



# Wearable Technologies in Athletic Performance

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## Abstract

Nowadays, not only training methods but also wearable player tracking systems provided by the developing technology to the experts play an important role in the development of sportive performance. Tracking of external load as work done in high-level athletes and by monitoring the internal load, these systems that train at the desired exercise intensity usage has increased. In addition, wearable technology products, which control the acute and chronic training load and related with increased injury risk, have started to serve as an important feedback mechanism in recovery from injury. It has been used in motion analysis to determine the activity pattern recently and to collect data within the competition. Wearable technology products use different ways such as "Global Positioning System, Local Positioning System, Micro Electromechanical System, Inertial Measurement System" and it should be taken into account that different sensors collect data at different frequencies and process this data with variable algorithms. With the widespread introduction of different commercial products in the last 10 years, using wearable technology can be said to be indispensable helpers for trainers working to improve performance in sports.

**Keywords:** Player load, Global Positioning System, Inertial Measurement System

## Sporda Giyilebilir Teknoloji Kullanımı

### Özet

Günümüzde sportif performansın geliştirilmesinde sadece antrenman yöntemleri değil gelişen teknolojinin uzmanlara sağladığı giyilebilir oyuncu takip sistemleri de önemli rol oynamaktadır. Üst seviye sporcularda yapılan iş olarak dış yükün takibi ve iç yük görüntüleyerek istenik egzersiz şiddetinde antrenman veren bu sistemlerin kullanımı artmıştır. Ayrıca, akut ve kronik antrenman yükü ile sakatlık risk artışını da kontrol eden giyilebilir teknoloji ürünleri, sakatlıktan geri dönüşte de önemli bir geribildirim mekanizması olarak görev yapmaya başlamıştır. Son dönemde aktivite paterni belirlemede ve müsabaka içi veri toplanması için hareket analizinde de kullanıldığı not edilmektedir. Giyilebilir teknoloji ürünleri Küresel Konumlama Sistemi, Lokal Konumlama sistemi, Mikro Elektromekanik Sistem, Atalet Ölçüm Sistemi gibi farklı yolları kullanmakta ve farklı sensorların farklı frekanslarda bilgi toplayarak değişken algoritmalarla veri işlediği göz önünde bulundurulmalıdır. Son 10 yılda farklı ticari ürünlerin yaygın olarak piyasaya sunulması ile kullanımı artan giyilebilir teknoloji sporda performans geliştirmek üzere çalışan antrenörlerin vazgeçilmez yardımcıları olduğu söylenebilir.

**Anahtar kelimeler:** Oyuncu yükü, Küresel Konumlama Sistemi, Atalet Ölçüm Sistemi

## INTRODUCTION

The use of glasses for the first time in the 1200s created the first example that existing technologies can also be used as a wearable. The use of television as glasses in 1963 enabled it to be integrated with technology even though the technology was still in its infancy. In addition, it enabled the emergence of the concept of cybernetics, but until today it has

been generally expressed at the level of science fiction. The use of wearable technologies in professional sports has been a popular trend recently. It reflects its impact on sports not only on athletes and technical teams but also on other supporters such as fans and media. The Nike IPOD link in 2006 and the Fitbit product introduced to the end user in 2009 have revolutionized and become

one of the most widely used systems in the world for physical activity tracking. Although there is no branded and widely used wearable sports-related product in our country, there are initiatives working on wearable technology in the health field. With the rapidly developing Wearable Technology applications after 2010, it has become easier for sports professionals to monitor the physiological load in athletes in real-time, to track and understand the development of fatigue. It is also of great importance for determining position-specific motion patterns and optimizing performance. Many professional league organizations have allowed use in their routine matches and training (10, 19). The wearable tech market is growing at an incredible rate, with a market value of \$34 billion by 2020, with an estimated 400 million wearable smart products sold (21). The aim of this study is to review the sports usage areas of wearable technologies, the advantages they provide and to expected development in the future.

### Monitoring Performance and Player Load

An intimate dose-response relationship should be observed between training programs and match requirements for optimal sporting performance. It is possible to understand these high-intensity load and physiological responses and hence the sport-specific requirements the concept of player load or training

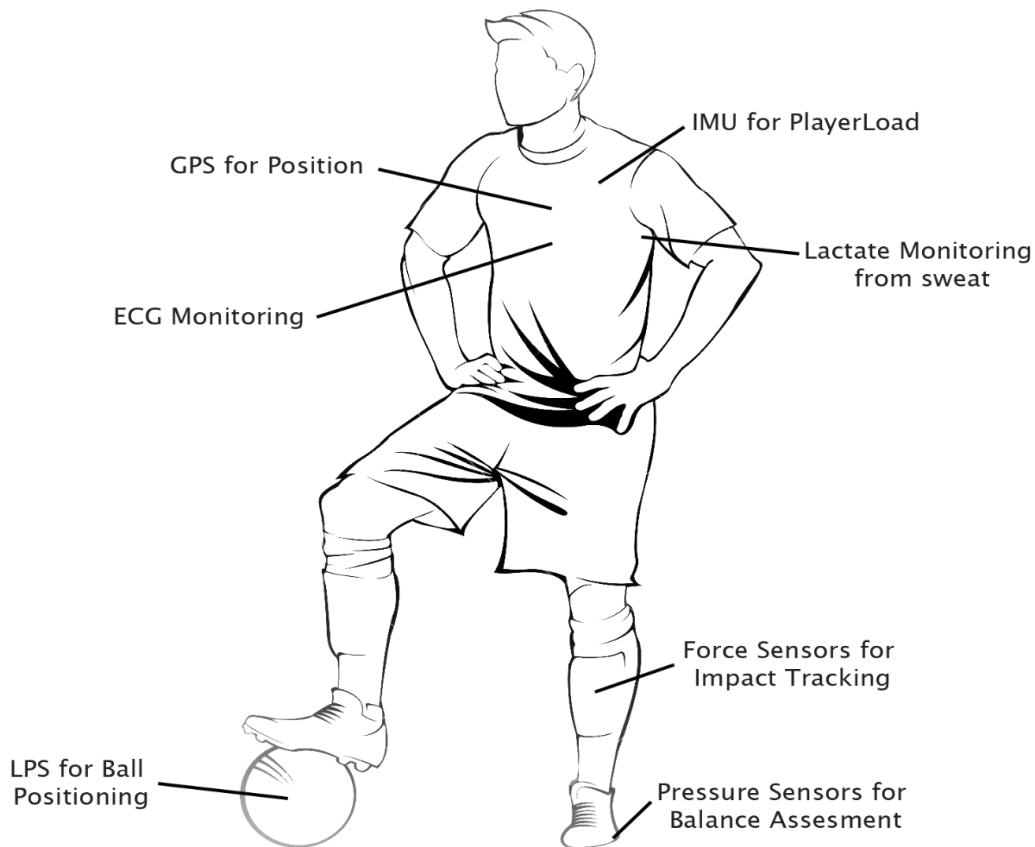
load. In professional sports, it is widely used today to measure athlete activities in training and matches (2, 24). In this way, coaches, sports physicians and performance experts determine the player and training load of the sports discipline and designs its training programs at a load-rest ratio suitable for match requirements.

We examine training or match load for athletes in two parts; External Load (EL) and Internal Load (IL). EL can be defined as the work done by the athlete; such as the distance a football player in a midfield position perform in the match and / or the distance covered at high intensity. EL is important in understanding the work done or the capacity of the work that the athlete can perform. IL is the physiological stress caused by the load on the athlete during training or matches, oxygen consumption and cardiac output responses of the cardiorespiratory system that are most exposed to this stress primarily (16, 26). Likewise, physical requirements such as total running distance, speed of running distance, movement patterns in the relevant sports are EL and physiological requirements such as heart rate, lactate concentration, oxygen consumption and the scale of perceived exertion by the body are accepted as IL (Table 1).

Table 1. The players' external and Internal loads according to physiological and biomechanical concept		
	External Load	Internal Load
<i>Physiological</i>	Distances covered	VO <sub>2</sub> consumption
	Running speed	Heart rate & Lactate level
		Rate of perceived Exertion
<i>Biomechanical</i>	Ground Reaction Forces	Joint load
	Accelerations & Decelerations	Muscle tendon forces
		Soreness
	Sum of Accelerations	Perceived effort

The most widely used technology in IL monitoring is heart rate monitors and metabolic analyzers. Also, portable for analyzing body fluids and easy-to-use blood, sweat, saliva and urine sample analyzers are useful to make inferences about the workload of the player during training and matches. Electromyography (Electromyography, EMG), Galvanic Skin Response (GSR) and Near Infrared Spectroscopy (NIRS) can be counted for internal load, muscle metabolism and neuromuscular parameter imaging technology (4). Thus, the concept of Biometric Data (BD) stands out, expressing the characteristic data created by the

physical, physiological and behavioral characteristics of the individual. BD in the sports industry, heart rate from athletes, Global Positioning Systems (GPS) data (such as running distance or the athlete's running speed), accelerometer data (calculating the athlete's energy expenditure or measuring body and limb acceleration), blood oxygenation, sleep analysis and body temperature comprises valuable biological information. This important BD collection method is made possible by wearable technology (Figure 1).



**Figure 1.** Demonstration of some instruments used as wearable technology in athletic performance.

Especially in team sports, because of the principle of individualization, it has become very important to monitor each player separately in order to determine a personal training load. Athlete tracking systems simultaneously describe the position, speed and acceleration of many athletes during the movement specific to the sport (5, 23). Among these systems, the ones based on using GPS were widely used in open field sports such as rugby and football (7, 20). Through to the technological developments, GPS started to be used to determine the external load in sports. GPS is a navigation system that uses 27 satellites orbiting the earth (22). However, it could not be applied for a long time due to the lack of GPS signal in indoor sports. Alternatively, the Local Positioning System (LPS) was developed. However, it has limitations such as high costs and requiring for fixed installation (17, 25). Currently, the image processing by camera method is widely used as a valid and reliable method, despite the limitations such as the need for manual intervention, image quality and camera

position (1, 11). The validity and reliability of GPS or accelerometer-based wearable technologies used in EL determination are important for the sensitivity of training programs.

The most important advance in this process are the development of factors such as physical size and battery duration, which are the basic limitations of this wearable technology. In addition, advances in biosensor technologies have facilitated the application of wearable technology in the field. From basic microprocessors that only count steps, we have reached the level of electrochemical analysis units.

Inertial sensors are used extensively in wearable technology products. Wearable products can be used to evaluate movement-related or complex movements. These sensors are in Micro Electro Mechanical Systems (MEMS) structure and contain gyroscope, accelerometer and magnetometer. The data from the Inertial Measurement Unit (IMU), which is one of the wearable technology products, shows the change of the body center of gravity in 3

axes and the load of the player is calculated using the following equation (18).

$$\text{Player load} = \sqrt{\frac{(a_{y1} - a_{y-1})^2 + (a_{x1} - a_{x-1})^2 + (a_{z1} - a_{z-1})^2}{100}}$$

In the formula, "ay" represents forward (anterior–posterior), "ax" represents lateral (medial–lateral) and "az" represents vertical acceleration. While the early sensors were 55mm x 34mm x 12mm and 22g, both memory increase and wireless connectivity were developed in the second generation production (13). In the future, the memory capacity of wearable devices needs to increase and by integrating 4.1 sensor elements in 2020, this problem was solved and an almost 3-fold increase was achieved (8). The data provided by the software of wearable technologies sold as commercial products are processed and prepared for the end user. For this reason, the problems encountered such as not providing raw data to work at research level and not specifying the algorithms used by some companies in calculations stand out.

#### Usage in Player Load and Injury risk Relationship

Thanks to this novel approach "Wearable Technology", it is aimed to reduce the probability of injuries such as tendon damage, fatigue and concussion in athletes. It is known that athletes' potential injury risk can be reduced with player load optimization (12). Recently, Gabbett (2016) emphasized in the Training-Injury Prevention paradox that athletes who have adapted to these high loads, who are exposed to high training volume, have less risk of injury than athletes working with low volume (14). Developments in wearable technology offer the opportunity to reduce the risk of injuries related to sports, as it allows monitoring, tracking and modification of athlete training and match load. Determination of neuromuscular fatigue facilitates the load management of athletes and allows player rotation and changes during the match and reduces the risk of injury (3). Recent studies focus on fatigue-sensitive measurements rather than traditional locomotor activities with accelerometer or GPS-based sensors. Accordingly, during the match, the reduction in the contribution of the total accelerometer load on the vertical axis to the player load (6), the ground contact time and the vertical

stiffness (15) parameters are gaining importance with wearable devices.

It is known that there is a relationship between running injuries and running mechanics and economy. Increased hip abduction and vertical impact load in running mechanics are mostly factors that lead to injury (9, 27). Using wearable devices that make real-time identification in running pattern correction training can transfer hip and knee kinematics data in the field instead of simple parameters such as running step footwork pattern, frequency of steps and tibial shock. Thus, tendon and joint loads are not assessed by subjective feedback from athletes. Increasing the data storage capacity of future products will facilitate the evaluation of records taken from long-term runs such as marathons, as well as IMU and algorithms will help the decision to return to sports by allowing the lower extremity bone, ligament and joint loads to be viewed and adjusted according to injury.

#### Commercial Products

One of the wearable technology applications is its use in determining the activity pattern. It has become widespread to use accelerometer when GPS signals cannot be used indoors to define sport specific movements or when movement occurs in three axes. The Adidas miCoach Elite System is used in the American Professional Football League (Major League Soccer, MLS). In addition, German National Football Team benefited from this system in 2014 FIFA World Cup, where it became the champion. The system contributes to the decisions of the coach by sending an instant feedback of individual performance from the speed, acceleration, distance, power and heart rate data to the coach and protects the athlete about potential injuries.

Developed in cooperation with American entrepreneurs in the professional racing world and the automotive giant Renaults' sports technology department, the application provides instant display of car speed, distance and heart rate information with a shirt worn by professional racers. Other basic parameters such as lap times, acceleration forces are also used to increase athlete performance. Another commercial product, the Kinexon, uses Radio Frequency Identification (RFID) to precisely locate players' positions and movements (acceleration and leap). It was officially used by players and referees in the 2017-18 final game of Next Generations Tournament in the European League in basketball. Further, Catapult is an Australian company and is

probably the first company to apply wearable technologies to sports. Approximately half of the teams of the American National Football League (National Football League, NFL) and approximately 1/3 of the teams of the National Basketball Association (NBA) use this system. Through to a sensor integrated into the commercial boxing glove called the Hykso, it provides feedback to the coach on the number, type and speed of punches thrown. The VERT Wearable Jump Monitor is another commercial wearable technology product actively used by US national teams in the volleyball, where vertical jumping is a very important performance component. In team sports, which play with a ball, the ball is tracked with sensors integrated into it, the number of shots and passes, and their speed can be measured, and the trajectory, angle and spin tracking provide technical corrections and suggestions.

## CONCLUSION

In this study, the basic working principles of wearable technology products, which are more commonly used to improve sports performance, and the parameters followed in athletes are reviewed. In addition, attention was drawn to the areas that stand out from commercial products in the market and are used most. While the data processing of the sensors, whose use is prominent in displaying player load, determining activity patterns and preventing disability, continues at the research level with different algorithms, it is seen that commercial products give feedback through applications that are easier to reach the end user. Since the development in the sensor technology used in these products can enable us to obtain more detailed information, the data of current studies should be closely followed in their use in sports. Despite the widespread use of these technologies, one of the disadvantages is that there is no definite opinion about the processing of the data here and the metrics used during calculation and analysis. A new metric and high performance claim suggested in each new article suggests that there is still a long way to go.

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