Chapter 14
Artificial Intelligence and Augmented Reality in Physical Activity: A Review of Systems and Devices

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Abstract In this chapter, we describe the existing AI devices aimed at PA monitoring and the most relevant AR software focusing on movement. Our review will present the latest findings, classified according to their accessibility and economic cost, and will describe the main characteristics, the basic instructions for use, and the practical applications of each of them. Within the domain of physical activity (PA), artificial intelligence (AI) has been applied primarily in the form of smart wearable devices, with the aim of improving people's living standards. Through the use of wearables (Xiaomi Smart Band, Fitbit, Apple Watch) and cameras (Alfa AI, Zenia, Peloton Guide, AndroVideo, Sportvu 2.0), AI can monitor the user's movements and physiological signals and can provide feedback about them. Augmented reality (AR) is now being employed to visualise, promote and motivate new forms of human movement. Although there are very innovative initiatives aimed at promoting the practice of PA in a virtual environment, very little is currently known about these environments. The use of AR has given rise to a myriad of proposals in all fields of motor research and development, ranging from psychomotor processes in children (FitnessMeter, AR Runner, DribbleUp) to educational/sports PA practice (Lü interactive playground, BEAM interactive floor, HADO), PA and health (PostureScreen, Complete Anatomy 2022), high-performance sport (My Jump Lab, Capture.U) and programs to promote PA in the elderly (Obie interactive projector, CyberCycle). There is software that uses both AI and AR, for example Alfa AI, Capture.U and

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CyberCycle. The use of these two technologies allows for the practice of PA in a new dimension, and enables personalised, real-time monitoring of a user's activity through innovative exercises.

14.1 Introduction

In recent decades, smart technology has become an essential element in the practice of physical activity (PA), as it can protect health, enable better decision making, and bring access to sport to more people. Numerous technological devices have been designed to promote health and the practice of PA, and advances in artificial intelligence (AI) and augmented reality (AR) have strong potential in terms of monitoring and motivating the practice of PA for every individual, regardless of their age and characteristics.

The aim of AI is to develop intelligent systems that mimic aspects of human behaviour, such as learning, perception, reasoning and adaptation (de Moraes et al. 2020). AI can be defined as the ability of a system to interpret and learn from external data and apply learning outcomes to achieve specific goals and solve problems through flexible adaptation (Wei et al. 2021). In the domain of PA and sport, AI enables the monitoring and recording of physiological data such as heart rate and energy expenditure, and the assessment of movement quality (Brickwood et al. 2019; Kristoffersson and Lindén 2022; Li et al. 2021). These types of information can promote the self-regulation of one's own PA, goal setting and the creation of action plans (Li et al. 2021). In addition, AI can provide feedback and create personalised training based on recorded data (Kristoffersson and Lindén 2022; Wei et al. 2021).

Also, AR can incentivise PA practice through the application of game dynamics in interactive environments. Exercise enhanced by AR is considered a new approach to exercise that can prevent non-communicable diseases within a population (Ng et al. 2019). Furthermore, the use of AR devices creates increases in PA and the motivation of users (Kosa and Uysal 2022; Nekar et al. 2022).

In view of this, the use of this technology has the potential to improve the health and well-being of the world's population. According to the WHO (2020), 28% of adults and more than 80% of adolescents have an insufficient level of PA. Physical inactivity is one of the main risk factors for chronic disease, mental health problems and increased adiposity (Cho et al. 2021; Li et al. 2021; WHO 2020). In order to combat this problem, new methods are being sought to encourage the practice of PA, such as the creation of programs or interventions aimed at its promotion (Creaser et al. 2021; Winand et al. 2020) and more concrete, accessible and attractive guidelines for the general population (Smith and Wightman 2021).

One of the key factors that can explain a lack of sustained PA over time is a lack of motivation (Winand et al. 2020). Other obstacles that have been found to prevent people from engaging in PA are social factors such as the cost of activities, the availability of transport, a lack of family support, and limited time availability (West et al. 2021). For this reason, there is a need to explore new technology-based intervention methods that are effective, accessible, and offer greater availability (Ni et al. 2019; Winand et al. 2020). Recent studies have claimed that technological interventions could lead to higher levels of PA and active participation in sport (Cho et al. 2021; Ni et al. 2019).

In order to bring this technology closer to the general population and to encourage its use in PA practice, we review and classify the AI devices intended for PA monitoring and the most relevant AR software focusing on movement and motor development. The latest findings are classified based on the type of device, its accessibility and the economic costs involved. We also describe the main features and basic instructions for use, as well as some of the practical applications of each device.

14.2 Artificial Intelligence Devices for Physical Activity Monitoring

AI may become very important in the field of PA, due to the relative difficulty of accurately analysing activity without expensive equipment. In conjunction with a lack of sports training of most people, this could lead to poor decision making that negatively affects their health (Wei et al. 2021). However, this can be avoided through the use of AI, which is capable of monitoring and supervising all training with the aim of giving information to the user and can even analyse all of the collected data to provide recommendations to the user on how to progress in their training (Ferguson et al. 2021; Wei et al. 2021). Furthermore, with these devices, the cost of personal trainers or gym memberships and the time spent travelling to fitness centres could be reduced (D'Amore et al. 2021; Oh et al. 2021).

Advances in this field allow sportspeople to improve their performance and avoid injury, thanks to the information provided by AI on breathing, heart rate and effort level. The most commonly used devices are wearables such as the *Xiaomi Smart Band* or *Apple Watch.* These devices synchronously record real-time physiological data such as daily steps, heart rate and energy expenditure (Brickwood et al. 2019). In addition to these, AI-enabled camera systems (smartphone or other specific devices) can be employed that are capable of collecting a wide range of biomechanical data from the user. In the following sections, we review the functionality of several types of devices and some of the most commonly used mobile applications offered for PA monitoring.

14.2.1 Wearables

Wearables are small portable devices that can take the form of accessories or clothing. They are designed to use modern information networks and various sensor technologies to collect, transmit and analyse the physiological and health parameters of the

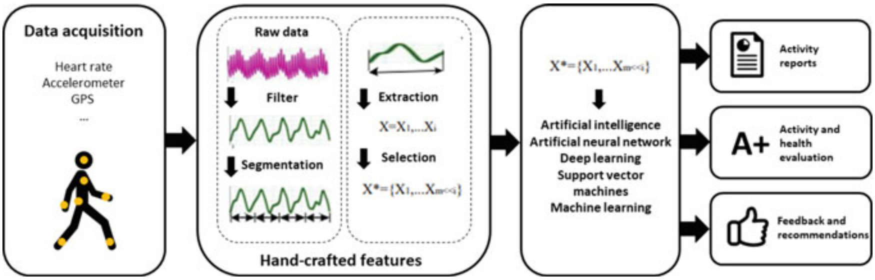

Fig. 14.1 Scheme showing how wearables obtain and process information

human body, in order to monitor the overall physical state of an individual (Nahavandi et al. 2022; Tang et al. 2020; Wei et al. 2021). Some of these parameters include energy expenditure, distance travelled, heart rate and sleep.

These devices can monitor the entire physical training process and can provide users with actionable advice through a big data analysis system. For example, wearables can accurately measure user-specific data during exercise, such as heart rate, and can issue warnings when a safe heart rate is exceeded. A diagram illustrating how the information collected by wearables is processed before being presented to the user is shown in Fig. 14.1.

Wearables are affordable, visually appealing, easy to use, and encourage an active lifestyle (Ferguson et al. 2021; Li et al. 2021; Tang et al. 2020). There is evidence that wearable devices are an effective way to increase steps and moderate-to-vigorous PA and can reduce sedentary behaviour in both young people (Creaser et al. 2021) and adults (Brickwood et al. 2019). Although there is a great variety of wearables, such as smart glasses or smart clothes, the most common are smart watches or smart bands, due to their accessibility and ease of use. In the following, we describe some current wearables, along with their main features and functions.

Xiaomi Smart Band*:* This model is one of the most accessible on the market. It has a wide variety of functionalities and sensors that allow it to monitor a multitude of biometric markers including heart rate, sleep quality, stress monitoring and breathing. From these data, the user can see a summary of his or her activity; however, for more detailed information on all metrics, the device must be linked to the *Zepp Life* app. It records all biometrics and provides feedback on sleep and workouts, and also offers video tutorials that aim to motivate the user and help to create a more active and healthy daily routine (Fig. 14.2).

This smart band model is designed for any user and aims to monitor some important variables for health.

Fitbit Charge 5: This has more functionalities and more sophisticated sensors than the *Xiaomi Smart Band*. *Fitbit* is able to perform electrocardiograms and to monitor electrodermal activity and oxygen saturation. In addition, this model has an integrated GPS, which is ideal for runners. This device also requires synchronisation with the

Fig. 14.2 Xiaomi Smart Band 6 performing a blood oxygen saturation (SpO_2) analysis (extracted from https://www.youtube.com/watch?v=DiNZT-wL89E&t)

Fitbit app to allow the user to see all of the relevant statistics and to access more functionalities; challenges, health and training programs are also provided (Fig. 14.3).

This smart band is more complete than the *Xiaomi Smart Band*, and its price is therefore higher. It is designed for more active users who want to monitor their health status with great accuracy.

Apple Watch Series 7: This smart watch has a large number of sophisticated biosensors, and a wide range of functionalities and applications that can be used without the need to link to a smartphone. It can be used to browse all the data collected, and various kinds of applications with a focus on the practice of PA and health can be installed (Fig. 14.4).

The *Apple Watch* is not a device with the sole purpose of monitoring activity and health, and also has many productivity and entertainment applications that can be accessed at any time from the wrist.

Fig. 14.3 Fitbit Charge 5 performing an electrocardiogram (extracted from https://www.youtube.com/watch?v=W0KfJCUEcTA&t)

Fig. 14.4 *Smart Watch Series 7* displaying daily activity data (extracted from https://www.youtube.com/watch?v=mpG1VWxOOec&t)

To choose the wearable that best suits the user's needs, several aspects must be taken into account, such as the type of sensors included, the autonomy of the device, and its price. Table 14.1 shows the specifications and price of each of the wearables described above.

14.2.2 Artificial Intelligence Camera Systems

AI camera systems consist of cameras and computers that are capable of capturing and automatically identifying people and analysing their movements by comparing them with the information available to the AI, in order to provide feedback on exercise performance (Wei et al. 2021). Although the information in a video can help users to analyse their performance, users can correct and assess all their movements more accurately with the help of AI analysis. A diagram of how AI camera systems obtain and process data before presenting information to the user is shown in Fig. 14.5.

The AI system detects each individual and their body structure. Following this, the system collects information about the execution of each exercise and compares it with the references stored in its database. It then calculates the level of coincidence and locates any errors in the execution. The system is able to estimate the amount of PA performed by individuals and to calculate the calories consumed (Cruz et al. 2021). Moreover, users can browse all the statistics related to their training and observe which aspects can be improved.

AI camera systems have two major advantages: the first is the comfort they offer the user when performing movements, since these systems are not invasive or uncomfortable, while the second is the amount of information that can be displayed in image or video format, making it easy to understand by any user (Mabrouk and Zagrouba 2018). However, this type of system is very expensive, and is not very feasible to

Table 14.1 Features and approximate price of some of the smart bands and smart watches on the market

Device		Features	Price
Xiaomi	*Smart Band 4*	• Designed for indoor and outdoor exercise • Up to 20 days of autonomy • Waterproof up to 50 m • Six training modes • Heart rate monitoring • Sleep monitoring (light and deep) • *Zepp Life* app can be used to check health and daily PA data	Under 20$
	Smart Band 5	• Up to 14 days of autonomy • Waterproof up to 50 m • 11 training modes • Intelligent 24-h heart rate monitoring with notification of any abnormalities • Sleep monitoring (light, deep and REM) • Three health modes to help users improve their health • Intelligent personal activity monitoring • Stress monitoring • Breathing exercises • *Zepp Life* app can be used to browse daily health and PA data, and special exercises are offered to meet individual needs	From 20$
	Smart Band 6	Smart Band 5 features plus: • 30 training modes • Blood oxygen saturation monitoring • Sleep monitoring of naps during the day and breathing quality during sleep	From 30$
	Smart Band 7	Smart Band 6 features plus: • More than 120 sport modes • Training load analysis	From 40$
Fitbit	*Fitbit Charge 5*	• 20 exercise modes • Waterproof up to 50 m • Up to seven days of battery life • Electrocardiogram application • Stress management level • Oxygen saturation monitoring (SpO_2) • Detailed heart rate monitoring and analysis with display of health and wellness statistics • Monitoring of HR, recovery level and time in Active Zone • Respiratory rate • Skin temperature monitoring • Electrodermal activity scanner • Sleep score and sleep phases • Integrated GPS	From 100$

(continued)

Table 14.1 (continued)

Device		Features	Price
Apple	*Apple Watch Series 7*	• Apps provided by the smartwatch itself – A large number of applications can be installed or linked – Training design: strength, aerobic, anaerobic, HIIT, etc. – Training control for various activities such as running, cycling, swimming, etc. • Intelligent monitoring of heart rate, breathing and sleep quality • Wi-Fi connection independent of smartphone connection • 18 h of battery autonomy and 80% battery charge in only 45 min • Monitors blood oxygen level • Checks the user's heart rate and can perform electrocardiograms • Sleep monitoring • Monitors respiratory rate even during the night • Integrated GPS	From $300

PA: physical activity; *HIIT*: high-intensity interval training

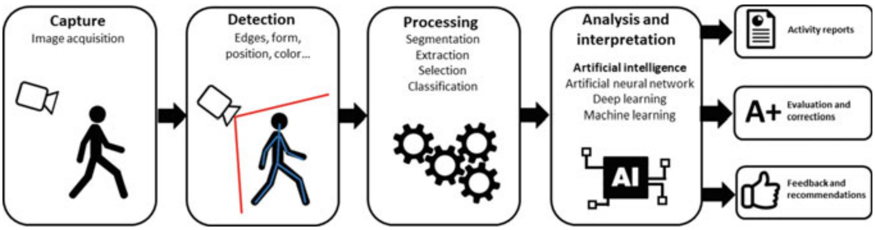

Fig. 14.5 Scheme showing the data acquisition and processing of AI camera systems, from image capture until the information is displayed to the user

install in a sports venue. Nevertheless, in places such as gyms or fitness centres, access to such devices may be valuable for performance improvement and injury prevention. In addition, it should be noted that the accuracy of these systems can be reduced by changes in lighting, frequent alterations in the scene background, the type of clothing worn by the subject and other disturbances (Mabrouk and Zagrouba 2018; Wang et al. 2019). Overall, however, AI camera systems are good tools for encouraging and improving PA practice, both for beginners (cheaper devices) and for advanced athletes (more expensive devices).

In the field of PA, this technology is mainly used to control the execution of exercises and to monitor a wide range of statistics for the entire training process. In this chapter, we review four of the most widely used AI camera systems in use today, from the most accessible to the least.

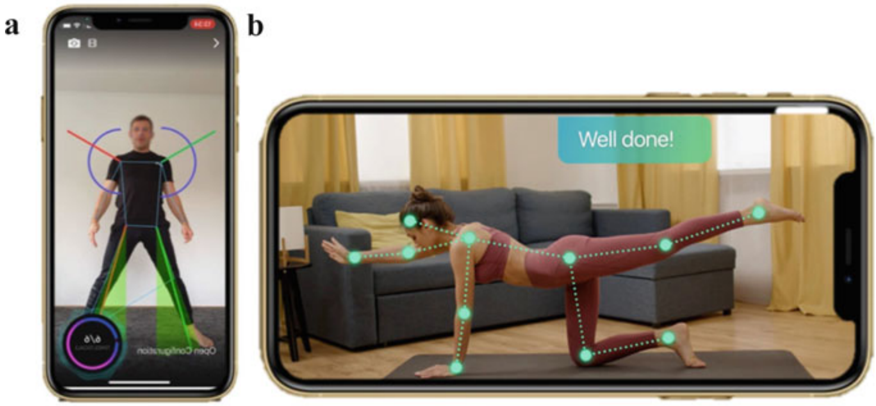

Fig. 14.6 **a** Image captured by *Alpha AI* during the performance of jumping jacks (taken from https://www.youtube.com/watch?v=SvuZ9MacW2g); **b** image captured by the *Zenia* app to evaluate a yoga pose (taken from https://www.youtube.com/watch?v=ZH4BbR8Zi-A).

(1) ***Alfa AI*** and ***Zenia*** are smartphone fitness apps that are capable of "replacing" personal trainers. These apps offer training sessions that monitor and provide real-time feedback on each exercise for optimal training. *Alfa IA* is dedicated to fitness exercises such as planks, push-ups and climbers, while *Zenia* focuses on yoga (Fig. 14.6). The biggest advantage of these apps is that they can be used anytime, anywhere. In addition, there are a wide variety of applications focused on PA tracking that are similar to these, with different functionalities and features, some of which are free and others are paid.

These applications are intended for personal use, and anyone can purchase them to start performing PA on a regular basis. For a more successful experience, personal motivation and some experience in sports practice are recommended. Both require monthly subscriptions starting at $5.

(2) ***Peloton Guide*** consists of a camera system connected to a television, which shows how to perform training, monitors the execution of movements, and provides feedback in real time (Fig. 14.7). This system provides recommendations for programs and workouts that can improve a training routine based on the data collected during each session. Another well-known example of a device that is similar to this technology is *Kinect* for Xbox.

This device is aimed at the general public, for personal use. It is not as accessible as a wearable, but it is capable of creating and presenting instructing workout routines while monitoring the execution of each exercise, in the same way as a personal trainer. Currently, it requires an outlay of approximately $300.

(3) ***AndroVideo*'s** AI camera systems detect the position of the user's body, provide real-time posture correction, automatically record the user's condition, display post-workout recommendations, and create a history log (Fig. 14.8). This is device is aimed at users of gyms or fitness centres. It is similar to *Peloton*

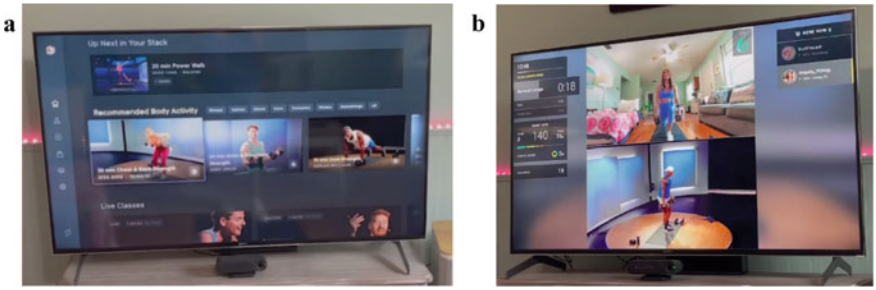

Fig. 14.7 **a** Main menu of *Peloton Guide* (extracted from https://www.youtube.com/watch?v=oZMXpoikDXs&t=757s); **b** screen capture of *Peloton Guide* during lunges (https://www.youtube.com/watch?v=sHGzPtVHk8Y)

Guide but acts as an artificial assistant rather than a personal trainer. It focuses on posture correction, exercise guidance, and condition monitoring. Using this device, trainers and users can access their exercise history and their statistics, in order to adapt their training plan according to their needs and goals.

(4) ***SportVU 2.0*** is a multi-camera system that collects high quality images of complex game situations, in order to provide accurate tactical (player positions) and physical (physical condition of each player) data. This system is used in elite sports such as the NBA and professional soccer leagues. Its function is to follow the ball and all of the players, and to provide statistics on their positions on the court in real time (Fig. 14.9). All of this information is intended to be used by teams to improve their performance. Using these systems, game broadcasts can show data about the game, such as the percentage of possession, the percentage of successful three-pointers, the maximum speed reached or the distance travelled by each player. However, this is a device aimed exclusively at elite teams with high budgets; for example, for use in the NBA, *SportVU 2.0* charges about $100,000 per team.

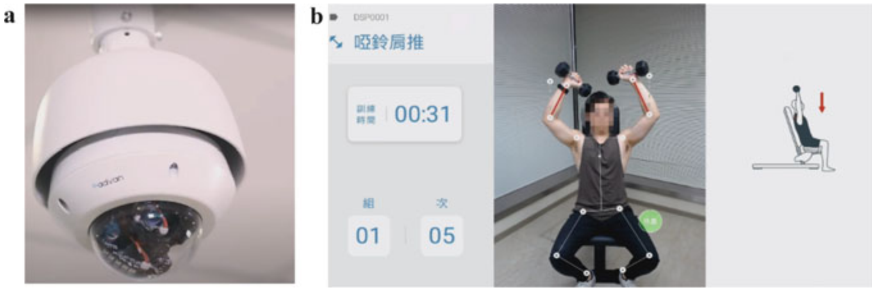

Fig. 14.8 **a** *AndroVideo* AI camera (extracted from https://www.youtube.com/watch?v=PtSGp6JGP_E); **b** *AndroVideo* screen, indicating in red that the user is performing a military dumbbell press incorrectly (extracted from https://www.youtube.com/watch?v=N19usqnNdHM)

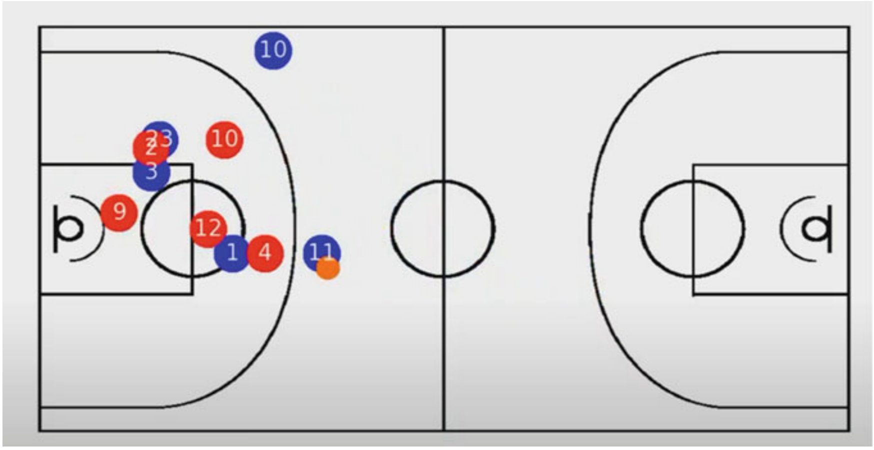

Fig. 14.9 Example of a situation in a real basketball game mapped with *SportVU 2.0* AI (extracted from https://www.youtube.com/watch?v=Yn_7bb_ruEw)

14.3 Augmented Reality Software for Movement and Motor Development

AR is a technology that involves generating new images, sounds or text from digital information in a real physical environment, thus simulating an environment in which the artificial and the real are mixed (Gil et al. 2021). With AR, the surrounding world becomes interactive and digitally manipulable. The use of AR opens up a wide range of possibilities in fields of research related to movement and motor development, from psychomotor processes in children to the promotion of PA in the elderly. Its exponential growth in recent years has also allowed increasing numbers of people to access this technology through smartphones, computers and other devices (Nekar et al. 2022).

Through AR, children can develop their abilities to perceive, recognise and process various objects and situations; there is also the possibility of adding, removing or modifying virtual aspects with the aim of personalising the experience according to their needs and abilities (Soltani and Morice 2020). In addition, several studies have revealed that AR games can increase daily PA levels and time spent outdoors (Bonus et al. 2018; Kosa and Uysal 2022; Ruiz-Ariza et al. 2018) and can stimulate players' development and cognition (Ruiz-Ariza et al. 2017; Soltani and Morice 2020).

AR systems feed augmented information to players' sensory modalities to help them understand the real-world environment (Soltani and Morice 2020). Mobile AR games have the potential to make environmental exploration enjoyable (Winand et al. 2020) and to create positive life experiences (Bonus et al. 2018). There are currently a number of AR games on the market, the most famous example of which is *Pokémon GO* (Ruiz-Ariza et al. 2018). In this game, AR is used to project images of Pokémon onto images of the real environment, using a cell phone camera. In both youths and adults, increases in moderate PA and numbers of steps were detected up to seven months from its first use (Baranowski and Lyons 2020).

Existing evidence indicates that PA practice and motivation can be improved through AR devices (Gil et al. 2021). Training with AR can not only replace traditional training but can be even more effective in developing certain skills or abilities such as balance, strength or muscular endurance (Nekar et al. 2022). At the same time, the experience of AR games contributes to well-being, as being voluntarily present in a virtual environment can elevate mood, regulate emotions and provide a healthy escape (Kosa and Uysal 2022).

In the domain of high-performance elite sport, AR is used by athletes, coaches and researchers. This technology can mine biomechanical data to project simulations onto the users of the movements they are performing. All of the information provided is used for movement correction and to improve the athlete's technique (Bolam et al. 2021). In addition, it can also be used as a validated assessment tool for various physical tests, such as jumping or running speeds (Bishop et al. 2022).

For the elderly, AR systems serve as a tool that can encourage rehabilitation through fun and entertainment (Jeon and Kim 2020). In studies of AR, seniors were interested and motivated by exercise, and exercise control was found to be easy for them (Jeon and Kim 2020). Table 14.2 briefly describes the main features of the AR applications and devices reviewed in this chapter, and they are described in more detail below.

14.3.1 Psychomotor Processes in Children

FitnessMeter: This is an advanced timing and measurement tool that can be used to perform various physical fitness tests. It is aimed at both coaches and physical education teachers, to allow them to evaluate their pupils and for personal use. It is capable of measuring speed, agility, jump height and general fitness through various tests: sprinting over 10 or 20 m, vertical jumping, the Course Navette test, and repetitions of push-ups, sit-ups or other exercises (Fig. 14.10).

AR Runner: This is an AR game which uses the camera to create a series of virtual control points over the terrain, which must be traversed as quickly as possible. All of the information is displayed on the phone screen (Fig. 14.11), and it is possible for a user to compete with other players from all over the world.

Table 14.2 Description, main target audience and approximate economic cost of apps and devices that employ AR

Field of work	Device/app	Description	Main target audience	Economic cost
Psychomotor skills in children	*FitnessMeter*	Fitness testing and physical performance evaluation	Any user	$2
	AR Runner	Competitive AR game in which the user races through checkpoints	Any user	Free
	DribbleUp	Intelligent fitness equipment connected to an app, with the aim of developing sports skills through different challenges or activities	Teenagers, young adults or amateur athletes	$49.99 + $16.99/month subscription
Educational/sports practice of PA	*Lü* interactive projector	Interactive projector that transforms any indoor space into an active and immersive educational environment in which children can participate physically, intellectually and socio-emotionally in different activities	Schools, institutes or youth centres	$20,000
	BEAM interactive floor	Play system with an interactive projector focused on the floor, which provides different active and educational games for children to learn and have fun	Schools, institutes or youth centres	$10,000

(continued)

Table 14.2 (continued)

Field of work	Device/app	Description	Main target audience	Economic cost
	HADO	New AR e-sport, which is played alone or in a team; equipped with an AR helmet and a connected armband to detect movements, the player can see virtual elements added to the real world and interact with them	Educational, sports or leisure centres	Rental from an official HADO site: 100$/hour or 10$/person for three games Installation cost unavailable
PA and health	*PostureScreen*	Assessment software that analyses and evaluates posture and body composition	Health professionals assessing posture and fitness	$50
	Complete Anatomy 2022	Complete anatomy platform with unique learning and collaboration tools; AR function available for mobile app	Students or health professionals	$75 for students $120 for professionals
High-performance sports	*Capture.U*	System that collects data through *Blue Trident* inertial sensors; displays real-time data overlaid on the video, allowing the user to make informed decisions	Amateur and elite sports professionals	From $6600

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Table 14.2 (continued)

Field of work	Device/app	Description	Main target audience	Economic cost
	My Jump Lab	Allows the user to carry out more than 30 tests, including jumps, lifts, sprints, changes of direction or even motion capture with great accuracy	Elite athletes and sport professionals	Free + $3.99/month subscription
Promotion of PA in the elderly	*Obie for Seniors* virtual interactive projector	Interactive game console that projects custom-made images onto any surface, encouraging active play through touch, movement and hand–eye coordination via the displayed images	Elderly people	From $3300
	CyberCycle	Type of exergame that combines a traditional stationary bike with virtual reality rides, competitive avatars and video game features	Elderly people	From $6000

PA: physical activity; *AR*: augmented reality

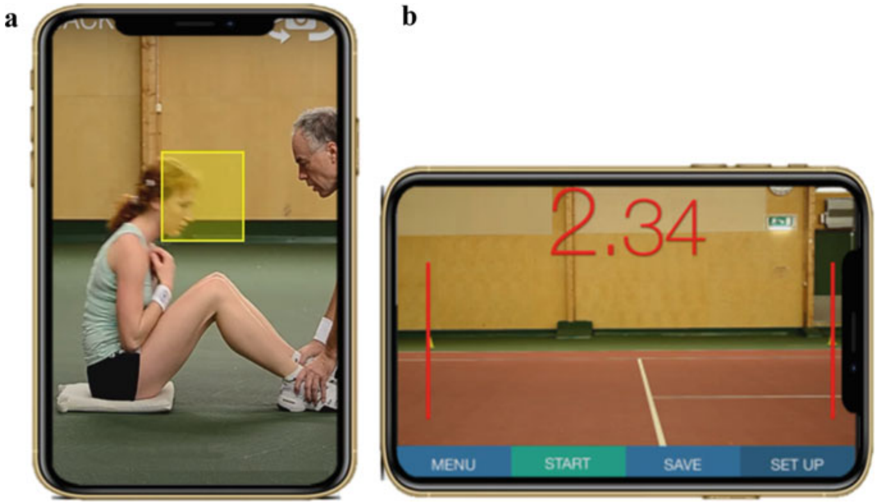

Fig. 14.10 **a** Abs test with *FitnessMeter*; **b** speed test with *FitnessMeter* (images extracted from https://www.youtube.com/watch?v=KuK1kTb7hp8)

Fig. 14.11 **a** Main menu of *AR Runner*; **b** screen during a game of "30 s rush" in *AR Runner* (images extracted from https://www.youtube.com/watch?v=5QouVbIjXgM&t)

Fig. 14.12 **a** Soccer technique training with *DribbleUp* (extracted from https://www.youtube.com/watch?v=1wYhFLVhp3M&t); **b** basketball dribble training with *DribbleUp* (extracted from https://www.youtube.com/watch?v=B3VeT7H62kQ)

DribbleUp**:** Smart equipment such as soccer balls, basketballs, medicine balls and boxing gloves can be linked to a smartphone via the *DribbleUp—Sports & Fitness* app. The app collects metrics such as crossing speed, dribbling motion, resistance, repetitions and other variables, via the cell phone camera and equipment sensors (Fig. 14.12). The objective is to improve the user's technique in different sports skills through exercises that are presented in the form of challenges, in the same way as a video game.

14.3.2 Educational/Sports Physical Activity

Lü **interactive playground:** *Lü* is an intelligent spatial environment that transforms a gymnasium or other indoor space into an interactive play area. It creates a virtual learning zone where young people can move and perform PA, in an attractive and innovative way.

This system consists of one or two video projectors, a computer, a 3D video camera, six static lights, two computerised lights and two loudspeakers. The complete system is able to project interactive games onto the walls, thus creating an interactive space in which young people can perform different innovative physical activities (Fig. 14.13). *Lü* offers various activities that encourage teamwork, competition and self-improvement through point systems. The different games that are available include subject matter such as mathematics, science, geography and foreign languages.

BEAM **interactive floor:** This is an interactive projection system that is focused on the floor, and allows several people to interact with it at the same time. It offers more than 200 educational games through which young people can learn via motion. *BEAM* can not only develop gross and fine motor skills, but also works on different aspects of cognition (memory, attention or perception). This system provides children and adolescents with the opportunity to explore, discover and interact through movement and fun (Fig. 14.14).

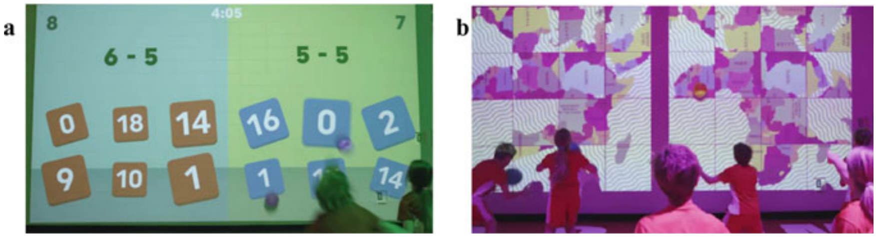

Fig. 14.13 Educational and active competitive team games projected on a wall with *Lü*: **a** active mental arithmetic game; **b** active game with geography content (images extracted from https://www.youtube.com/watch?v=n-gbscvwkGA)

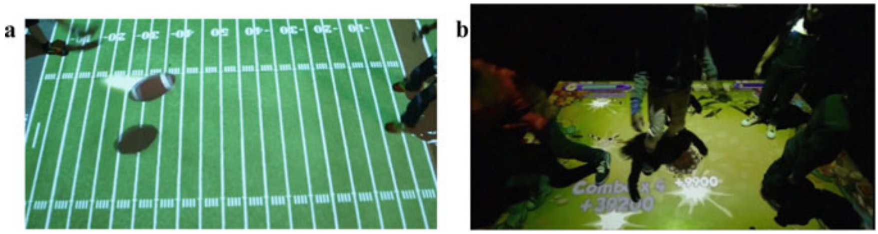

Fig. 14.14 Active games projected on the ground using *BEAM*: **a** competitive game of American soccer (extracted from https://www.youtube.com/watch?v=Z3rbKO1pv0U); **b** cooperative game of catch the mole (extracted from https://www.youtube.com/watch?v=SbCHRL-E4qY)

HADO: This is a new AR e-sport that can be played individually or in teams. Players are equipped with two smartphones: one is placed in a helmet to function as AR glasses, and the other is positioned in an armband to act as a motion sensor (Fig. 14.15). Players can see and interact with virtual elements added to the real world.

The main game offered by the *HADO* system is a competitive e-sport between two teams of three players. Each game lasts 80 s, and the team with the most points wins. Each team member must throw energy balls at the opposing team's players; if the opponent's body is hit, he or she loses one life cell. Each player has four life cells, and if all of these are lost, the other team gains one point. In addition to throwing energy balls, each player can create an energy shield for protection, and the balls can also be dodged. A bar is shown for each player, which indicates the level of energy available and limits the use of energy balls and shields (Fig. 14.16).

HADO is a very successful e-sport in Japan and is becoming increasingly widespread throughout the world. It is a new way of practicing sports that can be very attractive to the younger generation. It is an innovative device that illustrates the wide range of possibilities that AR can offer to the practice of PA, in terms of both promoting its practice and developing different motor skills.

Fig. 14.15 HADO equipment. Helmet and armband with attached smartphones (extracted from https://www.youtube.com/watch?v=GSXUtScLzEo)

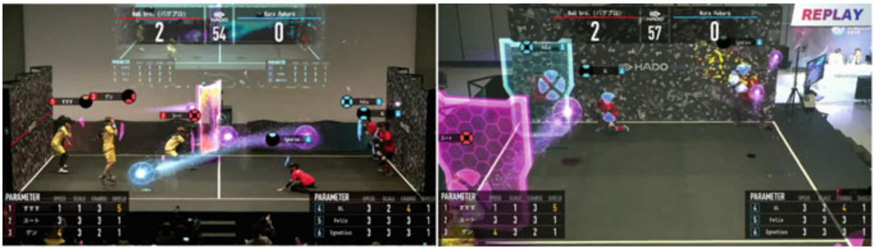

Fig. 14.16 *HADO* quarterfinal match at the 2019 World Cup (extracted from https://www.youtube.com/watch?v=GSXUtScLzEo)

14.3.3 Physical Activity and Health

***PostureScreen*:** This is a smartphone app that is available for both Android and IOS. It is an objective assessment tool for posture and movement that is capable of presenting and automatically emailing the results to the patient. It also offers customised, safe and functional postural exercises through another application called *WebExercises* to which it is linked (Fig. 14.17).

The use of this app for postural assessment is supported by scientific studies, such as those by Boland et al. (2016) and Szucs and Brown (2018), which report that the app demonstrates strong reliability and validity and can be employed in both clinical and research settings.

***Complete Anatomy 2022*:** This is a 3D anatomy mobile application platform with unique collaboration and learning tools. The user can interact with the model by selecting an element (muscle, organ, blood vessel etc.) and exploring and labelling

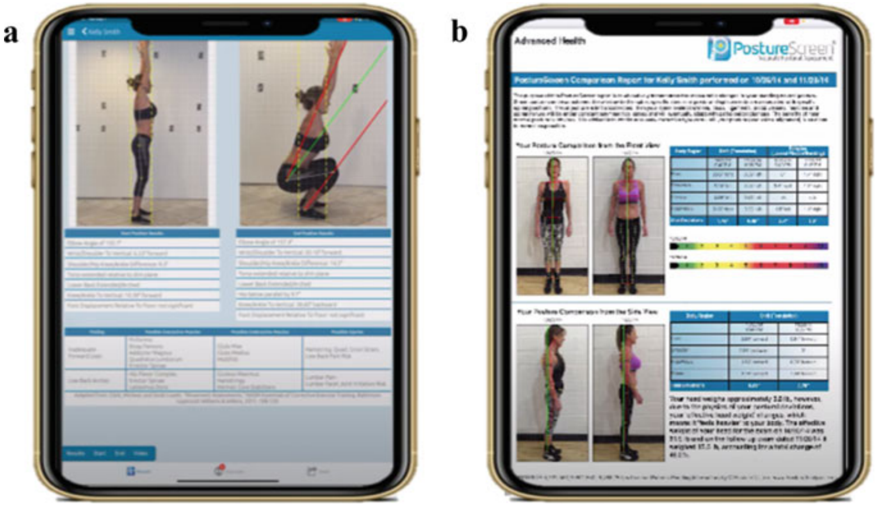

Fig. 14.17 **a** Report from *PostureScreen* on the execution of a squat; **b** report comparing the posture of the same person at different times (images extracted from https://www.youtube.com/watch?v=T_TLC91Ay_o&t)

the structures in real time. The program simulates the condition and details of the human body, allowing a user to explore human anatomy in depth using the cell phone or tablet as a "viewer" (Fig. 14.18).

The app has a set of tools that can cut out the layers that make up the body, allowing the user to explore the relationships between structures (muscular, skeletal,

Fig. 14.18 Images from the *Complete Anatomy 2022* mobile app, showing the composition of the human body at the muscular and vascular level (images extracted from https://www.youtube.com/watch?v=CjD-nFk7qtM)

vascular), simulate injuries and pathologies, animate pain points in the model, and add labels directly to a selected structure.

14.3.4 High-Performance Sports

Capture.U: The *Vicon* application collects and analyses biomechanical information from the human body in real time, and displays a simulation overlaid on the real image. This allows the user to make informed decisions in different situations, such as on the playing field, on the track, in the pool, on the court or in the lab. For full data collection, the user is required to wear *Blue Trident* sensors.

This application has a visualisation mode based on AR, in which 2D, 3D or both types of visualisations are shown at the same time (Fig. 14.19). There is also the option to select a particular joint of interest to view its kinematic data, positions and opening angles.

Some studies, such as that of Bolam et al. (2021), report that this application can be used both in rehabilitation for movement correction and in high-performance sports to improve execution.

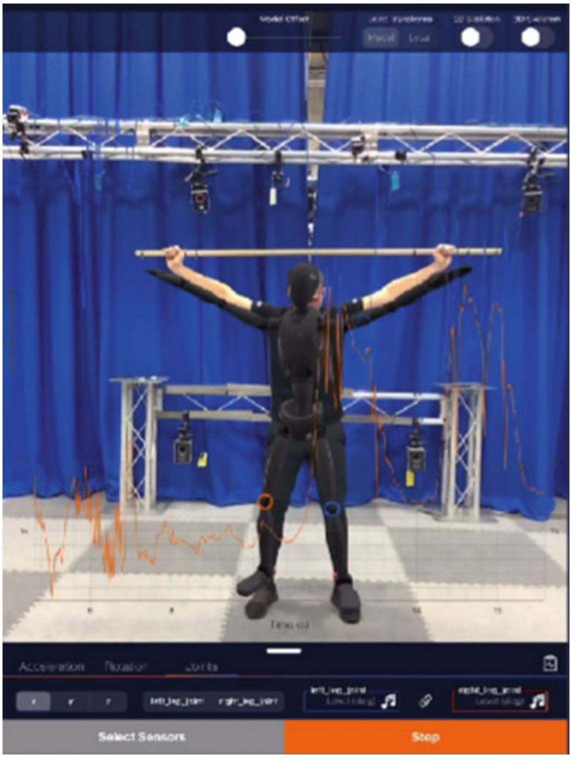

Fig. 14.19 3D model visualisation of squat movements in *Capture.U*, with a graph of the frequency and amplitude of the movements superimposed on a real-time image (extracted from https://www.youtube.com/watch?v=kRuio13OqQk)

Fig. 14.20 *My Jump Lab*: **a** main menu (extracted from https://www.youtube.com/watch?v=mObR35P_gm8&t); **b** vertical jump test (taken from https://www.youtube.com/watch?v=mObR35P_gm8&t); **c** speed test for each dead weight repetition (taken from https://www.youtube.com/watch?v=dKUEHvqKk5E)

My Jump Lab**:** This is an IOS application that performs the function of a portable and validated performance evaluation laboratory. No additional accessories are required for its use. Simply by using the smartphone's camera and sensors, the app is able to accurately record data on different physical skills (Fig. 14.20). With *My Jump Lab*, more than 30 tests can be performed, including jumping (counter movement jump, squat jump, repeated jumps, etc.), running and sprinting (contact/flight times, leg asymmetry, pronation/supination, etc.) and range of motion (dorsiflexion, neck extension/flexion, hip flexion and internal rotation, and shoulder flexion and internal rotation). This app is used by coaches, elite athletes, physiotherapists and researchers around the world. Its accuracy was validated by Bishop et al. (2022), who indicated that the app was a good measuring instrument for all the physical tests offered.

14.3.5 Promotion of PA in the Elderly

Obie **interactive surface:** This is a projector that can turn any floor, wall or table into an interactive surface. It uses sensors to detect movements such as bumps, taps, or shakes, and has more than 200 games to stimulate PA or cognitive skills (Fig. 14.21). The animated games are customised to different levels, and may include memory tests, musical contests, or speed coordination challenges.

CyberCycle**:** This is an interactive exercise bike that includes a virtual environment in which games, group rides, and competitions can be held to engage users in PA. A 19-inch HD monitor is used to immerse users in a virtual race, in which they

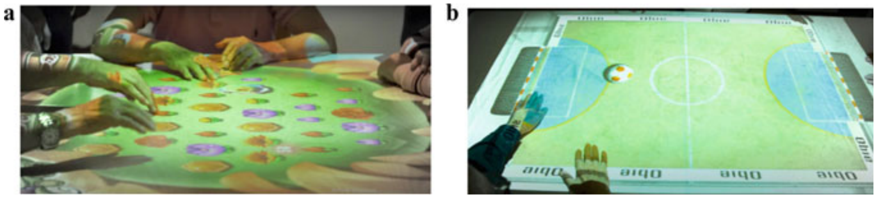

Fig. 14.21 *Obie* interactive surface: **a** collaborative memory game; **b** soccer competition game (images extracted from https://www.youtube.com/watch?v=Ml2pX8fiZJE)

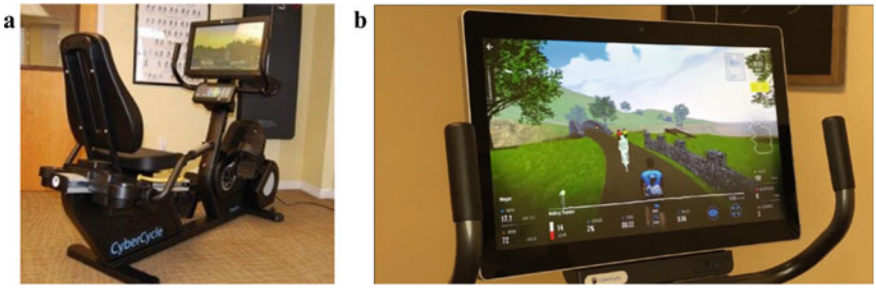

Fig. 14.22 **a** *CyberCycle* (extracted from https://www.prioritymarketing.com/gulf-coast-villages-new-cybercycle-takes-senior-fitness-to-a-virtual-level/); **b** screen capture during a virtual race (extracted from https://www.youtube.com/watch?v=acxXm10xsZ4&t)

ride through a 3D scenario (Fig. 14.22). This system is particularly suitable for the elderly, as it provides stimulation and keeps both body and mind fit.

14.4 Conclusions

AI and AR devices can encourage and enhance PA, as they increase motivation levels, monitor activity and optimise training. The use of either these technologies has great advantages for users, but the benefits are further enhanced by employing both simultaneously; this takes the practice of PA to a new level, as it allows for personalised real-time monitoring of activity via the big data processing enabled by AI and encourages PA with innovative activities offered through AR. For example, wearables can be used to monitor vital signs while exercising with AR systems (*AR Runner*, *DribbleUp* or *Lü* interactive playground), and the intensity with which the activities were performed can be checked at a later stage. Some of the devices and applications described above (*Alfa AI*, *Zenia*, *Capture.U* or *DribbleUp*) already use both technologies, where AI analyses the movements and presents feedback via AR, thus providing very complete information allowing the user to understand and correctly follow the instructions.

Emerging technologies such as AI and AR provide new opportunities for monitoring and promoting PA on a larger scale, for both personal and group use. Promoting the use of wearables and AR applications for smartphones or other devices could not only generate health and performance benefits at the individual level but could also improve the collective health of the population (Gal et al. 2018). Likewise, interventions aiming to promote PA can incorporate devices based on AI and AR, with the objective of expanding the possibilities and generating interest for a greater number of people.

Finally, as observed in this chapter, AI and AR are used in many fields of PA, from the promotion of PA at all ages to high-performance sports. In view of this, and due to the increasing accessibility of equipment with a multitude of highly reliable functionalities, the use of this technology has the potential to completely change the nature of PA and to create a more physically active society.

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