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Wearable Fitness Technology

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ABSTRACT

In recent years, wearable technology has gained immense popularity as a powerful tool for enhancing fitness and well-being. Wearable technology has emerged as a game-changer in enhancing fitness and well-being. Wearable fitness technology includes devices like smartwatches, fitness trackers, smart rings, and smart apparel that collect real-time data on physical activity, sleep, and physiological metrics such as heart rate and body temperature. With features like fitness tracking, heart rate monitoring, sleep optimization, and personalized coaching, wearables empower individuals to take charge of their health. Today, wearable devices can track more fitness and health biomarkers than ever before. In this paper, we examine how integral wearable devices have been across the fitness industry.

KEYWORDS: *wearables, wearable devices, wearable technologies, immersive technologies, fitness, fitness industry, wellness.*

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INTRODUCTION

Wearable fitness technology is everywhere. These devices offer real-time insights into how we move, exercise, and live our lives. From fitness trackers to smartwatches and biometric sensors, wearables have revolutionized how we monitor and manage our health. These tools empower individuals and athletes to monitor progress, personalize training, improve recovery, and identify health issues. People are already tracking their health in ways that were unimaginable a decade ago. Wearables like the Apple Watch, Oura Ring, and WHOOP are giving users unprecedented insights into their health. By prioritizing simplicity, wearable integrations fit seamlessly into daily routines [1].

Staying active and prioritizing our well-being has become increasingly important as we navigate the demands of modern life. The world of fitness technology is evolving rapidly, offering exciting opportunities for trainers, enthusiasts, and coaches alike. Wearable fitness technologies include devices such as smartwatches, fitness trackers, heart rate monitors, smart rings, smart glasses, and smart mouthguards worn on the wrist, chest, head, or in clothing to track various metrics during exercise and daily activities. These devices use sensors to collect data like heart rate, activity levels, and GPS location, which is then used to provide feedback and monitor progress. Figure 1 shows a range of wearable devices [2].

IS WEARABLE TECHNOLOGY?

A wearable device is any device that is worn comfortably on the body and enables user interaction. It is typically integrated into the clothing or attached to the body of a person to enhance human performance. It often includes smart devices that can be worn on the body or attached to clothes. Wearable devices have been around for centuries. The first one was introduced in the 1660s by the Qing Dynasty. Since then the popularity of wearables has shifted from royalty to the healthcare industry. Wearable computing is a natural evolution of the smartphone technology that has become so ubiquitous and indispensable in education, business, and medicine. We wear wrist watches to know the time. Perhaps the most crucial bit of wearable tech accessible today is Google Glass. There has been a proliferation of wearables from consumer gadgets to medical devices

that are approved by the Food and Drug Administration (FDA).

Wearable devices or systems are usually lightweight, miniature electronic or digital devices that are worn by a user, including clothing, watches, glasses, shoes, and similar items. A wearable computer is computer-powered device that is never-sleeping ever-present network-connected electronic system that can be used at anytime and anywhere and does not in any way disturb the user's interaction with the real world. It should be worn, much as eyeglasses or clothing are worn, and interact with the user [3]. It includes all manner of technology that is on or in the body such as fitness trackers, smartwatches, smart clothing, smart rings, smart glasses, wearable mobile sensors, smart jewelry, and smart ECG (electrocardiogram) monitors.

Wearables are always ready, unrestrictive, not monopolizing of user attention, observable and controllable by the user, attentive to the environment, useful as a communication tool, and personal devices [4]. Wearables are being used across healthcare, insurance, interactive systems, safety critical settings, wearable cameras, baby and pregnancy monitors, entertainment, fitness and sports, emergency responders, and military. Typical wearable devices are shown in Figure 2 [5]. Due to it wide range of applications, international corporations such Google, Apple, and Intel are investing heavily on wearable technology research and development [6]. As with any new technology, one must exercise caution when using a wearable device.

A wearable device essentially consists of two different components: wearable and body sensors. It incorporates sensors, memory, solar cells, and batteries. It stays in contact with the body for extended periods of time. Traditional materials for wearables are mostly metals and semiconductors with relatively poor mechanical flexibility. Modern wearable technologies are characterized by body-worn devices, as smart clothing, e-textiles, and accessories [7]. Wearable devices can be used to collect various data to support a series of innovative applications. Today, wearable devices have numerous applications due to their integration with artificial intelligence. Wearable devices can be attached to shoes, eyeglasses, earrings, clothing, gloves, and wrist watches [8].

WEARABLE FITNESS TECHNOLOGY

The fitness industry is at the forefront of technological innovation. In a world where technological advancements are shaping every aspect of our lives, it is no surprise that the fitness industry is also experiencing a revolution. Wearable technology has revolutionized the landscape of physical fitness, and its impact extends beyond traditional fitness trackers and smartwatches. Today, fitness technology transforms how we train, track progress, and stay motivated [9]. Wearables improve personal training performance and paid fitness program. Research on health and fitness trackers indicates that most people who use them tend to become more active, increase their step counts, and expend more energy at moderate and vigorous levels. Figure 3 shows a woman performing exercise [10], while Figure 4 shows a woman using wearable to track fitness [11].

Wearable devices represent one of the most popular trends in health and fitness. They seamlessly integrate with mobile apps and health platforms, creating a holistic approach to fitness and well-being. Wearable technology has gained in popularity among a broad segment of the general population including elite, competitive, and recreational athletes. Consumers and practitioners utilize wearable devices to track outcomes, such as energy expenditure, training load, step count, and heart rate. It has become evident that wearable activity trackers have advanced rapidly over the past decade and continue to feature new capabilities and metrics of interest to the end users. Individuals-coaches, athletes, or those pursuing health and wellbeing-seek to promote stress-induced adaptation while avoiding any injury or chronic fatigue elicited by the over-trained or overstressed state. For training load to be meaningful it must relate to an outcome, such as injury occurrence or performance, and investigations must validate the strength of this relationship [12].

TYPES OF WEARABLE DEVICES

Broadly speaking, there are two main categories of wearable tech: consumer wearables which are pieces that consumers can buy every day and medical-grade wearables which can help monitor someone with specific conditions like high blood pressure or diabetes. As shown in Figure 5 [13], there are different types of fitness wearables, with their key features and how they can fit into your lifestyle. Common types include [14]:

1. *Fitness Watches:* Fitness watches (or smartwatches) are the most popular type of wearable. They combine fitness tracking features (like step counting, heart rate monitoring, and GPS) with smartwatch functionalities (like notifications, calls, apps). An example of fitness watch is shown in Figure 6 [15].
2. *Fitness Rings:* These are compact, stylish wearables designed for those who want health tracking without wearing something bulky on their wrist. They are discreet and often focus on

wellness metrics. These devices offer fitness tracking (heart rate, steps, GPS) alongside smartwatch features like notifications, calls, and apps. Smart rings are still a fairly new concept that cram a watch's worth of sensing tech into compact finger bling.

3. *Smart Clothing:* This integrates fitness tracking technology directly into garments. Smart cloths are yoga pants with sensors that can tell you about your alignment, diabetic socks that can monitor you for ulcers and injuries, and smart jackets that can measure body temperature, heart rate, and lung function. These wearables are designed for specific activities, like yoga, running, or high-performance sports, offering advanced data such as muscle engagement and posture analysis.
4. *Chest Straps:* These wearables focus on high-accuracy heart rate monitoring by being placed closer to the heart or on larger muscle areas. They are ideal for athletes who need precise data during workouts.
5. *Smart Glasses*: The smart glasses can measure eye movements and even brain activity. Monitoring eye movements can help analyze stress, detect fatigue, and manage neurological conditions.
6. *Biosensors*: These are typically patches on the skin or small sensors in clothing that help monitor health conditions. They monitor specific health conditions, such as blood oxygen levels or continuous glucose monitors. Continuous glucose monitors are a type of biosensor. Sweat analysis patches also allow you to understand your sweat and sodium loss during a workout.
7. *Pedometer:* This is also known as step counter. It will help you track if you are doing too much or too little during a workout. You would be hard-pressed to find any fitness wearable that does not include this basic feature. We have all heard about the benefits of getting your 10k steps in each day; tracking them on a wearable is the easiest way to work towards that goal.

Wearables are designed to cater to all fitness levels. Choosing the right fitness wearable can feel overwhelming with so many options available. Choosing the perfect fitness wearable involves matching the device's features to your unique needs and preferences.

APPLICATIONS OF WEARABLE FITNESS TECHNOLOGY

There are plenty of wearable options out there for different lifestyles. These devices are commonplace on the wrists of everyone from ultra marathon runners to casual gym goers. Common applications of wearable tech in fitness include the following [9,16,17]:

- *Fitness Tracking*: Wearable devices provide comprehensive fitness tracking and activity monitoring capabilities. They accurately measure steps taken, distance covered, calories burned, and even monitor heart rate during exercise. By providing real-time feedback, wearables motivate individuals to stay active and adopt healthier lifestyles. An example of fitness tracking is shown in Figure 7 [9].
- *Sleep Tracking:* Sleep is crucial for physical and mental well-being. Wearable devices equipped with sleep tracking capabilities monitor sleep patterns, duration, and quality. They provide valuable insights into sleep stages, including deep sleep. Fitness rings like the Oura Ring are excellent for sleep tracking due to their comfort and advanced metrics.
- *Nutrition Tracking:* Fitness is not just about exercise; it is also about proper nutrition. Nutrition tracking apps help you monitor your dietary intake, count calories, and analyze the nutritional content of your meals. They can even provide personalized meal plans and recipes based on your fitness goals. A typical nutrition tracking is shown in Figure 8 [9].
- *Calorie Tracking:* Another great feature of many fitness wearables is calorie tracking. Many wearables combine data points (age, weight, sex) with heart rate monitoring so it can calculate an estimate for energy (calories) spent. Think about energy in its simplest terms–you need to expend more energy than you consume if your goal is to lose weight, you need to expend as much as you consume if your goal is to maintain weight, and you will need to expend less energy than you consume if your goal is to gain weight. Knowing how much energy you spend is invaluable in helping you achieve those goals.
- *Health Monitoring:* Advancements in wearable technology have paved the way for remote health monitoring and telemedicine. Wearables equipped with biometric sensors can monitor vital signs, such as heart rate, blood pressure, and oxygen saturation, allowing healthcare professionals to remotely monitor patients' health conditions. This capability is particularly valuable for individuals with chronic diseases or those in remote areas.
- *Gamification:* One of the most significant impacts of wearable technology is the gamification of fitness. Wearables often incorporate gamification

elements, turning fitness into an engaging and rewarding experience. Challenges, badges, and leaderboards motivate individuals to achieve milestones and compete with friends and peers. Gamification can make going to the gym a lot of fun. Wearable fitness trackers are a great resource for gamification as they can turn any workout into a challenge/competition.

- *Immersive Fitness:* Augmented reality (AR) and virtual reality (VR) technologies are integrated into wearable devices, particularly fitness. These devices could overlay digital information onto the real world, giving us instant access to directions, translations as well as maintenance manuals for complex machinery. Virtual reality (VR) has brought an exhilarating dimension to the fitness world, particularly through VR fitness games. VR is transforming workouts by immersing users in dynamic, virtual environments. This technology makes cardiovascular exercises more engaging, turning routine workouts into adventurous experiences. VR is also being integrated into group fitness, allowing participants to engage in virtual challenges together, adding a social dimension to the fitness journey. Users can now apply VR headsets and immerse themselves in virtual environments encouraging physical activity while making exercise feel more like an adventure. Incorporating augmented reality (AR) elements in these games further enhances the interactivity. AR overlays digital information in the real world, making your surroundings part of the gaming experience. Figure 9 shows an immersive fitness experience [9].
- *AI-Powered Personal Training:* Artificial intelligence is becoming a cornerstone in fitness, offering personalized workout plans and real-time coaching. AI-powered personal trainers represent a remarkable advancement in the fitness industry, offering users a tailored and responsive approach to their workouts. These virtual trainers leverage artificial intelligence to create personalized fitness plans, provide real-time feedback, and adapt routines as users progress toward their goals. AI personal trainers assess the user's body metrics, fitness level, and health goals.

BENEFITS

Wearable technology offers several key benefits that contribute to improved fitness monitoring, training efficiency, and goal setting. Fitness wearables can help you move more, sleep better, and stay healthy. Fitness trackers now serve up a vast array of fitness, health, and wellbeing metrics. Other benefits include the following [1,18]:

- *Personalization:* Many wearable devices offer personalized coaching and virtual training features. These devices provide users with customized workout plans, exercise routines, and instructional videos. This personalized guidance enhances the effectiveness of workouts, reduces the risk of injury, and keeps users motivated and engaged in their fitness journeys. If wearable technology companies provide consumers with more individualized capabilities, this would improve the generated outputs and represent an additional marketing tool to boost sales.
- *Convenience:* Wearable devices have revolutionized accessibility and convenience, making it easier than ever to prioritize your health and well-being. Having all this data at your fingertips has never been easier. Wearable fitness trackers, like fitness tracker watches, give you this information in real time. For some people, seeing the numbers motivates them. It makes setting and tracking goals easier.
- *Motivation:* Motivation is the cornerstone for fitness app success. Wearables can fuel motivation by providing real-time data and progress tracking. These devices and apps often use gamification elements like badges, challenges, and leaderboards to keep you motivated. It creates a sense of accountability, when you see your daily steps or exercise minutes on your wrist, you are more likely to take that extra walk or hit the gym to meet your targets.
- *Engagement:* Wearable technology has revolutionized group fitness classes by introducing interactivity and engagement. Real-time tracking and display of workout metrics have transformed the traditional class environment. The integration of wearable technology in workouts is more than a trend; it's a revolution in the fitness industry. Live-streaming workouts have emerged as a dynamic and engaging fitness trend, allowing individuals to participate in real-time fitness sessions from their homes. One of the key benefits of live-streaming workouts is their accessibility. As shown in Figure 10 [9], users from various areas can join sessions led by renowned fitness trainers and instructors.
- *Sustainability in Fitness:* As environmental awareness grows, so does the demand for eco-friendly fitness equipment. As people become aware of how their energy usage impacts the environment, more want the ability to monitor it in their homes. To help homeowners do this, the energy company created a smart assistant, which lets people control electrical devices in their

homes, provides real-time insights into energy usage, and helps manage consumption to minimize energy coming from non-renewable sources – all through a user-friendly interface. Gyms and consumers are gravitating towards self-powered cardio machines, sustainable materials, and energy-efficient designs.

- *Social Support*: Emerging technologies can provide ongoing support and motivation and interface with designated medical professionals. Wearable devices often offer connectivity features that allow users to share their fitness achievements, goals, and progress with friends, family, or online communities. This social support aspect fosters community, motivation, and accountability. Many devices tracking different health and fitness metrics can provide a better understanding of how you are doing, not how you think you are doing.

CHALLENGES

Despite all the advances that have been made, significant gaps still exist in validity and reliability, particularly in real-world performance circumstances. Major challenges of wearable fitness technology include concerns about data privacy and security, potential inaccuracies in tracking, the risk of obsessive or anxious behavior from over-reliance on metrics, and technical issues like frequent charging and compatibility problems. Other drawbacks are the cost of the devices, potential discomfort, and the fact that they may not be suitable for all fitness levels or activities. Accounting for individual differences and environmental factors is both complex and challenging, yet essential for the best performance of wearable devices. Other challenges include [12,18]:

- *Ethical Concerns:* As with any technology, data security and privacy are paramount. Data privacy and the potential for discrimination by employers or insurers based on collected fitness data are ongoing concerns. Wearable fitness devices and their accompanying apps implement encryption and secure authentication protocols to safeguard personal health data.
- *Cost:* Another negative aspect is cost. Higher-quality devices can be expensive, and it may be difficult to determine if the cost is justified by the benefits. The cost of wearable technology can range from a few hundred dollars to several thousand, depending on the features and brand. There is a tracker for every budget and style. As with any technology, the more you spend, the more you get.
- *Transparency:* Rather than place the burden on the scientific community, manufacturers should be encouraged to provide full transparency for the algorithms they use in their wearable devices with rigorous, transparent, and complete reporting of algorithm development, validation, and real-world testing. Improving transparency in development and validation of these metrics, along with better tailoring to individuals, should increase the validity and reliability of these devices.
- *Accuracy:* Everything on your wearable related to health and fitness is an estimate. Not all fitness trackers are created equal. They have varying degrees of accuracy. Any fitness tracker needs to accurately assess your activity level to be able to calculate it. Research indicates most trackers are reasonably accurate, but they are not perfect, which always leaves room for error. How much error depends on which device you choose. And another consideration is repeatability: Can the monitor accurately produce the same result on the same person on repeat use within a few minutes?
- *Battery:* Wearable need a power source to function, and battery life is a consideration. One of the biggest complaints about wearable technology is that they require frequent charging. This can be a real pain, especially if you are using your device for something like tracking your sleep patterns or monitoring your heart rate during a workout. Battery life varies widely.
- *Limitation:* As any exercise professional or clinician will attest to, there is no "one size fits all solution." Simply wearing a fitness tracker does not guarantee a person loses weight, but coupled with an exercise plan and a healthy diet, results become much easier to achieve. If an individual is not creating this plan themselves, the logical path to take would be to have a qualified professional, an expert, create it for them.
- *Obsession:* Users can become overly fixated on data, leading to stress, anxiety, or an unhealthy obsession with metrics like step counts and calories burned. This can detract from the enjoyment of exercise and may lead to a negative relationship with fitness. The technology may not work for everyone, especially those who are already prone to obsessive behaviors.

FUTURE OF WEARABLE FITNESS TECHNOLOGY

A wearable device is a piece of technology added to clothing and/or accessories that are worn on an individual's body. Wearable technologies are powerful tools for health and fitness and have become indispensable training tools for athletes of all levels. Since the 1960s, fitness tracking devices and the technology underpinning them have developed at a

rapid pace. They continue to evolve rapidly, with ongoing advancements in sensor technology, battery life, and data analysis capabilities. Wearable tech is changing fitness and the fitness industry continues to grow at an exponential rate. As more and more people adopt wearable technology, it is likely that this collective ability to better track health and fitness markers will have a positive impact on population health. As we plan for tomorrow, the fitness industry is poised for a technological explosion.

The future of how wearables could impact our lives remains relatively unknown. However, many companies have begun to set out their stalls, predicting what the next big thing will be. The fitness tracker and the wider wearables market show no signs of slowing down anytime soon [20]. Over the next few years, as wearable technology continues to evolve, with devices becoming smaller and more affordable, the interest and value will switch from hardware to data. From a consumer perspective, people need the raw data collected by their wearable device to be mined and presented in an understandable and meaningful format.

CONCLUSION

Wearable technology has become a part of everyday life. Fitness wearable technology has come a long way and the future holds more possibilities for fitness regimes. These devices offer real-time insights into health metrics like heart rate, sleep quality, and activity levels, aligning with the growing biohacking trend. They are here to stay, which means that users will continue collecting health- and fitness-related data, but will also desire assistance in interpreting these data. The evolution from basic monitors to today's multifaceted wearable devices reflects a significant shift in our fitness culture. This shift from simple to complex functionalities mirrors the evolving demands of fitness enthusiasts who seek deeper insights into their physical activities. Many fitness professionals are now in favor of their clients using wearables and actively encourage their use.

The wearable tech revolution is well underway. With advancements in wearables, artificial intelligence (AI), immersive technologies, and sustainable solutions, fitness professionals have more tools than ever. In today's fast-paced and health-conscious society, the popularity of fitness tech and wearable devices has skyrocketed. People are becoming more proactive in managing their health and wellness. Wearable devices have emerged as a game-changer, revolutionizing how we approach physical activity and health monitoring. More information about wearable fitness technology can be found in the books in [21-24].

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Figure 1 A range of wearable devices [2].

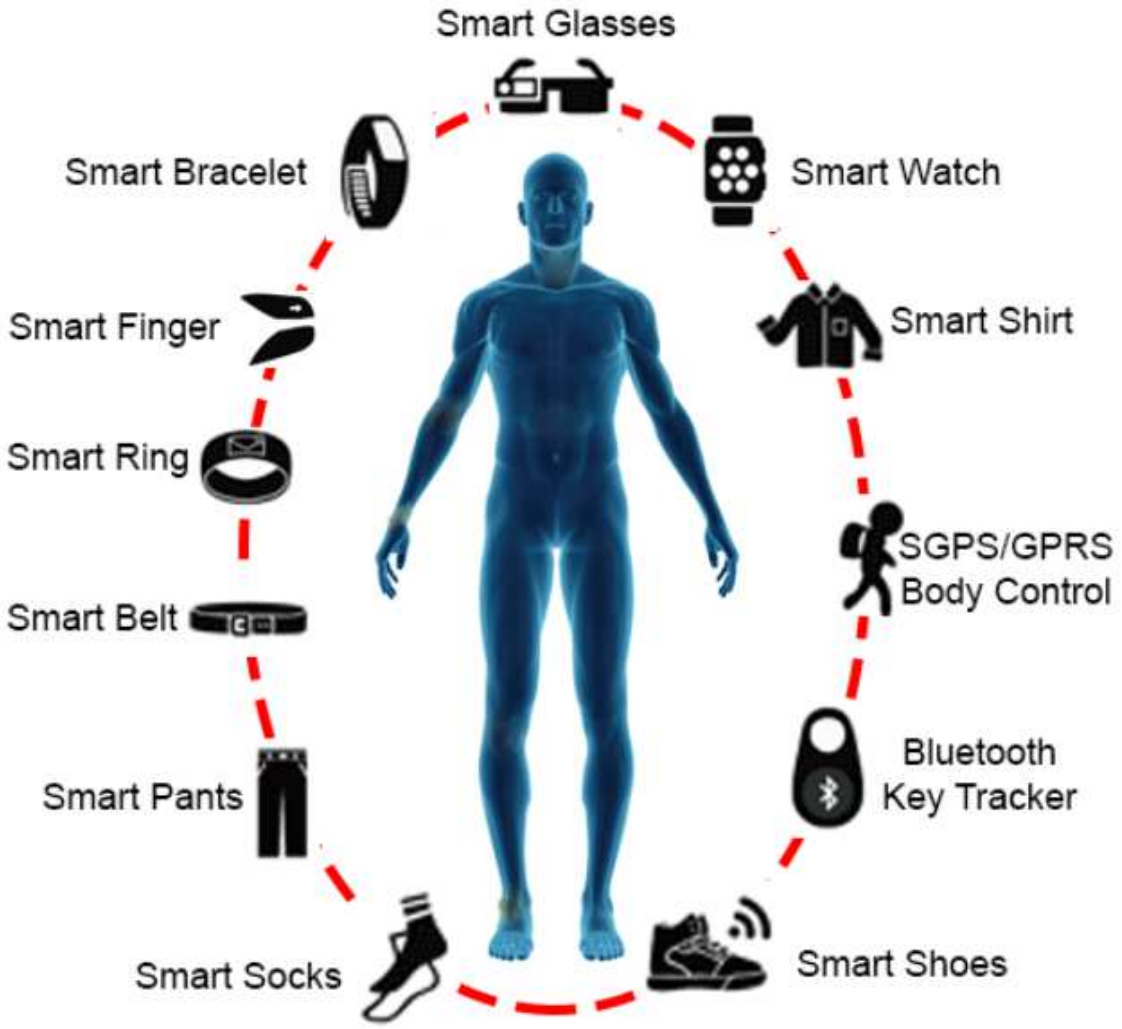

Figure 2 Different types of wearables on human body [5].

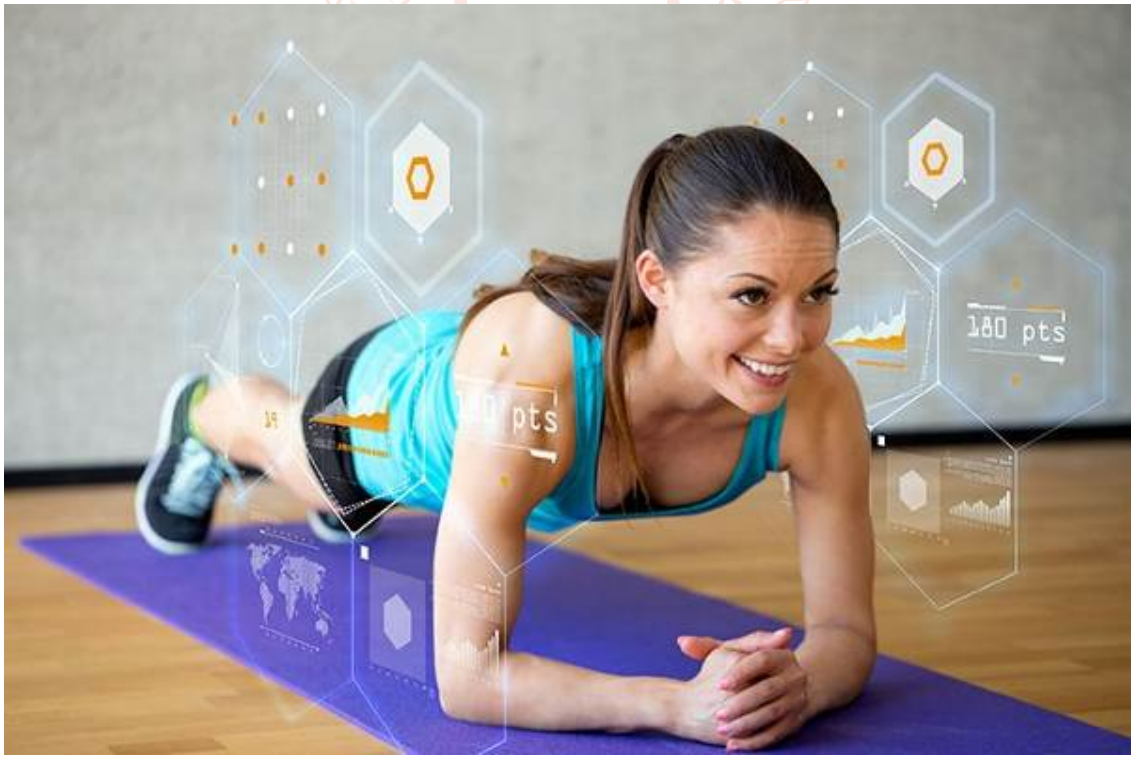

Figure 3 A woman performing exercise [10].

Figure 4 A woman using wearable to track fitness [11].

Figure 5 Different types of fitness wearables [13].

Figure 6 A typical fitness watch [15].

Figure 7 A typical fitness tracking [9].

Figure 8 A typical nutrition tracking [9]

Figure 9 An immersive fitness experience [9].

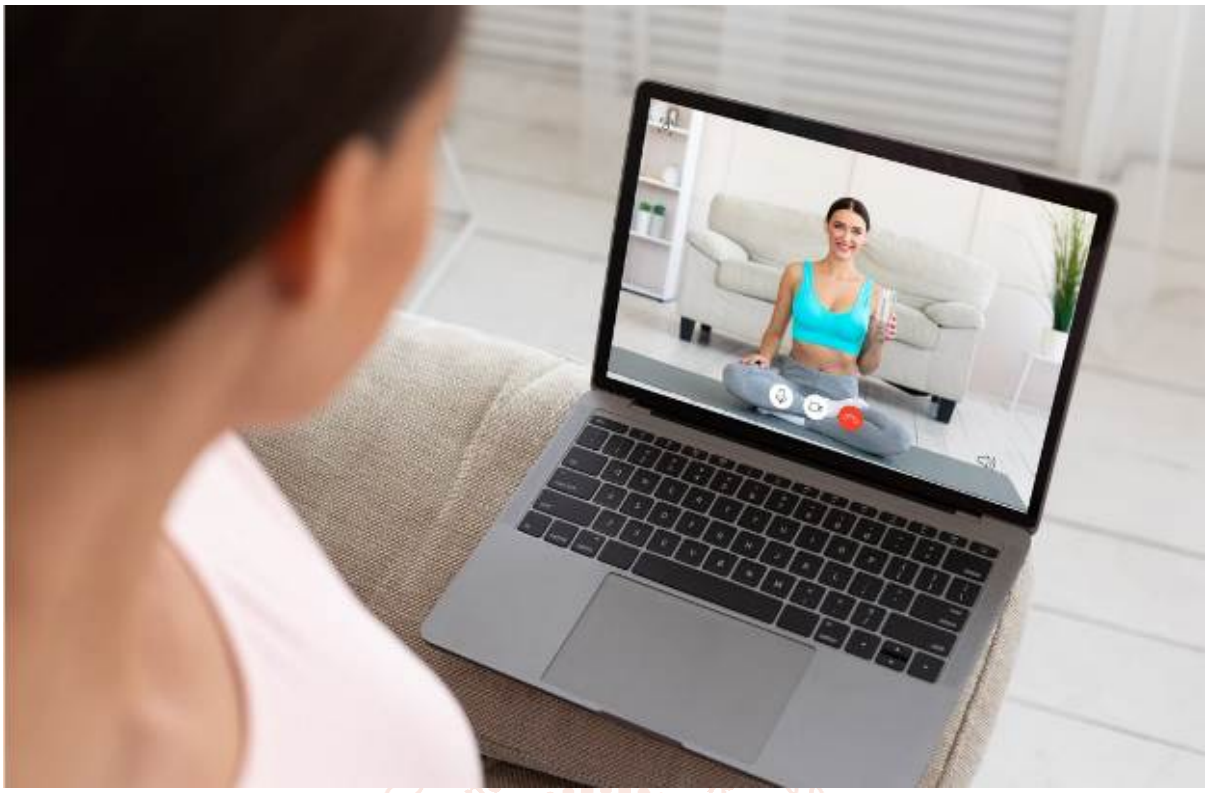

Figure 10 User joins sessions led by a fitness trainer [9].