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Wearable Sports Technologies

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ABSTRACT

Today, wearable monitoring systems created thanks to technological advances are integrated into the human body and are widely used in many fields from sports to health. These systems, in which multiple disciplines work together simultaneously, provide physiological and biochemical data, enabling the determination of the current situation and the creation of appropriate performance and improvement programs for individuals. In this review study, 23 articles, 4 of which were review articles, published in the Sports Sciences category on the Web of Science database in 2024 were examined using the keywords "wearable technology" and "sports". As a result of the review of these articles, it was determined that 8 articles were not related to the subject of wearable technologies in sports and were removed from the review (19 articles were included in the study). When studies on wearable technology in the field of sports sciences are examined, most studies are conducted on runners, and performance monitoring and injury prevention are among the main reasons for using this innovative technology. Considering the increasing technological developments, it is evaluated that the studies in this field will increase in parallel with this development and will make great contributions to the field of sports sciences.

1. INTRODUCTION

The role of technological products in sports, which exist in every aspect of our lives, has changed drastically with the developments in technology and digitalization. With the emergence of the internet and mobile technologies, technology has become indispensable for many sports [1].

Technology has contributed to playing sports potentially more exciting and challenging than ever before, playing a "vital role in being the best on and off the field" [2]. In these challenging conditions of high competition and performances that exceed human limits, the sports industry increasingly needs the use of technology to facilitate performance improvements [3].

Today, sport utilizes technology at the highest level, which has led to rapid advances in many sports [4]. However, technology has started to be used not only for performance improvement but also in the field of health to help individuals lead a healthier life and to understand the complex structure of the body. Collecting patient data with technological devices also informs healthcare professionals and influences their treatment decisions [5].

Wearable devices, which can be used daily in both sports and health fields and can provide information flow with numerical data, show a rapidly growing trend in this technology network [6]. This study aims to examine the studies on wearable technologies in the field of sports sciences in 2024.

Wearable Technologies

Although there are different definitions of wearable technology in the literature [7], it is defined as "tools that are comfortable to use and wearable, portable, have sensors, and provide information transfer even when not in active use" [8]. Although it seems to be a concept of today, the beginning of wearable technological devices dates back to the 16th century. Watches hung around the

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neck like necklaces took their first place in history as pocket watches that individuals carried with them [9]. On the other hand, the first wearable device example in the literature was produced to benefit the user by cheating in the roulette game. A device placed on the sole of the shoe informed the user which number would come out thanks to the vibrations it sent to the person, thus benefiting the user [10]. Today, wearable devices can be in many different forms such as watches, glasses, and wristbands [11]. These networked smart devices equipped with wireless communication capabilities [12] (Fig. 1.) can collect data, monitor activities, and customize experiences according to users' wishes and needs [13].

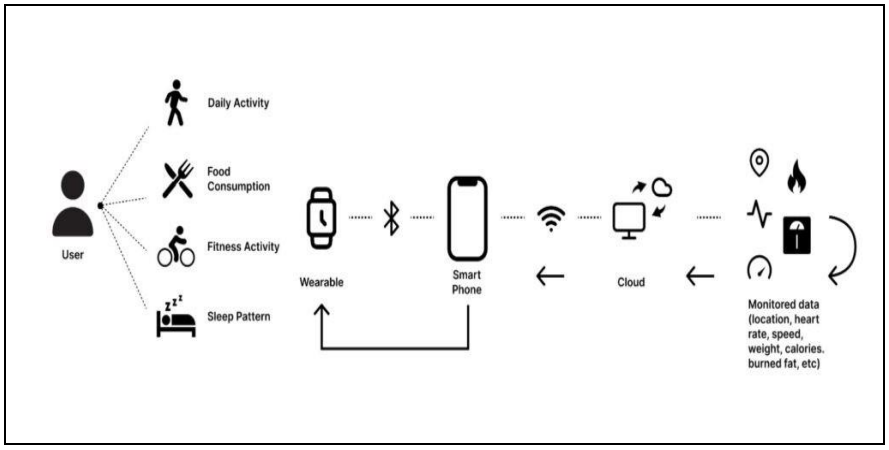

Figure 1. Block diagram example of a fitness wearable device process. [12]

When wearable devices work, there are 3 phases:

I. The first stage is sensors. Sensors are placed as close to the body as possible to monitor temperature, movement, and pulse.

II. The second stage is the connectivity and control part. Connecting via Bluetooth is the most widely used protocol for connecting wearable devices to a smartphone or home network.

III. The third phase is the data provision and reading of the wearable device [14].

The Place of Wearable Technology in Our Lives

Wearable technology products have now entered many areas of human life. Today, developing technology has accelerated the transition of societies from industrial society to information society. With this rapid transition, the contribution of wearable technological products, whose production and sales have increased, to the economy cannot be ignored. There is strong competition among wearable technologies, which have a wide market, and new features are added or completely renewed to the products produced daily. Companies' race to adapt to this changing and developing technology greatly affects the integration of wearable technology products in different sectors such as health, textiles, education, entertainment, and tourism [15]. The wearable technologies market has become increasingly competitive with new products designed to provide consumers with access to more services. China is the largest market for wearables and the US is the second largest. The market is growing strongly as low-cost products and basic devices attract new users [16]. In this market race, sensors and microprocessors in devices can be integrated into garments to increase the functionality of sportswear, even at invisible dimensions [17].

Places of Use

Ergonomic and anthropometric positioning of wearable devices is crucial for success, regardless of the intended use (e.g., athlete performance improvement, health). Consumers need to know the movement limitations when wearing the device before purchasing [18]. Data shows that wrist devices are preferred for ease of use [12] (Fig. 2.). However, despite the rapid increase in the use of these smartwatches and wristbands, some functional difficulties can also be experienced due to sensitive skin on the wrist skin due to application sites, poor attachment problems due to displacement, and motion artifacts (sudden high-frequency activity) [19].

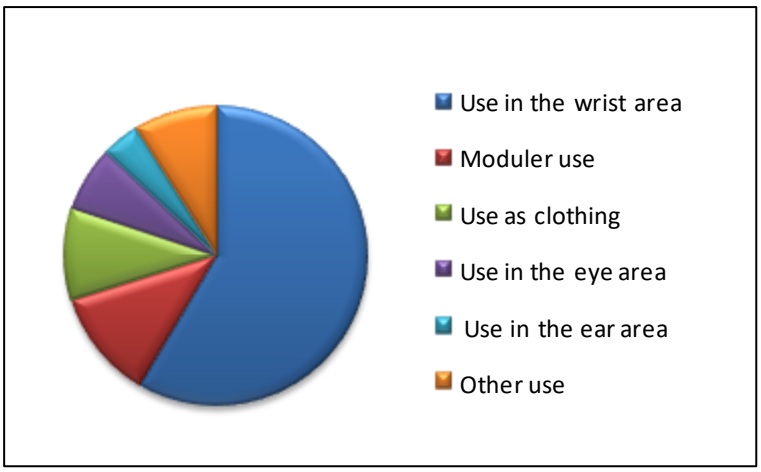

Figure 2. Worldwide wearable device shipments projected 2020

The main function of technological products used on the wrist among wearable devices is to monitor the basic characteristics of the body (such as heart rate, blood pressure, and concentration levels). These products make recommendations such as increasing the level of exercise or visiting a doctor [20]. Smart watches and wristbands (Figure 3.) have a wireless Bluetooth adapter that connects to a smartphone. With such devices, users can perform many actions such as answering phone calls, reading text messages and e-mails, analyzing physical activities, tracking fitness and health-related activities, and listening to music [21]. The use of these devices also dates to recent history. These devices are easy to use, compatible with many lifestyles, and allow tracking much more data than smartphones [22]. Apart from these popular body-worn devices (wrist), there are also modular equipment with embedded sensors or smart textiles [23]. The aim of these different approaches to wearable technology in sports is to enable users to track their performance in the best possible way without hindering any movement. This also depends on where the sensor is placed in the equipment, whether it is an accessory or not [24, 25]. In some sports, such as soccer, there is an external factor that affects biomechanical movements. Soccer shoes with sensors on the outsole are known to generate data showing the maneuvering characteristics of the ball (Figure 3.). It would be useful to monitor how the same sensors react when placed inside the shoe (insoles) (Figure 3.). Correlating this with precise biomechanical movements allows the user to maximize the understanding of their movements. The opportunity to self-learn different ways to improve devices is a great function of human-centered design [26].

With the advances in technology, flexible sensors, conductive yarns, and materials with smartphone features have been developed and embedded in clothing [27, 28]. These devices can be used without the need to place them in any accessory as in modular use, and the clothing design itself has been made suitable for monitoring data [29]. A wearable product, referred to as a smart shirt, can measure important body variables such as heart rate, breath rate, heart rhythm patterns, calorie intake, sugar, and blood pressure (Figure 3.), record their values via a digital assistant, and notify with an audible warning system in case of a negative situation [30-32]. Similarly, smart socks (Figure 3.), a product called “Owlet”, were developed for babies by Jacob Colvin, an academic at Brigham Young University, and enabled the monitoring of values such as heart rhythm and body temperature from smartphones [33].

Wearable technological devices are also involved in visual and auditory mechanisms. Like a minicomputer that contains images and sounds from the outside world, they have internal and external sensors that can collect data from computers, smartphones, and other electronic devices. Moreover, these devices have wireless connections that support GPS, Wi-Fi, and Bluetooth, allowing users to connect to the internet, watch videos and listen to audio. Some smart glasses also include facial recognition software, built-in cameras, GPS, and other applications[34].

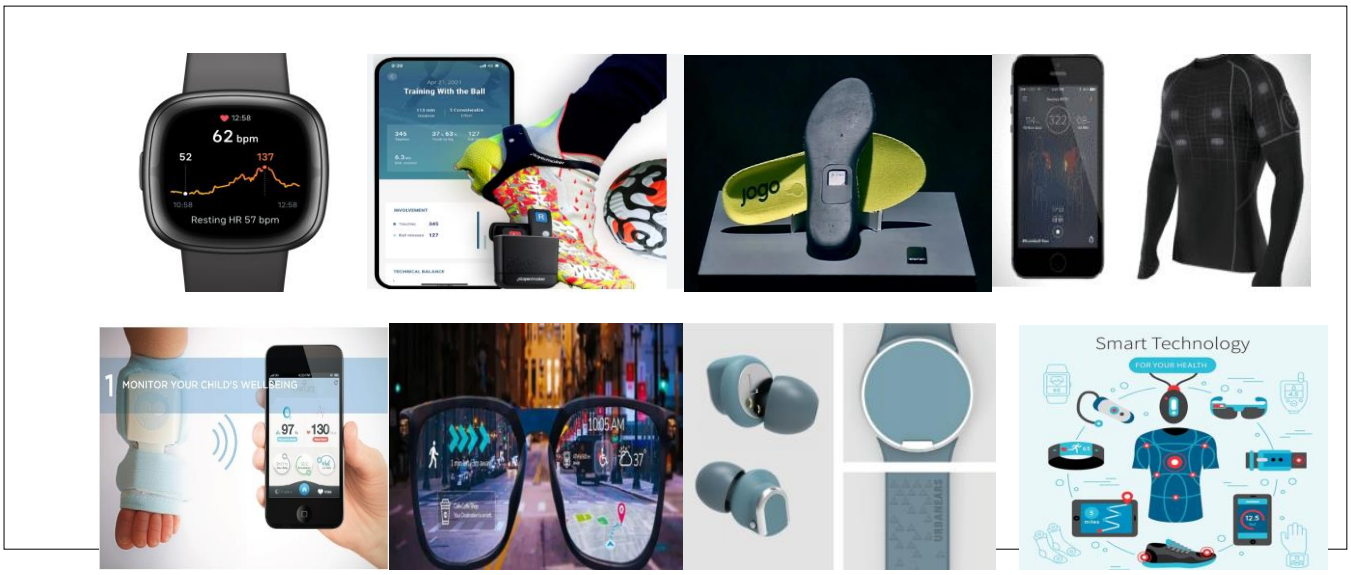

Figure 3. Wearable technological products used in the field of Sports Sciences

Performance athletes and the use of wearable technology

Wearable technologies are now accepted and widely used in numerous sports and fitness activities across all performance levels, from recreational athletes to professionals, individual sports, and team sports, including non-disabled athletes [35]. Wearables can track athletes' performance (e.g., distance and speed) and the techniques they use to produce that performance (e.g., joint angles). The most common types of wearable devices available are typically wrist-worn smartwatches, chest straps, devices mounted on or inside shoes, or, more recently, devices built into sportswear [12]. Analysis of the data obtained with these devices can be used to measure subsequent fitness improvements, help reduce the risk of injury [36, 37], monitor recovery [38], monitor technique [39], or simply increase motivation at the user level [40]. Typical sensors used in wearable technologies are as follows:

- Inertial measurement units (e.g. accelerometers),
- Global positioning systems (GPS-based tracking devices)
- Heart rate sounders (electrocardiography, ECG)
- Muscle stimulation sensors (electromyography, EMG)

People with disabilities and the use of wearable technology

Today, wearable technologies lack accessibility for people with disabilities. However, considering the high accessibility in the laboratory stage, new developments in wearable technologies can be observed. When we look at some of these developments; a device called “Goby” [41], a swimming aid for visually impaired individuals, can prevent the athlete from going out of the lane and hitting the wall in turns by sending audio feedback with a camera placed on the body facing down in the water (Figure 4).

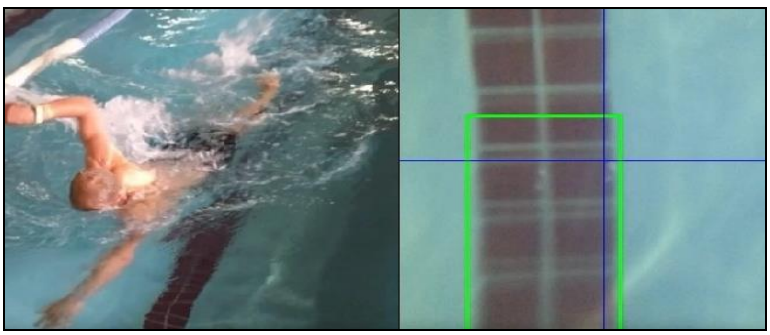

Figure 4. Goby is a wearable device that provides audio feedback for swimmers. Left: A swimmer wearing the Goby prototype in the pool. Right: Goby's wearable camera identifies and tracks a lane marker at the bottom of the pool [41].

Use of wearable technology in healthcare

Wearable technologies have been applied in exercise physiology, rehabilitation and other disciplines and have become a convenient tool for nurses and other healthcare professionals. These devices can provide information about important parameters related to the patient, such as location, heart and respiratory rate via GPS (Global Positioning System), and also have diagnostic applications that help in clinical decision-making [5].

Difficulties such as increasing health costs, shortage of personnel, inadequate health services in underdeveloped regions have accelerated the transition to new technology instead of traditional health services [42]. With wearable health products, patients can be monitored regularly and continuously, and patients and doctors can be informed about the stages of the disease. Smart health products store information such as the user's blood sugar, pulse, sweating, and blood pressure [15]. During the monitoring of these variables, systems that can notify in case of symptoms such as deterioration in heart rhythm, loss of balance, low blood pressure, and even intervene in the first place have taken their place as important application areas in the field of health [43]. The benefits of wearable devices for clinical applications can be summarized as follows [44]:

- ✓ Ability to make and transmit simultaneous instant and accurate measurements,
- ✓ Patient follow-up in home environment
- ✓ Ensuring patient compliance and participation in treatment,
- ✓ Reducing costs that may arise from the need for clinics.

2. MATERIALS AND METHODS

2.1. Screening and identification of articles

''Web of Science'' search engine was utilized in this review study. The keywords ''wereable technology'' and ''sport'' were used for the search (Fig. 5.). The articles were identified as ''sport science'' (Fig. 6.) and ''review'' and “article” (Fig. 4.) and only studies conducted in 2024 were included.

Figure 5. Web of science ındex

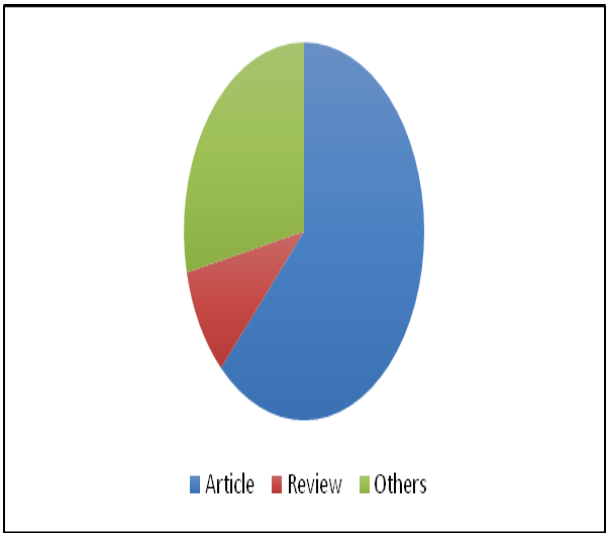

Figure 6. Publication types

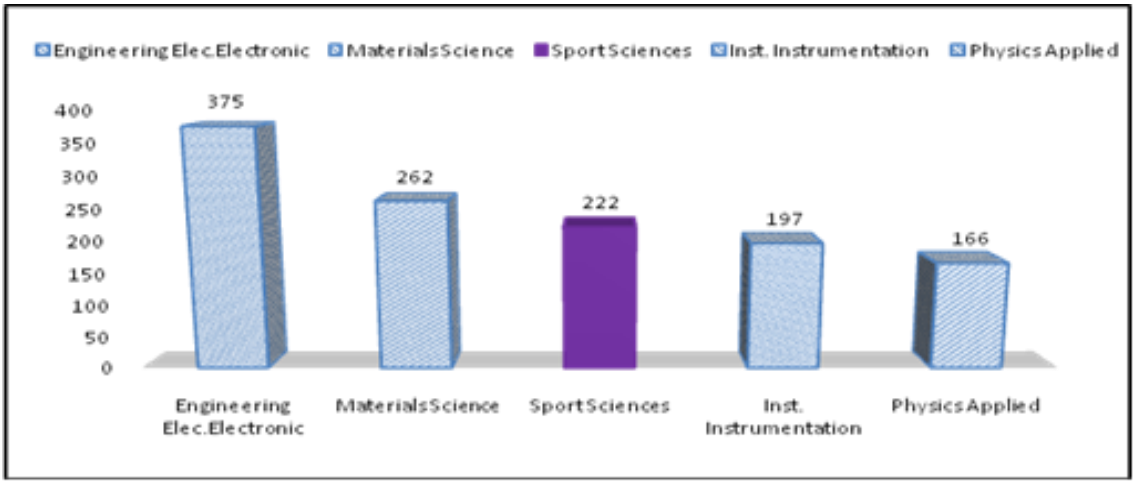

Figure 7. Number of publications by science fields

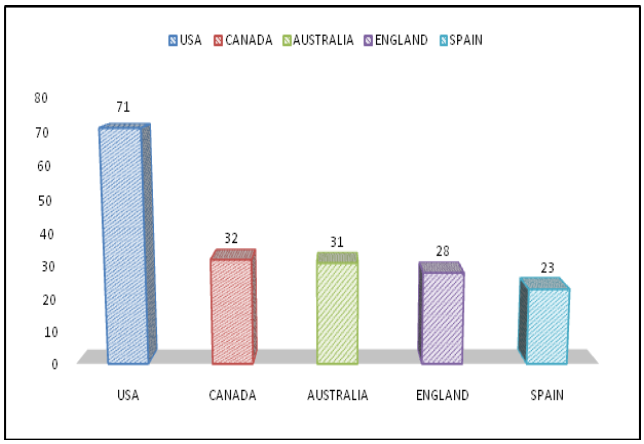

Figure 8. Number of publications by sport sciences

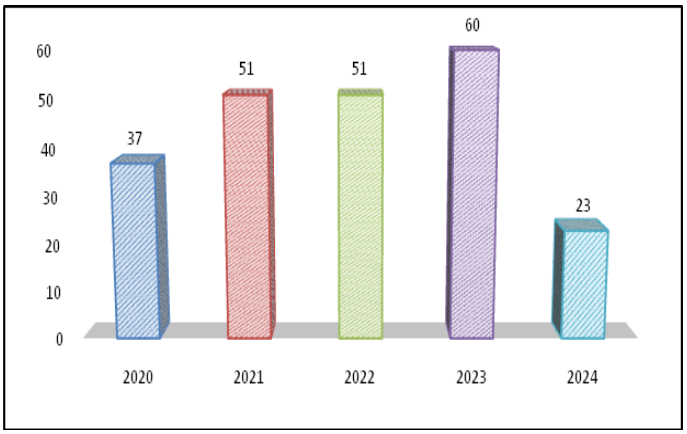

Figure 9. Number of publications in sports sciences by year

2.2. Statistical Analysis

In our study, descriptive statistics method was used. In the review, data on the year, method and methodology, sample group, areas where wearable technologies are used and results of the studies were used.

3. Results

Initially, 2906 publications on wearable technologies were reached (Fig. 5.) and review scans (Fig. 4.) were performed. The distribution of studies according to countries is shown (Fig. 6.). In the field of sports sciences, 222 studies were found (Fig. 7.) and their distribution by country was shown (Fig. 8.). 23 studies Article and 4 rewiev) from 2024 were found (Fig. 9.) In this study, 19 study articles were analyzed.

When the studies are examined, it is seen that they are mostly done on team sports [45-49] and runners [50-54]. When we look at the use of wearable technology in sports sciences, it is seen that performance tracking and analysis [45, 49, 51, 53-58] are the primary reasons for preference. In addition, it is observed that wearable technology is among the reasons for preference in preventing sports injuries. When the performance tracking of Paralympic athletes is evaluated, the point that wearable technology has reached is more clearly seen.

This technology is about to take its place among the indispensables in individual sports [58-60] and studies related to healthy living [61, 62]. The use of wearable technology also draws attention to determining the validity and reliability [47, 63] of tests and devices.

4. Conclusion

The rapid advancement of technology has enabled different disciplines to come together and produce new products.

The ever-growing wearable technology market continues to progress every day, attracting the attention of researchers and marketing professionals. In a field that is constantly updated, the continuity of research has also increased. The rapid advancement of technology provides a great deal of benefit. However, as it facilitates human life, it also brings some potentials. In the use of wearable technologies, it is very important to adopt these technologies, to use them effectively, to have sufficient knowledge and to evaluate the data obtained consciously.

Wearable technologies have opened the door to many exciting applications, leading to another technological revolution similar to the internet and mobile communication industries. They have been widely applied and preferred in industries such as electronics, fashion/textiles, education, health, defense, etc., which have a significant impact on world trade due to the convenience they provide. Wearable technologies have developed more and more every day and wearable technology products have become a part of everyday life. These developments are progressing to dizzying heights for both businesses and consumers. The underlying technology and logistics of wearables in healthcare are still in their infancy and more work is needed. As a result, more work needs to be done by physicians, programmers, and wearable device manufacturers to overcome logistical and practical barriers and ensure the seamless incorporation of wearables into the digital platforms of healthcare systems. In addition to the analysis of all this data, personal data security also stands before us as a very important security issue for wearable technological devices.

Considering the increasing technological developments, it is evaluated that the studies in this field will increase in parallel with this development and will make great contributions to the field of sports sciences.

Conflict of Interest

No conflict of interest is declared by the authors. In addition, no financial support was received.

Author Contributions

Study Design, DSSU, NEA; Literature Search, DSSU, NEA; Data Collection, DSSU, NEA; Manuscript Preparation, DSSU, NEA; All authors have read and agreed to the published version of the manuscript.

REFERENCES

1. Ratten, V. (2019). Sports technology and innovation. *Cham: Springer Books*, 95-111.
2. Schmidt, S. L. (2020a). 21st Century Sports (S. L. Schmidt (ed.). *Springer International Publishing.* [**CrossRef**]
3. Trabal, P. (2008). Resistance to technological innovation in elite sport. *International review for the sociology of sport*, *43*(3), 313-330. [**CrossRef**]
4. Haake, S. J. (2009). The impact of technology on sporting performance in Olympic sports. *Journal of Sports Sciences*, *27*(13), 1421–1431. [**PubMed**]
5. Wilson D. (2017). An Overview of the Application of Wearable Technology to Nursing Practice. *Nurs Forum,* (*52*), 124-132. [**PubMed**]
6. Emperador, V., Gasparyan, K., Hile, H., Jestice, M., & Teeple, A. (2014). Industry analysıs: wearable technology.Available online: https://www.csus.edu/indiv/h/hattonl/documents/WearableIndustry.docx (accessed on 1 June 2024).
7. Raj, D.&Ha-Brookshire, J. (2015). Exploration of Knowledge Creation Processesand Work Environments in the Wearable Technology Industry. *International Textile and Apparel Association Annual Conference Proceedings*, (*11*), 137.
8. Rhodes, B.J. (1997). The wearable remembrance agent: A system for augmented memory. *Personal Technologies 1*, 218–224. [**CrossRef**]
9. Desjardins, J. (2015). The History of Wearable Technology. Visual Capitalist.
10. Sağbaş, E. A., & Ballı, S. (2016). Wearable Smart Devices: Past, Present and Future. *Academic Informatics Conference*, February 3-5, Aydın.51.
11. Ching, K. W.& Singh, M. M. (2016), "Wearable Technology Devices Security And Prİvacy Vulnerability Analysis", International Journal of Network Security &Its Applications,8 (3), 19-30. [**CrossRef**]
12. Aroganam, G., Manivannan, N., & Harrison, D. (2019). Review on wearable technology sensors used in consumer sport applications. *Sensors*, *19*(9), 1983. [**PubMed**]
13. Thierer, A. (2015). The ınternet of things and wearable technology: Addressing privacy and security concerns without derailing ınnovatio. *Richmond journal of law&technology*, 21 (2). http://jolt.richmond.edu/v21i2/article6.pdf
14. Infinite Information Technology (2019). IoT Wearables – Wearable Technology. Available: http://www.infiniteinformationtechnology.com/iot-wearableswearable-technology
15. Kılıç, H. Ö. (2017). Wearable technology products market and usage areas. *Journal of Aksaray University Faculty of Economics and Administrative Sciences*, *9*(4), 99-112.

16. Chowdhury, H. (2018). China's Xiaomi takes lead over Apple as top seller of wearable technology globally, Available: https://www.telegraph.co.uk/technology/2018/12/04/chinasxiaomi-takes-lead-apple-top-seller-wearable-technology/
17. Komolafe, A., Torah, R., Wei, Y., Nunes-Matos, H., Li, M., Hardy, D., ... & Beeby, S. (2019). Integrating flexible filament circuits for e-textile applications. *Advanced Materials Technologies*, *4*(7), 1900176. [**CrossRef**]
18. Kalantari, M. (2017). Consumers' adoption of wearable technologies: literature review, synthesis, and future research agenda. *International Journal of Technology Marketing*, *12*(3), 274-307. [**CrossRef**]
19. Auepanwiriyakul, C., Waibel, S., Songa, J., Bentley, P., & Faisal, A. A. (2020). Accuracy and acceptability of wearable motion tracking for inpatient monitoring using smartwatches. *Sensors*, *20*(24), 7313. [**PubMed**]
20. Coşar, M. Ş. (2016). What is Wearable Technology? https:// www.wearlogy.com/wearable-technology-what-is /3/, (15.02.2017).
21. Rouse, M. (2014). Internet of Things (IOT),[ONLINE] Available: http://whatis. techtarget. com/definition. *Internet-of-Things [Acedido em 23 Junho 2015]*.
22. Bove, L. A. (2019). Increasing patient engagement through the use of wearable technology. *The Journal for Nurse Practitioners*, *15*(8), 535-539. [**CrossRef**]
23. Kamišalić, A., Fister Jr, I., Turkanović, M., & Karakatič, S. (2018). Sensors and functionalities of non-invasive wrist-wearable devices: A review. *Sensors*, *18*(6), 1714. [**PubMed**]
24. Ferraro, V. (2015). Smart textiles and wearable technologies for sportswear: a design approach. *Sensors and Applications*. [**CrossRef**]
25. Ebling, M. R. (2016). IoT: From sports to fashion and everything in-between. *IEEE Pervasive Computing*, *15*(04), 2-4. [**CrossRef**]
26. Zhou, B., Koerger, H., Wirth, M., Zwick, C., Martindale, C., Cruz, H., ... & Lukowicz, P. (2016, September). Smart soccer shoe: monitoring foot-ball interaction with shoe integrated textile pressure sensor matrix. In *Proceedings of the 2016 ACM International Symposium on Wearable Computers* (pp. 64-71).
27. Anzaldo, D. (2015, November). Wearable sports technology-Market landscape and compute SoC trends. In *2015 International SoC Design Conference (ISOCC)* (pp. 217-218). IEEE.
28. Patel, S., Park, H., Bonato, P., Chan, L., & Rodgers, M. (2012). A review of wearable sensors and systems with application in rehabilitation. *Journal of neuroengineering and rehabilitation*, *9*, 1-17. [**PubMed**]
29. Awolusi, I., Marks, E., & Hallowell, M. (2018). Wearable technology for personalized construction safety monitoring and trending: Review of applicable devices. *Automation in construction*, *85*, 96-106. [**CrossRef**]
30. Park, S., & Jayaraman, S. (2003). Enhancing the quality of life through wearable technology. *IEEE Engineering in medicine and biology magazine*, *22*(3), 41-48. [**PubMed**]
31. Park, S., & Jayaraman, S. (2004). e-Health and quality of life: the role of the Wearable Motherboard. *Stud. Health Technol. Inform*, *108*, 239-252. [**PubMed**]
32. Park, S., Gopalsamy, C., Rajamanickam, R., & Jayaraman, S. (1999). The Wearable Motherboard [C]: A Flexible Information Infrastructure or Sensate Liner for Medical Applications. *Studies in health technology and informatics*, 252-258. [**PubMed**]
33. Boyacıoğlu, K. (2015). *Global Ekonominin Yeni Trendi: Giyilebilir Teknoloji*.
34. Schweizer, H. (2014). Smart glasses: technology and applications. *Student report*.
35. Rum, L., Sten, O., Vendrame, E., Belluscio, V., Camomilla, V., Vannozzi, G., ... & Bergamini, E. (2021). Wearable sensors in sports for persons with disability: A systematic review. *Sensors*, *21*(5), 1858. [**PubMed**]
36. Clermont, C. A., Duffett-Leger, L., Hettinga, B. A., & Ferber, R. (2020). Runners' perspectives on 'smart'wearable technology and its use for preventing injury. *International Journal of Human–Computer Interaction*, *36*(1), 31-40. [**CrossRef**]
37. Benson, L. C., Räisänen, A. M., Volkova, V. G., Pasanen, K., & Emery, C. A. (2020). Workload a-WEAR-ness: monitoring workload in team sports with wearable technology. A scoping review. *Journal of Orthopaedic & Sports Physical Therapy*, *50*(10), 549-563. [**PubMed**]
38. Di Paolo, S., Lopomo, N. F., Della Villa, F., Paolini, G., Figari, G., Bragonzoni, L., ... & Zaffagnini, S. (2021). Rehabilitation and return to sport assessment after anterior cruciate ligament injury: quantifying joint kinematics during complex high-speed tasks through wearable sensors. *Sensors*, *21*(7), 2331. [**PubMed**]
39. Rana, M., & Mittal, V. (2020). Wearable sensors for real-time kinematics analysis in sports: A review. *IEEE Sensors Journal*, *21*(2), 1187-1207. [**CrossRef**]

40. Rupp, M. A., Michaelis, J. R., McConnell, D. S., & Smither, J. A. (2018). The role of individual differences on perceptions of wearable fitness device trust, usability, and motivational impact. *Applied ergonomics*, *70*, 77-87. [**PubMed**]
41. Muehlbradt, A., Koushik, V., & Kane, S. K. (2017). Goby: A wearable swimming aid for blind athletes. In *Proceedings of the 19th international acm sigaccess conference on computers and accessibility* (pp. 377-378). [**CrossRef**]
42. Baş, Ş. (2011). A patient monitoring system proposal to be realized with the use of personal area networks and wearable computers. *Department Master Thesis*
43. Bonato, P. (2010, August). Advances in wearable technology and its medical applications. In *2010 annual international conference of the IEEE engineering in medicine and biology* (pp. 2021-2024). IEEE. [**PubMed**]
44. Rodgers, M. M., Pai, V. M., & Conroy, R. S. (2014). Recent advances in wearable sensors for health monitoring. *IEEE Sensors Journal*, *15*(6), 3119-3126. [**CrossRef**]
45. Dawson, L., McErlain-Naylor, S. A., Devereux, G., & Beato, M. (2024). Practitioner usage, applications, and understanding of wearable GPS and accelerometer technology in team sports. The Journal of Strength & Conditioning Research, 38(7), e373-e382. [**PubMed**]
46. Cormier, P., Meylan, C., Agar-Newman, D., Geneau, D., Epp-Stobbe, A., Lenetsky, S., & Klimstra, M. (2022). A Systematic Review and Meta-Analysis of Wearable Satellite System Technology for Linear Sprint Profiling: Technological Innovations and Practical Applications. The Journal of Strength & Conditioning Research, 10-1519. [**PubMed**]
47. Düking, P., Ruf, L., Altmann, S., Thron, M., Kunz, P., & Sperlich, B. (2024). Assessment of Maximum Oxygen Uptake in Elite Youth Soccer Players: A Comparative Analysis of Smartwatch Technology, Yoyo Intermittent Recovery Test 2, and Respiratory Gas Analysis. Journal of Sports Science & Medicine, 23(2), 351. [**PubMed**]
48. Han, X. (2024). Decısıon Support For Basketball Athlete Injury Protectıon Based On Pattern Recognıtıon. Revista multidisciplinar de las Ciencias del Deporte, 24(95).
49. Salim, F. A., Postma, D. B., Haider, F., Luz, S., Beijnum, B. J. F. V., & Reidsma, D. (2024). Enhancing volleyball training: empowering athletes and coaches through advanced sensing and analysis. Frontiers in Sports and Active Living, 6, 1326807. [**PubMed**]
50. Reiter, A. J., Martin, J. A., Knurr, K. A., Adamczyk, P. G., & Thelen, D. G. (2024). Achilles Tendon Loading during Running Estimated via Shear Wave Tensiometry: A Step Towards Wearable Kinetic Analysis. Medicine and Science in Sports and Exercise.
51. Van Hooren, B., Plasqui, G., & Meijer, K. (2024). The effect of Wearable-based real-time feedback on running injuries and running performance: a randomized controlled trial. The American Journal of Sports Medicine, 52(3), 750-765. [**PubMed**]
52. Weidensager, L., Krumm, D., Potts, D., & Odenwald, S. (2024). Estimating vertical ground reaction forces from plantar pressure using interpretable high-dimensional approximation. Sports Engineering, 27(1), 3. [**CrossRef**]
53. Thome, M., Nimphius, S., Jordan, M. J., & Thorpe, R. T. (2024). Relationship Between External Training Load and Session Rating of Perceived Exertion Training Impulse in Elite Sprinters. International Journal of Sports Physiology and Performance, 1(aop), 1-6. [**PubMed**]
54. Van Hooren, B., Jukic, I., Cox, M., Frenken, K. G., Bautista, I., & Moore, I. S. (2024). The relationship between running biomechanics and running economy: a systematic review and meta-analysis of observational studies. Sports Medicine, 1-48. [**PubMed**]
55. Nikolis, L., Graff, C., Nikolis, A., & Tow, S. (2024). Wearable electronic devices in parasports: A focused review on para athlete classification. PM&R, 16(4), 404-408. [**PubMed**]
56. Luo, C., & Yang, H. (2024). Athlete training load monitoring using sensor-based technology and motion image analysis. Revista multidisciplinar de las Ciencias del Deporte, 24(94).
57. Chahin-Inostroza, N., Bracho-Milic, F., Velasco-Bahamonde, E., Navarrete-Hidalgo, C., & Serón, P. (2024). Impact of the COVID-19 pandemic on training and technology use among Chilean amateur athletes. Frontiers in Sports and Active Living, 6, 1302023. [**PubMed**]
58. Hu, X., Zhang, W., Ou, H., Mo, S., Liang, F., Liu, J., ... & Qu, X. (2024). Enhancing squat movement classification performance with a gated long-short term memory with transformer network model. Sports Biomechanics, 1-16. [**PubMed**]
59. Cheng, K. C., Chiu, Y. L., Tsai, C. L., Hsu, Y. L., & Tsai, Y. J. (2024). Fatigue Affects Body Acceleration During Vertical Jumping and Agility Tasks in Elite Young Badminton Players. Sports Health, 19417381241245908. [**PubMed**]

60. Jayakumar, B., & Govindarajan, N. (2024). Multi-sensor fusion based optimized deep convolutional neural network for boxing punch activity recognition. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 17543371241237085. [**CrossRef**]
61. Lordall, J., Oates, A. R., & Lanovaz, J. L. (2024). Spatiotemporal walking performance in different settings: effects of walking speed and sex. Frontiers in Sports and Active Living, 6, 1277587. [**PubMed**]
62. Ferrara, P. M. M., Zakrajsek, R. A., Eckenrod, M. R., Beaumont, C. T., & Strohacker, K. (2024). Former NCAA Division I athletes' perceptions of intervention components to improve post-sport physical activity. Journal of Applied Sport Psychology, 1-19. [**CrossRef**]
63. Szot, T. (2024). Evolution of sport wearable global navigation satellite systems' receivers: A look at the Garmin Forerunner series. Proceedings of the Institution of Mechanical Engineers, Part P: Journal of Sports Engineering and Technology, 17543371241237319. [**CrossRef**]