, non-wearable gadgets are those that are placed in sports equipment and goods. They are non-removable and only work on specific tools. These include sports balls, punching bags, rackets, and similar items equipped with electrometers. In the following, we will examine each type of gadget, its role in athletes' training sessions, its components, and how the movement-based sensors of these devices work.

## 2. Discussion

Nowadays electronic devices and gadgets are mainly used in portable smart products such as mobile phones and smartwatches, building management systems and security systems, health care, fitness, sports, and many other applications [1]. In the last two decades, the commercial importance of small carriable electronic gadgets and the efficiency and applications that they offer in the field of medicine and sports have attracted the attention of many investors and large pioneering companies, including Google, Tesla, Apple, Samsung, Adidas, etc. The market for such products has grown exponentially with the introduction of products such as smartwatches and small medical devices by several companies [3, 4].

In day-to-day life, we see people who use a heart rate sensor while exercising, a pedometer due to dieting, or an oxygen sensor equipped wristband when they are sick. Such devices either have their display to show the measured information, or they connect wirelessly to your portable smart device, which is usually a mobile phone, and transmit the data to it for analysis and display. In this case, it is also possible to send information quickly and with no interference to your doctor or health care provider. Since, on the one hand, the treatment and health caring are expensive, and, on the other hand, the average age of the world population is increasing, such a feature of these devices allows doctors and physicians to monitor a person's health without his or her presence in a care center [5]. This is a stunning advantage of these devices for monitoring and managing the condition of the elderly, people with chronic illnesses, people with special disabilities, and the rehabilitation of patients after surgery by their treating physician or relatives [1].

### 2.1. Importance and application of Electronic Sports Gadgets (ESGs)

As mentioned, the purpose of using electronic sports gadgets in training sessions is to monitor the player's activity to improve their performance and prevent their injuries [6]. These devices allow coaches, physicians, physiologists, and trainers to observe and analyze a player's performance in real-time. It also makes it possible to record, compare and review the vital components of the individual and the physical activities that user has done in different training sessions. It is feasible to compare measured parameters of several players, as well. Since the most common type of injury in amateur and professional athletes is soft tissue injury, the majority of these injuries are preventable with ESGs. Because the main cause of these injuries is overtraining, dehydration, and poor training conditions that can be observed and controlled using these devices. These injuries, if exacerbated, can cause chronic pain, dysfunction, and eventually loss of time [7, 8].

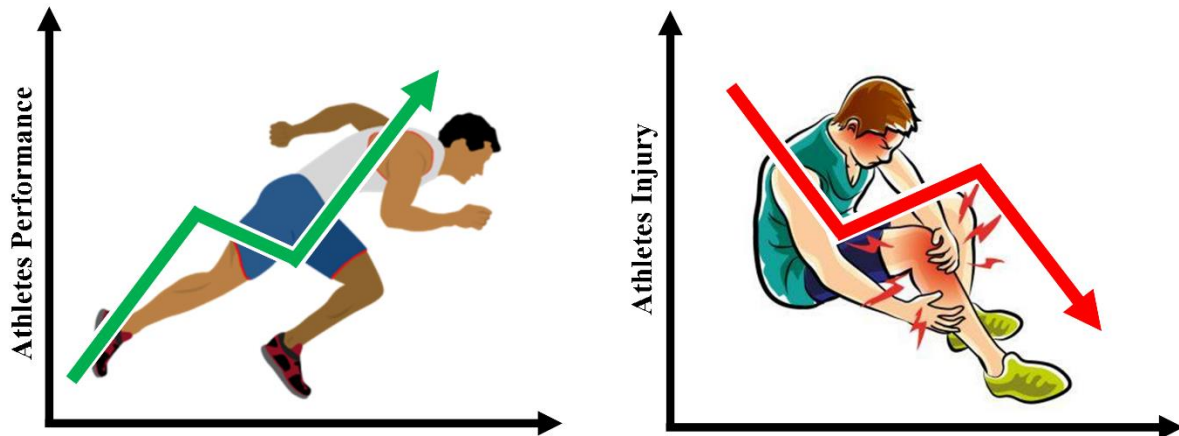


Figure 1. ESGs improve performance of athletes and mitigate their injuries.

As mentioned earlier, ESGs are generally classified into two categories: wearable and non-wearable. Wearable ESGs (WESG), which are placed in a person's clothes and accessories, have integrated electronic hardware that is packaged in a small frame and attached in a way to the athlete or put in a pocket that it usually fits on the back of their jersey [9]. The portability of these gadgets during training makes it possible to measure the athlete's movement parameters and eliminates the need for video recording of the entire training session that was previously used. Wearable electronics have already been reasonably successful in minimizing sports injuries, helping injured players' recovery, and improving the quality of athletes' training.

Another type of ESGs is Non-wearables ESGs (NESGs) that are inserted in sports equipment rather than athletes' clothing. These gadgets, like WESGs, are generally assembled in small dimensions and do not restrict the users' movement in their exercises. In general, ESGs, in addition to preserving the privacy of athletes, allow them to monitor and record the data of their training sessions in a wide range of locations and situations. They provide multi-tasking capabilities, flexibility, and convenience, and the information they provide is reliable. But the problem with these gadgets is that they are expensive and sometimes heavy, and the information stored in their memory or transmitted by them can be hacked.

The technology used in these ESGs either has the capability to measure movement parameters or has the ability to monitor vital signs or both. Determining a person's position using the Global Positioning System (GPS) and the number of steps taken using an accelerometer-gyroscope sensor is one of the most important motion parameters measured by electronic gadgets. The distance traveled, the speed of walking or running, and the acceleration of a person's movement can also be measured using the same sensors. On the other hand, blood oxygen and heart rate are the most basic vital signs that can be measured using their respective sensors. Burned calories during training and sleep quality are Other vital parameters that can be measured with accelerometer-gyroscope and heart rate sensors. Integrating these sensors and modules on an electronic board can provide a wide range of services to its user. In the following, we will examine two sport products that are upgraded with ESGs.

One of the ESG products is the Woop wristband. This device, which is available for purchase, was used by the National Basketball Association (NBA) at the Summer Olympics of 2016 in Rio de Janeiro, Brazil. It has the capability of measuring the body temperature, heart rate, and body movements of the athlete. A study conducted by Whoop from

2015 to 2016 on 119 athletes of different nationalities and from different sports showed that using this product reduces player injuries by 60%. This research also presented that using this wristband improves sleep quality and time, reduces resting heart rate and its variability. Micoach smart soccer ball is an example of a NESG-equipped product [10]. This ball was introduced by Adidas in 2014 and although it was not very commercially successful, it is still one of the most advanced products in the field of smart balls. Micoach is equipped with an internal electronic circuit, charges wirelessly, and can detect the impact, measure its intensity and calculate the speed, spin, and flight path of the kicked ball. It connects to the user's mobile phone via Bluetooth protocol and displays the information of the impact through Micoach software. Such a feature allows the users to view, receive feedback, and improve their ball kicking.



Figure 2. Wearable ESGs are placed in the athlete's clothing or accessories [2].

## 2.2. Electronic characteristics of ESGs

So far, the importance and role of electronic gadgets in sports, their types and the parameters they measure have been discussed. In this section, we will specifically examine the electronic components integrated into these devices. Naturally, the most important issue about these devices is how well they work in different conditions. The modules, sensors, and chips inserted in these gadgets must have other characteristics in addition to high performance, such as small size, lightweight, low power consumption, operation at different temperatures, durability, flexibility, and stretchability.

The reason that the electronic circuit of these products should be as small and light as possible is not to restrict the user's movement. So that an athlete does not notice any disturbing factor in training session. Reducing power consumption increases the operating time of the electronic gadget. The power-on time of them should be such that it covers the entire training session of the athlete, which may keep working to several hours. Here, there is a technical trade-off between the weight of the device and its operating time. Because with the increase in the capacity of the battery, which acts as the power supply of the system, although the ESG provides services to the user for a longer time, its overall weight increases as well. This issue must be optimized by the electronic designer of the device. Working at different temperatures is more related to Non-wearable ESGs. Where in some cases the electronic device with all its components is inserted into sports equipment rather than the athlete's clothing. In this case, the inserted electronic device may participate in the production process of the upgraded sport product, which may include a high-temperature process; Like the procedure of producing smart balls. In such a situation, the electronic circuit inside it, must be able to withstand the high temperature. In the next section, we will examine the two general movement modules used in ESGs and investigate how they are used to measure the desired parameters.

## 2.3. Investigation of motion-based sensors

In sports competitions and exercises, the most important component that coaches and trainers want to measure is how much players move and how they move. The advent of motion-based sensors, GPS and accelerometer-gyroscopes, has made significant progress in accurately and efficiently measuring players' movements. As well known, GPS is used to find a person's geographical location. Therefore, by using it, in addition to evaluating the location of the person, one can determine the speed, acceleration, and the changes in the direction of their movement. Hence, this module plays an important role in observing and analyzing the performance of players and allows the coaches or trainers to monitor and

evaluate the physical activities of the player in real-time or to compare his performance at different time intervals. The only problem with these modules is their low precision. The accuracy of the commonly used modules based on these systems is about 10 meters. In such cases, the precision drops sharply, and it is even possible to record a movement for a resident person by these devices. This is where the accelerometer-gyroscope sensors step in.

Since, on the one hand, both accelerometer and gyroscope sensors are devices based on microelectromechanical systems (MEMS) and are made with micromachining technology, and on the other hand, they have a similar function, and by combining the information obtained from them, we can calculate the motion of an object in three-dimensional space with high accuracy, generally, these two sensors are integrated on a single chip. That is why it is referred to as accelerometer-gyroscope in this paper. In practice, this sensor is either used in wearable ESGs solely to count the number of steps taken or in combination with GPS, as mentioned, to improve the accuracy of positioning. Since not taking a step and generally not creating any movement, which generates an acceleration, means stillness, the integration of this sensor with GPS solves the problem of recording motion in a state of immobility. Since the steps taken by a person during walking is in the range of about 30-70 cm (depending on the height and speed of that person) and the range of 70-150 cm while running, this sensor can also be used to increase GPS accuracy in motion. This is done by measuring the distance traveled by the person using the number of steps taken and comparing it to the person's movement in GPS. Therefore, to calculate the player displacement, these two sensors are generally used in combination [11]. Accelerometer-gyroscope sensors are also used in non-wearable ESGs to detect impact and in some cases to determine its intensity and type in accordance with the equipped sports product with an electronic circuit. Because with a series of simple mathematical calculations, the force of the impact, its speed and direction, and in certain conditions, the displacement resulting from that impact can be obtained by using acceleration changes.

#### 2.4. User interface of electronic sports gadgets and how they transfer information

As mentioned earlier, ESGs either have a display to show the measured parameters to the user in real-time, or it transmits the information of the athlete's training session wirelessly to user data hub, which is usually a mobile phone or a tablet. In the first case, since the data of the training session displayed to the user Simultaneously, the electronic circuit of the device does not need a memory unit to store information. But in the second case, a memory unit added to the gadget of the sports product to save the measured parameters to transfer them to the hub when ESG connects to it. The connection method is generally via Bluetooth. This well-known serial communication protocol, which is suitable for wireless data transmission over short distances, has a high data transfer rate and a wide bandwidth, which makes it feasible to send a noticeable volume of information in a short time.

### 3. Conclusion

In this paper, the importance of using electronic devices in the sports section and the role they play in improving the training conditions of athletes were studied. Both wearable and non-wearable gadgets, their application, and their presented parameters were examined. It was explained how an athlete can use these gadgets. In the following, the electronic technology used in sports electronic gadgets and sensors that are commonly integrated into them was studied. It was stated that these technologies are used either to extract and display a person's vital indicators such as blood oxygen level and heart rate or to detect the type of movement of the user and measure its amount. Finally, due to the importance of measuring the movement characteristics of players and the need for high accuracy of these calculations, two motion-sensors of GPS and accelerometer-gyroscope were technically analyzed, and their hardware limitations and advantage of their combined functional was investigated.

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