WEARABLE TECHNOLOGIES

DR. EDA ACAR
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DOI: https://dx.doi.org/10.5281/zenodo.10495406

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(The Licence Number of Publicator: 2014/31220)
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ISBN: 978-625-367-621-6
Cover Design: İbrahim KAYA
December / 2023
Ankara / Türkiye
Size = 14,8x21 cm

PREFACE

The rapid development of today's technology significantly influences our lifestyle and daily activities. Alongside this change, next-generation devices, especially wearable technologies, come to the forefront. These technologies that touch our lives not only make life easier but also play a crucial role in various sectors such as health, sports, and the military.

Wearable technologies have become an essential field, facilitating daily life and reducing the workload of professionals in areas like health and the military. They are also used for continuous monitoring of individuals' location and health status, as well as tracking and assessing changes in body parameters during daily activities like sports.

This book aims to provide a comprehensive guide to readers who want to understand the complexity, learn the history, and foresee the potential of wearable technology. Wearable technologies encompass a wide range of products, from those directly integrated into different parts of the body to designs integrated with textile products. The book emphasizes the significance of wearable technologies in the textile industry by addressing how textiles interact with these technologies to understand this diversity.

Together with this book, the development of wearable technology, its applications, advantages, and disadvantages are thoroughly researched. It seeks to inform the reader about the current significance and future production-marketing potential by introducing wearable technology applications in various areas, ranging from smartwatches to garments that can measure body parameters.

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INTRODUCTION

After the industrial revolution, manufacturers striving to create differentiation in the face of increased competition are placing greater emphasis on the technological element. Wearable technologies, products innovatively created with the assistance of technology, can be considered one of the most crucial technological elements of the 21st century (Çakır et al., 2018). Wearable technology products have emerged to meet the demands of individuals who seek access to information while on the move, rather than being confined to a fixed location. These products can be successful by combining fashion and technology to provide both functionality and aesthetics simultaneously (Kılıç, 2017).

The convergence of clothing and technology has transformed today's wearable technologies, turning the human body into a carrier for technology. Factors influencing the wearable technology market include the increasing market share of technical textiles, the development of portable and user-friendly smart garments, growing health consciousness, high production costs, and technological advancements. These significant factors have contributed to the adoption of wearable devices in various sectors such as health, defense, entertainment, and industry (Karamehmet, 2019).

The global market for wearable technology reached a value of USD 61.30 billion in 2022 and is forecasted to experience a compound annual growth rate (CAGR) of 14.6% from 2023 to 2030 (Figure 1). The growth of the industry is

driven by the growing adoption of smart wearable technology products by consumers. These devices play a vital role in health monitoring, tracking metrics like cholesterol levels, calories burned, and oxygen levels through integrated sensors. Additionally, many companies are introducing wearable technology watches and accessories that come with health tracking solutions. This functionality is expected to appeal to consumers, providing them with the means to monitor their health and contributing to the overall expansion of the market (Grand View Research, 2023).

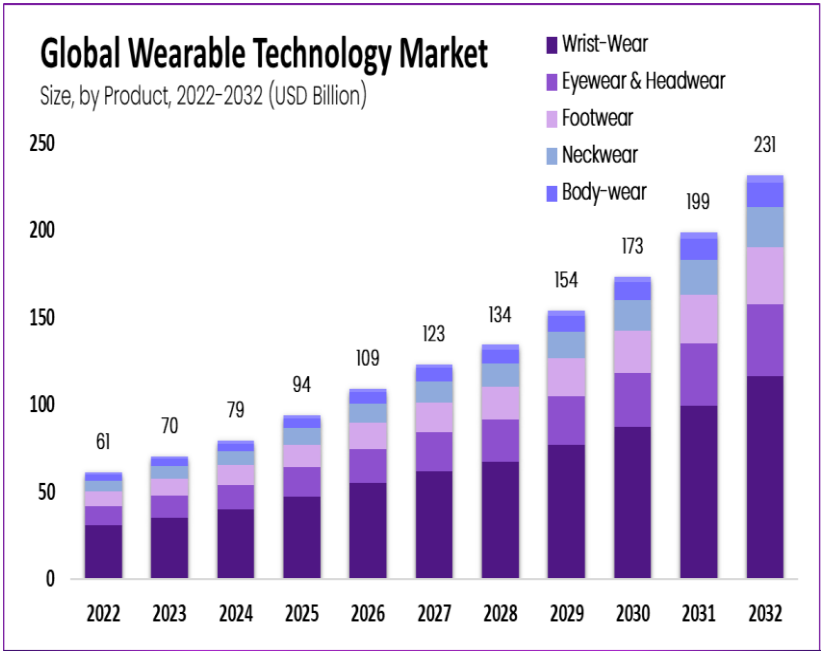

Figure 1. Global wearable technology market(https://market.us/report/wearable-technology-market/)

According to a study, wearable technology products are predominantly utilized in the fields of sports and health (Sultan, 2015).The graph for wearable technologies on a segment basis for the year 2022 is provided below (Figure 2). In 2022, the consumer electronics application segment emerged as the leading sector in the wearable technology industry, contributing to more than 48.95% of the total revenue. The healthcare segment is expected to experience the second-highest growth rate from 2022 to 2030. The expanding use of wearable devices in the pharma sector is projected to drive growth in this segment throughout the forecast period.

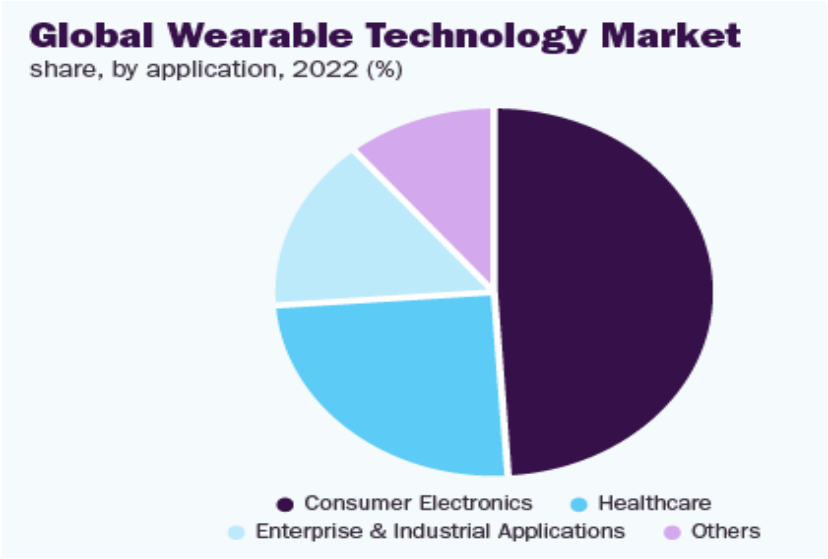

Figure 2. Global wearable technology market segment(Grandview Research, 2023).

Growth in wearable technology products is rapidly advancing from both a business and consumer perspective. The substantial market potential for businesses is crucial for the emergence and implementation of innovative and creative ideas. The introduction of products that enhance and simplify consumers' lives is a promising development. The race for businesses to adapt to evolving technology significantly influences the integration of wearable technology products in sectors such as health, textiles, education, entertainment, and tourism (Kılıç, 2017). In the present day, technology companies are increasingly directing their focus toward wearable technology. Creating wearable technology designs that combine technology with clothing in terms of functionality and ergonomics involves complex processes. The realization of these designs requires expertise and knowledge from various fields. It is expected that functional products will also appeal to consumers' personal expectations and preferences as aesthetically pleasing items (Değerli, 2019).

As an example of the earliest known wearable technology in history, pocket watches used in the 16th century are often cited. Wearable designs emerged in 1850 with the use of various corsets and belts for electrotherapy purposes (Gürcüm vd., 2015).

In today's context, wearable technology products, which are categorized into several types, can be used for various purposes. These include smartwatches, smart clothing, smart shoes, head-mounted displays, smart wristbands, smart jewelry,

smart glasses, and computers embedded in the body. However, as evident from the given examples, in applications utilizing wearable technologies that attract significant attention, the importance of information security is paramount. In such application areas, potential security threats must be thoroughly examined, and necessary precautions should be taken (Bostancı, 2016). The pairing of wearable technologies with their associated main devices and the transfer of data pose a risk, as certain information may be copied and backed up without the users' knowledge (Lee et al., 2018). Additionally, there are challenges in terms of the constant need for recharging, the importance of regular data recording, and despite efforts to reduce costs by making sensors smaller every day, there are still issues regarding clothing comfort. Desired features in wearable electronics from a user perspective include having a comfortable and flexible structure, being easily washable and cleanable, easy to recharge, and offering a variety of designs and uniqueness (Öymen, 2017).

With the fast pace of life and evolving human needs, many people have now begun to adopt wearable technology products. In the realm of wearable technology, which is increasingly becoming a part of daily life, the impact of design is significant from a consumer preference perspective. In terms of design, products should be produced in a way that allows them to seamlessly integrate into daily life, offering comfort without compromising on elegance. The design should make the wearer feel psychologically comfortable. In addition to design,

considering the relatively high cost of these products, ensuring their longevity and durable use is crucial for consumers. The process of creating wearable technology is a technical matter, but its journey to reaching the user involves contributions from various disciplines such as electronics, computer science, fashion, and design (McCann and Bryson, 2009). Leveraging advancing technology through multidisciplinary collaborations has led to the emergence of innovative products. Achieving both functionality and aesthetics simultaneously in wearable technology products can be successful through the integration of design and technology. Addressing challenges related to user interaction and commercialization in wearable technology products can be facilitated by forming interdisciplinary teams (McCann and Bryson, 2009). This approach allows experts from different fields to collaborate and contribute to the resolution of issues related to user experience and marketability.

Wearable technologies, rapidly growing alongside the omnipresence of the internet in all aspects of our lives, are considered a trend whose impacts will be increasingly felt in the coming years. The possibilities offered by wearable technology products are virtually limitless. Originating as a luxury consumption in many areas, wearable technology products have evolved into significant necessities in the face of changing lifestyle standards, with diverse variations catering to users from all walks of life. This study provides general information about

wearable technology, discussing its history, classification, advantages and disadvantages, as well as expected features.

1. THE CONCEPT OF WEARABLE TECHNOLOGY

Wearable technologies have emerged in various aspects of our lives in recent years, in tandem with developments in the field of technology. Wearable technologies are technology-based innovative products and are considered one of the most important technological elements of the 21st century (Çakır et al., 2018).

Especially in the health and fitness domain, wearable technology products like various physical activity trackers have already been embraced by many users. In the existing literature, numerous approaches and definitions for wearable technology have been proposed. Therefore, making a clear and universally accepted definition for wearable technology is challenging. Although they go by different names such as wearable computers, wearable devices, wearable electronics, smart clothing, the common purpose of wearable technologies is to track our activities, distinguishing them from everyday clothing.

In 1998, Mann defined wearable technologies as an open and accessible computer (Mann, 1998). In 2003, Viseu defined wearable technologies as the transition from digital simulation to digital reality (Viseu, 2003). In the definition by MacLean (2013), wearable technologies are described as devices that can record the user's movements, physical data, psychological data,

location, or current situation, as well as habits, through sensors (MacLean, 2013; Barfield and Coudell, 2001).

Dunne and Smyth (2007) provided a brief definition for wearable devices, describing them as electronic devices worn on the user's body (Dunne and Smith, 2007). Wright and Keith (2014) define wearable technology as smart computers incorporated into clothing, fashion accessories, and other daily items and accessories worn by consumers (Wright and Keith, 2014).

Wearable technology products are the general term for technological and mechanical products that can be worn by humans (Raj and Brookshire, 2015). These products, also referred to as wearable computers in the literature, create a relationship between the user and the computer, enriching the individual's daily life experiences (Sezgin, 2016).

Despite many detailed and extensive definitions until the year 2017, Yetmen (2017) defined the concept of wearable technology as the integration of technology into everyday clothing and accessories (Yetmen, 2017). In other words, wearable technology is a category of electronic devices that can be worn as accessories, embedded in clothing, placed on the user's body, and even tattooed onto the skin (Hayes, 2022).

Wearable technologies, the general term for technological devices worn on the body, involve a distinct distinction. For a product to be called "wearable technology," it must wirelessly transfer information from smart sensors to a smartphone. These devices can take various forms, such as watches, glasses,

bracelets, or jewelry (ICTA, 2020). As seen, the field of wearable technologies, being so dependent on and open to technological advancements, does not have a single definition.

2. HISTORY OF WEARABLE TECHNOLOGY

In addition to the current importance and impact of wearable technologies, examining the literature reveals that these technologies have a long history, and it is necessary to explore their historical development. Wearable technology products had an impact on military and healthcare fields before entering the consumer market. Over time, the use of wearable technologies has increased in different fields and sectors. There are varying perspectives in the literature regarding the history and initial use of wearable technologies. The concept of wearable technology, starting with the invention of eyeglasses in the year 1286, was initially developed to enable individuals with myopia to see distant objects. In 1510, the first portable timekeeping device, known as the "Nuremberg Egg," became a part of the history of wearable technology. Unlike the familiar wristwatches of today, these early timepieces were worn around the neck and were cumbersome tools to carry (Karamehmet, 2019). In the early periods of the Chinese Kingdom dynasty in the 17th century, a ring-shaped abacus took its place among wearable technology devices (Figure 3).

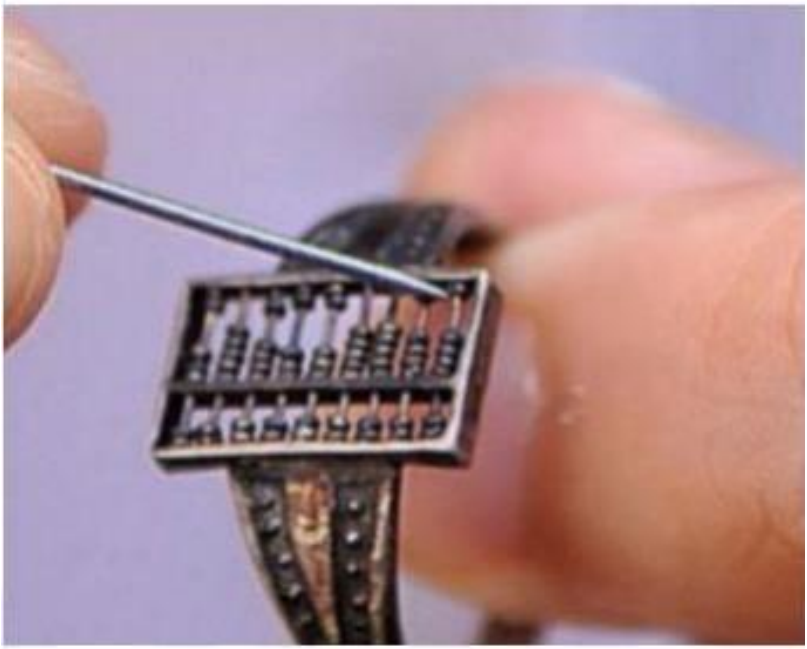

Figure 3. Abacus Ring Based on China's Qing Dynasty (Değerli, 2019).

In the subsequent years, wearable technologies have been incorporated into stage performances in the performing arts. In a ballet performance called "La Farandole," dancers danced with headpieces containing electric lamps powered by hidden batteries in their costumes (Guler et al., 2016) (Figure 4).

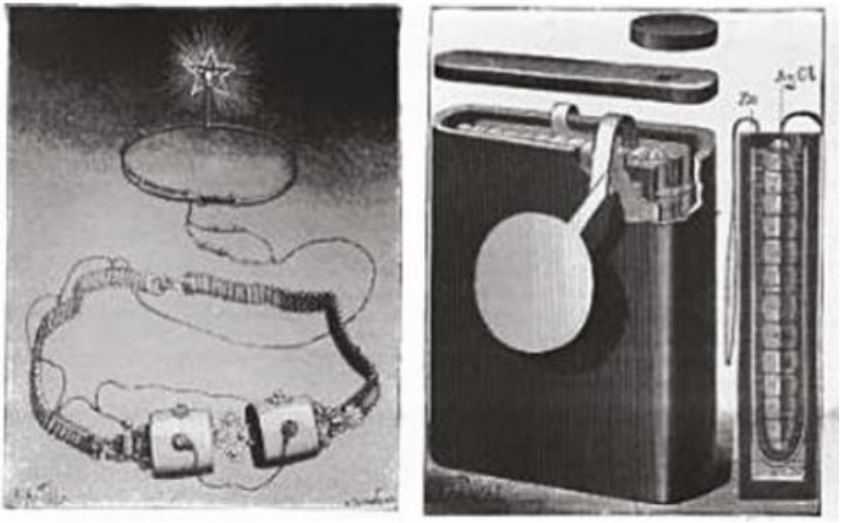

Figure 4. Wearable Electric Headpiece, La Farandole Ballet, 1883(Guler et al., 2016).

In the year 1961, two mathematicians named Edward Thorp and Claude Shannon developed computing devices capable of predicting where the ball would land on a roulette wheel, increasing the chances of winning a bet by up to 44% (Figure 5). Indeed, with one of the devices concealed inside a shoe and the other within a cigarette packet, Edward Thorp considers himself the inventor of the first wearable computer, specifically with the creation of this gambling shoe. Although the roulette wheel predictor did not possess a considerable amount of computing power, it perfectly exemplifies the emergence of wearable computing (Malmivaara, 2009).

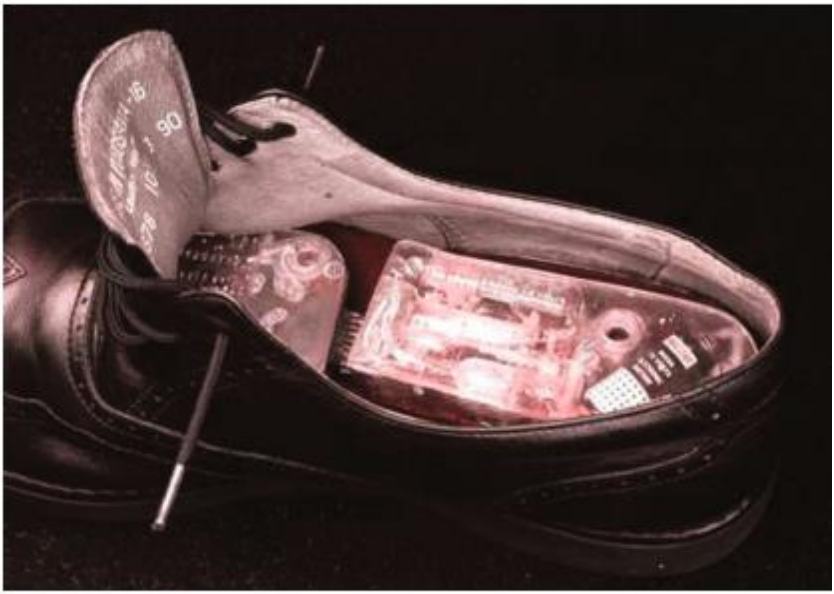

Figure 5. The first modern concept of a wearable device invented by Thorp and Shannon (Guler et al., 2016)

In the 1980s, significant developments occurred in wearable technologies. Steve Mann, a prominent figure in wearable technologies, designed a multimedia system consisting of a flashlight, battery, and camera mounted inside a helmet and attached to a backpack to track daily activities (Haider Raad, 2021; Malmivaara, 2009). In subsequent years, Steve Mann further developed this system, contributing to innovations such as Lifelogging and Eyetap Digital Eye Glass, enabling individuals to document their entire lives through photo and video recording.

In the 1990s, another significant development was the introduction of the first wireless heart rate (HR) monitor by

Polar. This monitor consisted of a wrist-worn receiver with a chest belt transmitter for measuring heart rate. Additionally, in 1993, an Australian researcher designed the first underwater wearable computer called WetPC, which was mounted on a mask (Motti, 2020).

The 2000s marked a period of rapid development for wearable technologies. During this time, the number of academic studies and commercial products in the field of wearable technology significantly increased. Collaborations between major fashion brands and technology companies took place, leading to the emergence of new wearable products. One such product is the ICD + Jacket resulting from the collaboration between Levi's and Philips (Figure 6). Classified as the first commercially known wearable electronic product, this jacket facilitates communication between a mobile phone, music player, and headphones through conductive fibers and fabrics, controlled by a remote (Karamehmet, 2019).

Figure 6. Smart Jacket
(https://y2kaestheticinstitute.tumblr.com/post/160516119792/levis-icd-jacket-with-built-in-cellphone-and-mp3)

In 2003, the Garmin Forerunner, a watch that tracks the user's performance, was introduced. Towards the end of the 2000s, several Chinese companies began producing Global System for Mobile (GSM) phones integrated into wristbands and equipped with mini screens (Haider, 2021). In 2007, Medynskiy and colleagues released a wearable RFID system with the aim of shaping tangible game interfaces. Researchers at Intel Research Seattle utilized this technology to design a glove named iGlove in the same year. This glove was developed as an RFID-based device (Sağbaş et al., 2016).

3. CATEGORIES OF WEARABLE TECHNOLOGIES

According to the literature, wearable technologies are classified into three main categories: wearable health technologies, wearable textile technologies, and wearable consumer electronics. These products include smartwatches, smart clothing, smart shoes, head-mounted displays, smart wristbands, smart jewelry, smart glasses, and body-embedded computers. Existing products have been classified in various ways within specific scopes in the literature. Wearable technology products are categorized into sections such as head, eyes, arms, legs-feet, ears, torso, wrists, and others. This classification is based on the positioning of wearable technology products on the body and is illustrated in Figure 7 below.

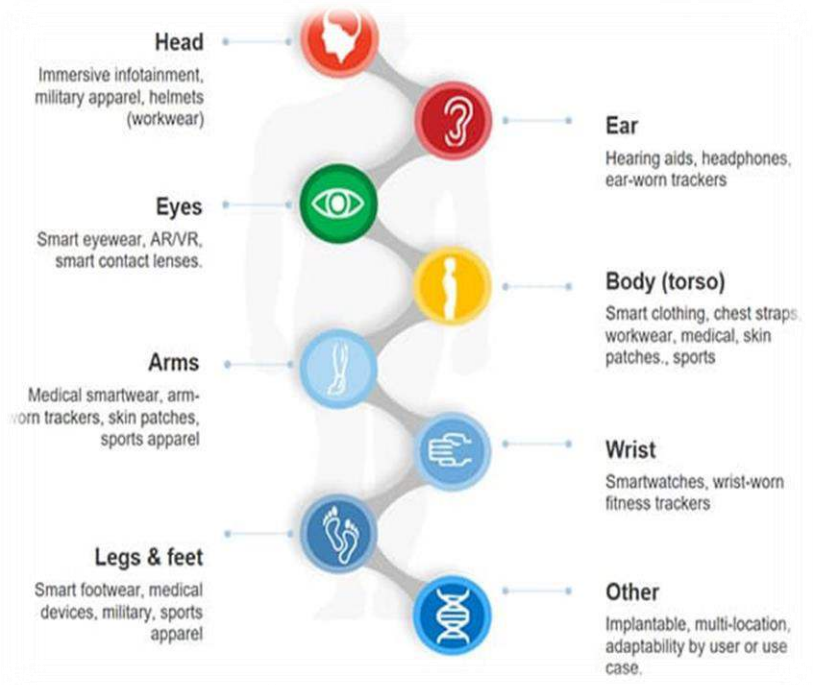

Figure 7. Wearable technology products based on their locations on the body (https://www.i-scoop.eu/wearables-market-outlook-2020-drivers-new-markets/)

According to another classification with a different perspective, wearable technologies are grouped based on functionality, type, placement method, communication method, single or multiple use, and application area. The classification is provided in Figure 8 below.

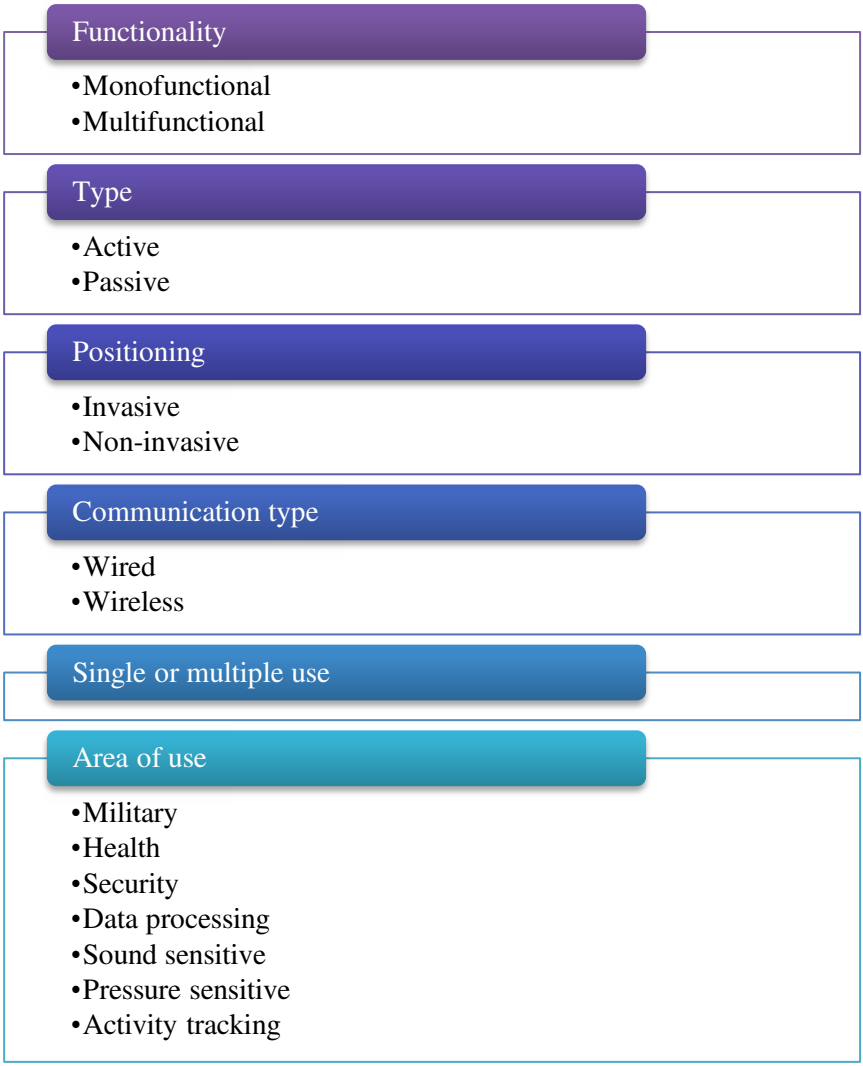

Figure 8. Classification of wearable technologies (Park ve diğ., 2014).

Mewara et al. (2016) have classified wearable technologies into two main groups. This classification is based

on product form and product functionality. In terms of product form, there are head-worn products (such as glasses), body-worn products (smart clothing), hand-worn products (bracelets, watches, etc.), and foot-worn products (shoes, socks, etc.). Product functionality encompasses items with specific functions, such as fitness bracelets used for a healthy lifestyle (Mewara et al., 2016).

With the developments in wearable technologies and the progress of technology, the diversity of wearable technology products is increasing day by day. Consequently, the scope and development of classification are also diversifying, and many researchers continue to work on the classification of wearable technology products.

4. USAGE AREAS OF WEARABLE TECHNOLOGIES

The concept of wearable technology has shown rapid development in recent years, and although it may seem like a new concept, previous studies reveal that it has a long history. Before wearable technology products entered the consumer market, they had an impact in military and healthcare fields. However, over time, the use of wearable technology products for changing purposes has become widespread in different fields and sectors. Wearable technology products have created a new market by providing opportunities for innovation and meeting the increasing demand for technology in various areas such as health, sports and fitness, information exchange and

entertainment, education, industry, tourism, military, fashion, etc.

Looking at the general trend, it is evident that the use of these products has significantly increased in recent times and has begun to have an impact in every aspect of life. In the coming years, it is predicted that the number of products in the wearable technology devices market and their usage areas will continue to grow.

5. WEARABLE TECHNOLOGIES IN HEALTHCARE

Due to the rapid development of technology every day, undoubtedly, all sectors have benefited from the advancing technology. The progress of technology has significantly advanced in the field of health to sustain human life. As a result of these developments, new technological products have taken their place in the field of health. Wearable health technologies increase opportunities for a healthy life through individuals' ability to track their own data in daily use. According to the World Health Organization (WHO), all devices, products, and methods that enhance an individual's quality of life and serve as intermediaries in solving health problems are defined as health Technologies.

Health technologies are used to enhance an individual's quality of life, identify conditions that pose risks for diseases, and serve purposes such as imaging, treatment, and monitoring. In some cases, health technologies are utilized to alter the course

of a disease, slow down its progression, or monitor an individual's life outside the hospital setting. Wearable health technologies, by providing users with timely feedback, have the potential to increase health awareness and build awareness. Through continuous monitoring of physiological data, the diagnosis and treatment of illnesses can be significantly facilitated, or illnesses can be prevented before they occur.

Wearable technology products in the healthcare sector, while reducing healthcare expenses, have also improved the quality of healthcare services by providing the opportunity to collect accurate and personalized patient data during treatment planning. Therefore, the use of wearable technology products in healthcare, one of the most crucial sectors of the economy, is significantly increasing. The strong integration of new technologies, increased health awareness, rising healthcare costs, and individuals' preference for virtual networks over face-to-face communication are revitalizing the wearable technology market in the healthcare sector. The continuous and regular monitoring of any disease, the ability to make real-time interventions, informing authorized healthcare units, and the presentation of many smart wearable technology products that can contribute to the recovery process after surgeries are rapidly continuing in the market, creating new areas of use. According to a study conducted by the PwC Health Research Institute in March 2016, the rate of purchasing and using wearable technologies for health is at the forefront. 63% of the participants in the study stated that wearable devices could

reduce obesity, and 70% believed that they could contribute to an increase in lifespan (Bothun and Lieberman, M. (2016).

The benefits of wearable devices for clinical applications are outlined as follows (Albayram and Öztekin, 2023):

Allows monitoring of patients in a home environment.

Conducts simultaneous and accurate measurements of patient data.

Provides close monitoring capability and has the feature of instant data transmission.

Enhances patient compliance and participation in treatment.

Reduces clinical needs and complications, thereby lowering costs.

In the study conducted by Yang et al., 2000, it was possible to monitor patients' blood flow continuously for 24 hours using a ring called the Ring Sensor shown in Figure 9. The ring is equipped with a detector that measures blood oxygen saturation and pulse. The measured data are transmitted to a computer via digital wireless communication, enabling continuous and remote analysis of the patient's health status (Yang and Rhee, 2000).

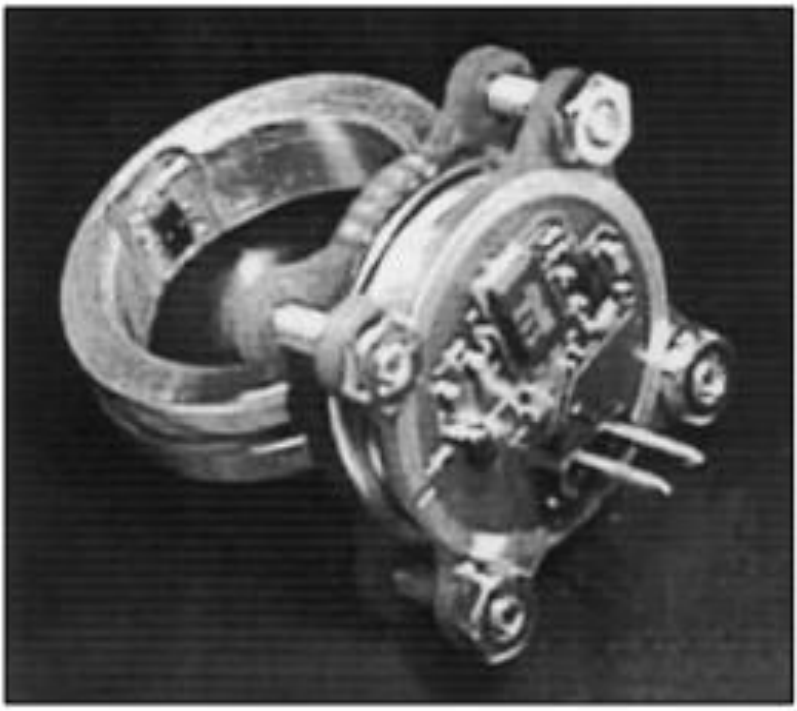

Figure 9. Ring sensor (Yang and Rhee, 2000).

As seen in Figure 10, in the year 2004, Grossman and colleagues designed a vest named LifeShirt, consisting of a garment, a data recorder, and computer-based analysis software. This vest continuously measures respiration and heart rate (Grossman, 2004).

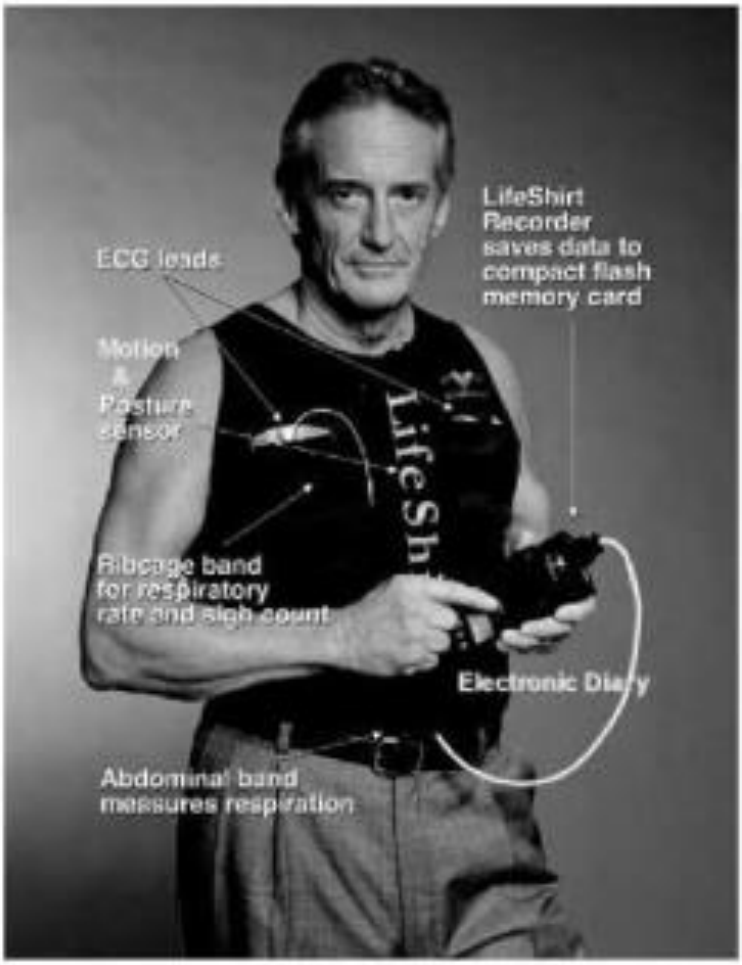

Figure 10. Lifeshirt (Grossman, 2004).

Especially for infants who cannot provide feedback regarding discomfort and health complaints in daily conditions, the collection of objective data is crucial. Additionally, continuous monitoring of health parameters for infants admitted

to the neonatal intensive care unit is of critical importance for optimal treatment and outcomes. To address this, Linti et al. developed a sensory baby vest in 2006. This vest, designed for continuous monitoring of infants in both clinical and home conditions and for detecting excessive sweating, incorporates fully integrated sensors to measure respiratory rate, heart rate, temperature, and humidity parameters. The goal of the vest system is the early detection of life-threatening conditions and the identification of stages in the development of diseases (Linti et al., 2006) (Figure 11).

Figure 11. Sensory baby vest (Linti et al., 2006).

In another study conducted in 2020, wearable system integrated with flexible material-based non-invasive sensors for newborn monitoring was proposed. The system aims not only to monitor reliable vital signs but also to provide comfortable clinical environments for newborns. The system consists of a smart vest and a cloud platform. The wearable smart garment seen in Figure 12 allows parents to monitor the comfort and health status of their babies at all times (Chen et al., 2020).

Figure 12. Prototype vest for babies (Chen et al., 2020).

The design seen in Figure 13 is developed for patients with chronic kidney disease. Ronco and colleagues developed the first wearable system for continuous ambulatory peritoneal dialysi in 2007. This system, named VIWAK (Vicenza Wearable Artificial Kidney), aims to allow patients to continue their daily activities during dialysis. The device's control panel

includes buttons for measured data and intervention when necessary (Ronco et al., 2007).

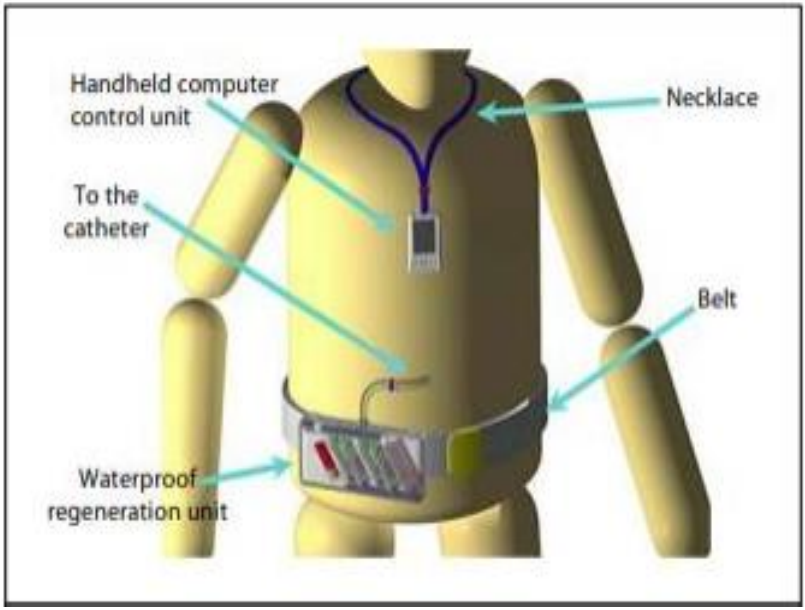

Figure 13. Wearable dialysis device template (Ronco et al., 2007).

Patel and colleagues conducted a study in 2009 to assess the utility of wearable technologies in monitoring excessive motor system changes in patients with Parkinson's disease from home. A wearable EKG, respiratory, and motion sensors were used, and the data obtained from these sensors were sent to the hospital's central network through a web-based mobile application. The collected data reached the responsible physician's computer. This system was employed for data collection in Parkinson's patients to evaluate complications

resulting from changes in the motor system and the severity of symptoms (Patel et al., 2010).

In 2011, a team of surgeons, engineers, and computer scientists at the University of Arkansas developed a personal heart monitor based on e-Nanoflex nanosensors. These sensors can be integrated into wearable garments that are washable and worn like other clothing. e-Nanoflex can be utilized in surgery, medical compliance monitoring, and tracking neurological disorders, or optimizing athletes' training routines. The developed nano-sensors function as a portable, wearable electrocardiogram (EKG) system (Varadan, 2011).

With the growing interest in recent years, developments in wearable technology have also become a research topic in our country. A project titled "Design of Smart Clothing Displaying Electrocardiography (EKG)" has led to the development of smart clothing that detects the heart's rhythm through the specially designed texture of the fabric and transmits it to smartphones via Bluetooth connection (https://www.ksu.edu.tr/default.aspx?DId=32369).

Wearable technologies are not only used for measuring health data but also for treatment and rehabilitation purposes. For example, in 2018, a smart garment was developed for use in the rehabilitation training of stroke patients. A study was conducted on 17 stroke patients in three hospitals in Shanghai. Inertial sensors provided guided feedback on a tablet to assist patients in rehabilitation. The subjects supported the study, stating that

technology-assisted training felt more reliable compared to training with therapists (Wang et al., 2018).

In a study conducted in a hospital in China in 2019, involving 60 young oral and maxillofacial surgery patients, vital signs such as ear temperature, pulse, and blood pressure were measured using both traditional and wearable medical devices. The results showed that wearable medical devices required significantly less time throughout the entire measurement process and data transcription compared to other medical devices (Fan et al., 2019).

In 2020, Lonin and colleagues conducted a study on leveraging wearable electronics to control the spread of the globally impacting Covid-19 pandemic and detect individuals infected with the virus. Continuous variable symptoms were recorded with a general screening every two minutes. A wearable, soft, body-conforming sensor was used to monitor data related to physical activity, cardiorespiratory function, and cough sounds (Lonini et al., 2020).

For individuals with Autism Spectrum Disorder (ASD), Tomczak and colleagues presented a stress monitoring system specially designed and developed for an educational institution in 2020. The stress monitoring system includes an autonomous wearable device (bracelet) comprising both electronic and mechanical components, along with software application for data analysis. The wearable device is designed to measure heart rate, skin resistance, temperature, and body movement (Tomczak et al., 2020).

The wearable health technology product named Adamm provides asthma management. This device collects data such as the user's cough rate, respiratory pattern, and medication usage, and transfers it to a smartphone. The device records the user's daily values and issues alerts to the user in case of any asthma symptoms. This allows both the patient and the responsible healthcare professional to monitor respiratory problems (Demirci, 2018).

In recent years, various studies have been conducted in the field of wearable technology related to posture disorders. For example, in 2020, a study was conducted on the design and development of an innovative smart garment for real-time ergonomic risk assessment. The system is based on inertial sensors and employs a biological feedback strategy that uses haptic stimulator to alert the user about hazardous postures, promoting more ergonomic postures. The results demonstrated that providing real-time biological feedback improved posture awareness and had a significant impact on reducing ergonomic risk (Cerqueira et al., 2020).

One of the most significant advantages provided by wearable health technologies is monitoring. Through monitoring, individuals can easily access data about their health status and gain insights into potential future illnesses. Additionally, these data collected from patients can serve as a reference in the diagnostic process for healthcare professionals (Büyükgöze, 2019).

With the increasing population, the growing burden on healthcare institutions leads to significant expenses. Additionally, hospital treatments can adversely affect patients' psychological well-being in the long run. Health technologies enable individuals to be monitored outside hospital settings, receive treatment without hospitalization, and obtain health-related data quickly. This convenience has positive effects on the budget allocated for healthcare services. In this context, the use of wearable health technologies contributes to both individual and societal benefits (Aydan and Aydan, 2016).

When examining the applications described above for wearable health technologies, it is observed that a significant portion of existing products are designed to measure vital signs such as heart rate, respiration, and sleep patterns. The features of these devices enable users to easily monitor their routine health conditions. Regular tracking of this data is crucial, especially for individuals with chronic illnesses. In this context, it can be said that wearable health technologies represent vital devices. Although the developed devices have not yet reached the desired level, there is a rapid increase in research and development in this field (Işık, 2022).

The increasing use of wearable health technologies brings about both advantages and disadvantages. Studies indicate that the use of wearable health technologies is easy, fast, and practical. Thanks to these products, users can access various data without straining their physical and cognitive abilities. This situation allows for time savings and the quick organization of

tasks. In this regard, one of the most significant advantages of wearable health technologies is their ability to collect and organize a large amount of data for individuals in a short period (Sezgin, 2016).

On the downside, when it comes to technological products, various cybersecurity problems are observed. This situation gives rise to the problem of malicious individuals stealing personal data. While wearable health technologies provide many advantages for an individual's health, the transfer and processing of data to different locations can lead to serious problems.

6. WEARABLE TECHNOLOGIES IN MILITARY

Wearable technology is not confined solely to social contexts but has also transitioned towards major industries such as the military, instigating a comprehensive transformation. There is a notable interest in innovative approaches to the applicability of existing technologies to enhance their functionality within this domain. Naturally, wearable technologies have attracted significant attention. Any wearable technology introduced should aim to reduce complexity and workload for various defense operators. The development of smart clothing and wearable technology solutions in the military sector is expected to bring about efficiency improvements and cost savings, presenting new opportunities for advancements in security, usability, and operational effectiveness (Kılıç, 2017).

The increasing demands for the coordination, training, and health of soldiers, alongside uncertain geopolitical conflicts and military modernization programs, are factors accelerating the growth of the military wearable market. Wearable technologies in the military domain contribute to monitoring the physical condition of soldiers during missions, improving communication between units and military outposts, and providing comprehensive information about the situation. Wearable technologies enable a command and control unit to monitor soldiers more accurately, facilitating the ease of tracking their safety during high-alert operations and reducing the risk of errors. Wearable devices for the military are classified into army, navy, and air force applications. To enhance soldiers' combat capabilities, many countries worldwide have increased the utilization of wearable computing devices (Sharma et al., 2020).

It is expected that wearable technologies be lightweight and portable. Particularly in the context of military operations, the weight of equipment is of significant importance for soldiers. Wearable energy harvesting technology is considered the most suitable solution to provide power to a soldier's electronic devices and reduce the number of portable batteries, which add extra weight. Energy harvesting systems capture small amounts of wasted energy in the form of light, kinetic, heat, or vibration. Therefore, in 2017, Othman and colleagues designed a wearable energy harvesting system using piezoelectric transducers embedded in the soles of military boots

to capture the energy generated by footstep sounds (Othman, 2017).

Wearable sensor devices are utilized to monitor human movement within military zones. The purpose of these sensors is to track and detect unauthorized entries (conflicting actions/behaviors) among all soldiers in the military network (Gopal, 2014).

Additionally, systems based on specific sensors related to military networks and the health of soldiers and field personnel during a mission are being developed and tested. Measurements of various physical parameters such as respiration, blood pressure, pulse, body temperature, sweating, oxygen consumption, and motion tracking are conducted. In these systems, the parameters of soldiers are continuously measured and wirelessly transmitted to necessary locations (Kang et al., 2020).

Detecting data related to the psychological profile of a soldier is crucial to determining the degree of adaptability to the mission-related situation at a specific time. In a system developed for this purpose, wearable sensors measure the physical responses of the soldier's body. The goal is to predict environmental stimuli that surpass the physiological and psychological abilities of the soldier while performing tasks (Rozanowski et al., 2015).

Virtual Reality (VR) based interventions, wearable technology, are used to enhance the diagnosis and treatment of military and mental health conditions. Wearable technologies

are also employed to detect mental health conditions and increase motivation for ongoing treatment. A computer-animated virtual agent provides online coaching for patients with Post-Traumatic Stress Disorder (PTSD) in their homes to improve treatment adherence. Through a head-mounted display, PTSD patients can reexperience past experiences and reassociate them with new meanings (Vermetten et al., 2020).

ASELSAN developed the CENKER project in 2015. The Cenker system consists of products weighing 2 kg that are worn on the eye, ear, and arm. Thanks to the embedded software, the health status of the soldier and ammunition tracking can be quickly performed. The equipment worn by soldiers includes a wearable computer, smart battlefield goggles, a smartwatch, a pulse monitor, a command computer, a durable battery set, a laryngeal microphone isolated from ambient noise for precise speech, a live streaming camera, software-based radio, and a weapon-mounted command unit (Karakoç and Asal, 2017).

The Dismounted Soldier Training System (DSTS) is an application developed for military training, serving as a strategic and educational game-based military training system. Soldiers participating in digital training use the DSTS system to execute orders and tasks in a realistic war scenario. These training sessions take place in a confined and small physical space, simulating virtual exercises in mountainous, forested, desert, and terrain environments. Soldiers in the training use wearable equipment and weapons to see the virtual environment, hear

sounds occurring during conflicts, and communicate with their teammates simultaneously (Flores, 2013) (Figure, 14).

Figure 14. Soldiers Training with Augmented Reality (Flores, 2013).

The Holographic Tactical Sandbox (HTS) is an operational, planning, and tactical system that enhances the war

and exercise area by transferring it into holographic augmented reality through digital eyewear. It is utilized by the command and management level during the planning and execution phases of operations. HTS comprises augmented reality, wearable technologies, and three-dimensional imaging systems with high resolution (Karakuş and Gönen, 2022).

7. WEARABLE TECHNOLOGIES IN SPORTS

In today's world, sports activities have become an integral part of daily life, and the positive impact of engaging in sports on the quality of life is well-known. One of the areas where wearable technologies provide benefits and are widely utilized is in the field of sports. Wearable devices not only motivate individuals for a healthy lifestyle but also assist in monitoring and enhancing their physical development.

Various products, such as smartwatches, smart wristbands, smart clothing, and smart headphones, are widely used in the field of sports. Wearable technological sports products are believed to contribute to athletes' development in their daily lives, nutrition, rest, training, and competitions by providing support and guiding them in a more systematic way. The data collected through these devices can be used to assist individuals in achieving their health and sports goals or to track specific goals in a particular sport or exercise. Physiological sensors in these devices enhance the perception of physical performance more specifically by adding more details about body movements and activities.

Wearable technology products in sports encompass a wide range of sensors, including but not limited to respiratory rate, neural activity, heart rate, body temperature, frequency, brightness, refraction, light wave, temperature, humidity measurement, location, displacement, speed, and energy (Barfield and Caudell, 2001). Athletes can monitor almost every aspect of their daily lives by using these sensors to track their personal measurements.

Wearable technologies are increasingly used for promoting a healthy lifestyle in daily life, and their use in professional sports is becoming more widespread. With the advent of technological devices, a wealth of information can be collected for professional athletes or those aspiring to be professionals, ranging from real-time performance metrics, distances covered, body responses, to even the intensity of impacts. These data can be processed through various programs, providing athletes and coaches with guiding insights for future physical, technical, and tactical training, as well as performance and health management. The utilization of wearable technologies and beyond is becoming more prevalent in professional fields with each passing day (Baydemir, 2017).

Video-based analysis is a common method for analyzing human movements in sports. Therefore, wearable sensors and video cameras are used to detect a sports movement and automatically provide image sequences of the movement using a system developed by Kim and Kim. The system has been evaluated by implementing it as an example application,

specifically a soccer kicking analysis system (Kim and Kim, 2017).

Wearable sensor devices provide valuable additional information to athletes during training, coaches, or to patients and healthcare professionals during therapy. Real-time biofeedback systems can enhance the effectiveness of training or therapy. Sensors, actuators, and wireless technologies vary widely in their features. A study has examined the applicability and usage of biofeedback systems in sports and rehabilitation (Kos, 2019). Recording and analyzing the calories burned from different exercises in a single day is not easy. To address this, a wearable device-based home sports recording system has been developed, capable of analyzing and recording five common sports behaviors including walking, running, hula hooping, sit-ups, and push-ups (Chang et al., 2020).

With the smart sock developed by the company Sensoria as shown in Figure 15, processes such as step counting, speed measurement, calorie tracking, and distance calculation can be realized.

Figure 15. Smart sock (https://www.webtekno.com/kendi-kendini-sarj-edebilen-coraplar-giyilebilir-cihazlariniz-icin-yeni-guc-kaynagi-olabilir-h64087.html)

HEXOSKIN-branded wearable smart shirts can collect real-time data on blood pressure, body temperature, blood oxygen levels, heart rate, and electrical activities (electrocardiogram), as well as respiration rate and volume, steps per minute, and acceleration (Sarı et al., 2021). The collected data can be wirelessly sent to mobile devices for processing or analyzed in their own software for further insights. These shirts serve as a sleep monitoring device and can be used in various sports and physical activities to track personal development and assess whether workouts are suitable for one's health (Figure 16).

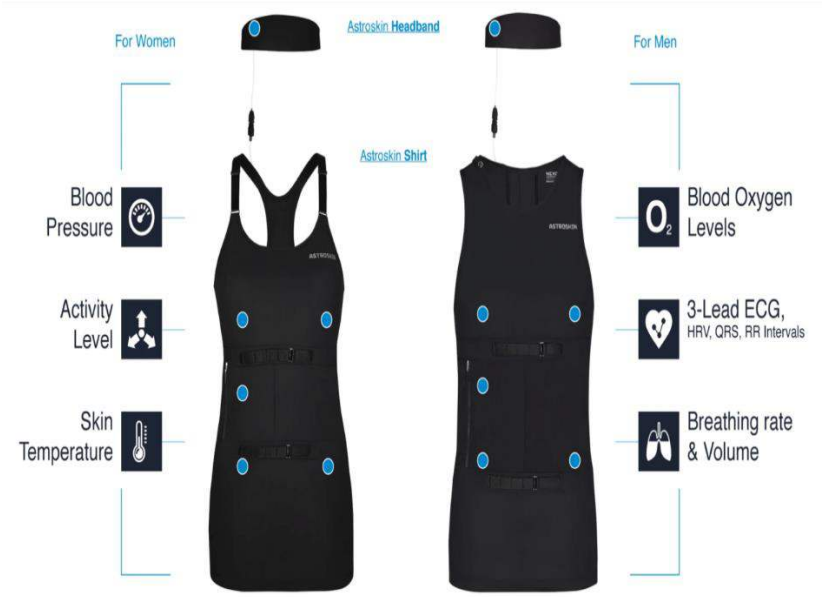

Figure 16. Smart t-shirt (https://hexoskin.com/pages/astroskin-vital-signs-monitoring-platform-for-advanced-research)

Athos shorts, used by professional athletes, can observe and analyze all muscle movements with their 12 built-in sensors (Figure 17).

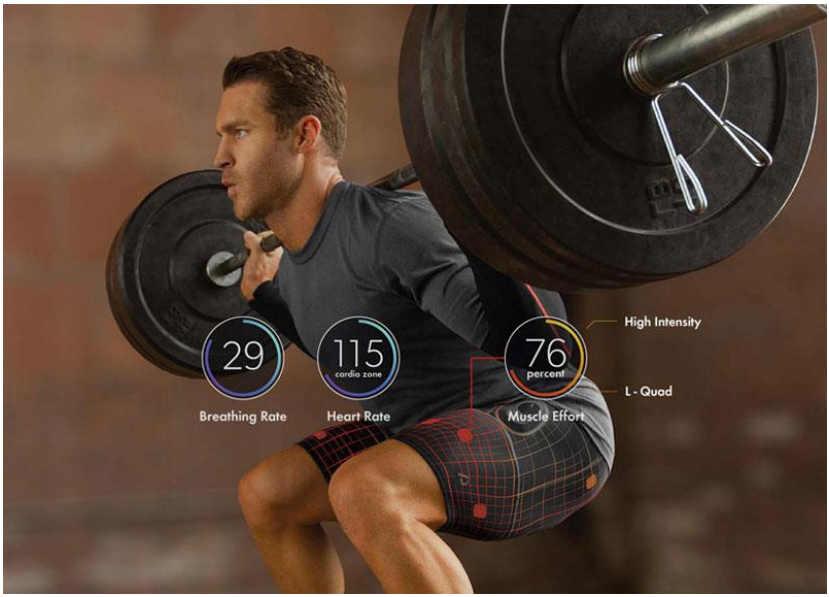

Figure 17. Smart short (https://www.bigapplebuddy.com/blog/athos-clothing-international-shipping/)

The Nike Adapt BB, part of the Nike Adapt series, is specifically designed for basketball players. Compatible with smartphones, the Nike Adapt technology allows the shoe laces to be fastened and loosened with a single button. Additionally, the laces can be automatically tightened or loosened. This product aims to maintain the desired tightness level set by individuals during the game, preventing the shoelaces from coming loose and ensuring that the athlete's performance is kept at its peak (Figure 18).

Figure 18. Smart shoes (tps://www.nike.com/si/a/nike-adapt-bb-release-info)

Form Swim Goggles, developed by the Form brand for swimmers, are smart goggles that are waterproof up to 10 meters. These goggles provide real-time data such as heart rate, calories, stroke count, speed, and distance directly in front of the swimmer's eyes (Figure 19).

Figure 19. Smart glasses (https://eu.formswim.com/products/smart-swim-goggles)

The production and design of wearable sports technologies continues for a wide variety of purposes and for varying purposes. Although these products have many benefits, they also have potential drawbacks that need to be considered, such as the privacy and security of data collected by the devices. The accuracy of the data they provide can be concerning, as these devices may not always produce accurate results. As with any technology, it is important to carefully evaluate the potential

risks and benefits and use these devices responsibly (Akkaya and Ekan, 2023).

In addition to the specific areas discussed in the study, the market offers a plethora of diverse products that continuously evolve. Among these are products specifically designed to prevent poor posture and promote an upright stance. An example of such innovation is the "Posture Reminder T-Shirt," originating from a Kickstarter project based in Sweden, aimed at addressing posture issues (Figure 20). Furthermore, there are corsets available that use vibration alerts to discourage unintentional slouching, aiding individuals in maintaining an upright posture in their daily lives (Figure 20).

Figure 20. Posture Reminder T-Shirt and smart corset (https://listelist.com/ilginc-giyilebilir-teknolojiler/,https://www.bitenekadar.com/sensorlu-dik-durus-korsesi-sarjli-titresimli-982973-firsat-urun#)

A hat has been designed to prevent drivers who use vehicles for extended periods from succumbing to sleep and fatigue, ensuring they wake up if they doze off behind the wheel by monitoring the driver's head movements. Recognizing the attention lapses and fatigue inherent in the profession of long-haul truck drivers, Ford has developed the "SafeCap." This system tracks the driver's head movements using motion sensors and gyroscopes, coupled with specialized software, aiming to

eliminate the distraction and fatigue brought about by the profession before any accident that could result in loss of life or property occurs. Drivers are alerted through vibrations, sounds, and lights from the device, which resembles an ordinary hat (Ford Media Center, 2017).

The shoes produced by the ShiftWear company allow customization through an embedded display. Users can personalize the shoes with their preferred designs using a smartphone. Additionally, the product is water-resistant, machine-washable, and features wireless charging technology(Figure 21).

Figure 21. Smart shoes (https://www.bonjourlife.com/shiftwear-e-paper-sneaker-lets-you-design-your-own-edition/)

Garments have been designed to regulate body temperature according to environmental conditions. Ministry of Supply, using durable smart fabrics and minimal designs, has created a waterproof and lightweight jacket that adapts to various weather conditions, from snowy days to windy and rainy autumn weather. The jacket features sensors both on the inside and outside surfaces that measure the ambient temperature. The jacket, controllable via Bluetooth through a mobile application, learns user preferences and has the ability to automatically adjust itself based on the ambient temperature over time (https://www.dijitalajanslar.com/hava-kosullarina-adapte-olabilen-akilli-mont/)

The PolarSeal sweater, designed with a lightweight, flexible, and breathable structure, features two separate heaters located on the back and waist. By pressing the buttons on the left sleeve of the sweater, users can activate the heating function for the desired area. This feature aims to balance body temperature during outdoor sports activities (Figure 22).

Figure 22. Smart sweater (https://www.dijitalajanslar.com/usumeyi-engelleyen-isiticili-kazak-polar-seal/)

8. ADVANTAGES AND DISADVANTAGES OF WEARABLE TECHNOLOGIES

With the integration of wearable technology products into our lives, the products individuals use in their daily routines have begun to respond to more desires and needs, driven by the increased functionality of these products. The convergence of various disciplines has led to the emergence of new innovations with advancing technology. Wearable technology products, which initially found their place in crucial areas such as health, education, and security, have now become part of our daily activities, impacting various aspects of our lives. Research studies have highlighted the superior features of wearable technologies and how they contribute to making life easier and enhancing the quality of life.

In the examination of studies in the field of wearable technology, several usage advantages come to light, influenced by designs crafted for ergonomic use. Noteworthy features include ease of portability, rapid interaction, freedom of movement, and user-friendly interfaces. When considering frequently employed terms in the wearable technology domain, it is observed that these products aim to enhance the user's cognitive, communicative, and sensory capacities without unduly challenging physical constraints. Moreover, the widespread adoption of these products not only enables the tracking of daily tasks through commonly used smartphones but also facilitates the expeditious completion of various activities.

Consequently, wearable technology products have been noted to provide users with time-saving benefits (Çakır et al., 2018).

Overall, the advantages of wearable technologies are summarized as follows:

Productivity: Wearable technologies contribute to increased efficiency through their diverse applications across various sectors. In the healthcare industry, for instance, doctors can easily address issues such as examining a patient's veins without the need to wait for scans or X-rays, thanks to the utilization of wearable technology. In the business realm, wearable technology products play a significant role in expeditiously resolving issues, thereby providing substantial benefits to both the company and its clientele.

Employee Satisfaction: The proper selection of wearable technology products significantly enhances employee satisfaction and engagement for businesses, thereby increasing the value of the investment.

Utilization of Different Technologies: One of the key features of wearable devices is their ability to connect to other systems. Investing in these wearable devices enhances the effectiveness of connected investments and contributes to the increased value in the market.

Other: Wearable devices enable the simultaneous completion of multiple tasks, leading to time savings. They also allow the use of advanced voice recognition systems instead of lengthy messages and texts. (https://www.naturalhr.com/2017/05/16/pros-cons-wearables-

workplace/)

In addition to the numerous benefits and advantages of wearable technologies, there are also some disadvantages as outlined below:

Distracting Potential: Similar to smartphones, wearable technologies also present distracting features. For instance, smartwatches offering numerous features and receiving constant updates may lead users to continuously focus on new functionalities.

Cost: Wearable devices that provide meaningful functionality tend to be relatively expensive, potentially limiting accessibility.

Dependency on Platforms: Many wearable devices require different platforms for proper functioning. In this case, investing in wearable devices may also necessitate investment in new systems simultaneously.

Size and Battery Limitations: Despite technological advancements, many wearable devices still face limitations in terms of size and battery capacity, resulting in usability challenges and reliability issues.

Privacy Concern: Ensuring privacy and data security is crucial, and it is imperative that products are designed with these considerations in mind.

The rapidly increasing popularity of wearable technology products in various aspects of daily life brings about significant developments in technology and science; however, it also introduces a set of security issues. In the realm of wearable

technologies, which can still be considered a relatively new field, numerous risks and threats exist. When evaluating this concept in conjunction with the Internet of Things (IoT), it becomes evident that the risks associated with the internet are also applicable to these products (Öymen, 2017).

Due to the convenience and advantages they offer in our daily lives, wearable technologies, in which we store a substantial amount of personal data, pose the risk of users' personal information being shared with third parties. Additionally, there is the concern of these data being sold to businesses in digital environments (Çakır et al., 2018).

Similar to many technological devices, wearable technology products are susceptible to issues such as data theft, cyber attacks, or the installation of malicious software on the device. Problems may arise during the wireless transfer of information from these products to another computer or another smart device, including data theft or malicious interference, sharing, or manipulation of systems by malicious individuals. Ongoing efforts are being made to develop preventive measures against potential risks that may arise in wearable technology products (Çakır et al., 2018).

9. EXPECTED FEATURES OF WEARABLE ELECTRONICS

Users have certain expectations regarding the performance, long-term usage, maintenance, and design of wearable electronics. From a usability perspective, expected

features of wearable electronics include having a comfortable and flexible structure, being easy to wash and clean, easy to charge, and having design diversity and originality (Öymen, 2017). Research is also being conducted on the energy sources used to power wearable electronic devices. It is expected that the batteries and cells used should be low-cost, lightweight, small-sized, and have high-performance characteristics (Wahba et al., 2020). Additionally, factors such as usage time, sensor technology, and cost are crucial for the development of healthy solutions for long-term use, the collection and processing of more accurate data, and the widespread adoption of these technologies by reducing their costs.

When designing and developing wearable devices, certain features must be taken into account. From a design perspective, the production should enable the device to seamlessly integrate into daily life, providing comfort as well as maintaining a sense of elegance without compromising on functionality. The designed device should be aesthetically pleasing and user-friendly, and it should be as small and lightweight as possible. Furthermore, it is essential for the device to be resistant to different weather conditions and environmental factors.

10. CONCLUSION

Wearable technologies have increasingly evolved day by day, establishing a presence in the market, and wearable technology products have now become an integral part of

everyday life. These technologies have opened the door to many exciting applications, leading to a technological revolution similar to the internet and mobile communication industries. These developments are progressing towards dizzying dimensions, both from the perspective of businesses and consumers. When considered from the perspective of businesses, having a large market potential is a significant factor in the emergence and implementation of innovative and creative ideas. Due to the conveniences they provide in industries such as electronics, fashion/textiles, education, health, defense, which have significant impacts on global trade, they have found ample application and preference.

Research indicates that there are wearable devices designed for various fields and purposes in the market. Therefore, considering the role that technology plays in our lives, it is anticipated that these products, which we use in our daily lives, will become increasingly popular and reach a wide user base over time.

Currently, the proliferation of wearable technologies is in its initial stages when considering the potential future processes for both society and companies. In the near future, wearable technologies will continue to evolve, and these technological devices will be produced by societies and companies with developed functions and designs. As a result, they will be increasingly embraced by users.

It is claimed that these products will become richer every day, taking into account technological advancements and

consumer needs. This situation may imply that smart products could perform more crucial tasks in the future and play a more significant role in our lives. The rapid progress of technology allows various disciplines to come together and generate new innovations. The growing wearable technology market, which is advancing day by day, attracts the attention of academics and marketing professionals, leading to ongoing research and emerging as a highly promising area for development.

While the rapid advancement of technology has greatly facilitated human life, it can also bring about some potential issues mentioned. Before adopting this technology, it is essential to be aware of effective use and protection methods, requiring conscious consideration.

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ISBN: 978-625-367-621-6