

CHAPTER 17

Current Technological Approaches in Physiotherapy and Occupational Therapy

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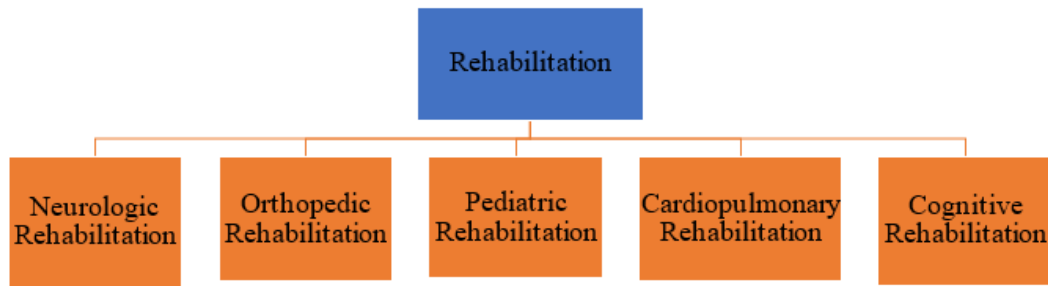
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Introduction

Rehabilitation aims to improve the patient's quality of life and social cohesion by maintaining independence in activities, minimizing pain and disability, and improving the ability to adapt to changing conditions. It is a problem-solving process shaped within the framework of the holistic biopsychosocial model and is presented with an individual-centered approach. It is carried out under the guidance of a specialized and multidisciplinary health team such as physicians, physiotherapists and occupational therapists, in cooperation with the individual and his/her family in line with appropriate goals (Wade, 2020). To achieve rehabilitation goals, the focus is not only on the diagnosis, but also on the current health status, developmental difficulty, disability and the impact of the person's physical, mental and psychological potential on their life. It involves working in partnership with the person and their loved ones so that they can maximize their potential and independence and have choice and control over their own lives (NHS England, 2016).

Today, different fields of physiotherapy and rehabilitation and occupational therapy have emerged according to the needs of the individual included in the rehabilitation program, their current problems and the type of disease or diagnosis. The formation of these areas ensures both the specialization of trained health personnel in certain areas and more effective service for individuals in need of rehabilitation. (Figure 1).

Figure 1
Rehabilitation Fields



The principles of rehabilitation applied in almost all of these areas are based on motor learning principles for the acquisition of motor skills. Motor learning occurs through structural and functional development in the neural system, leading to neurobehavioral changes. The neural system transfers the mechanism of movement from conscious-voluntary control to an unconscious control mode. The flexibility and modifiability of cortical reorganization underlies motor learning (Tarakci & Arman, 2019).

Today, new applications and treatment approaches have emerged with the reflection of the rapid development of technology in the field of rehabilitation. Different technological applications and devices are used in the field of rehabilitation to improve the sensory and motor abilities of patients.

The use of technology in rehabilitation offers the opportunity to manipulate the learning environment and achieve a more intense learning experience. Gains in cognition, motor control, emotion and willpower, social, personal and media use competencies can be achieved using technology (Tarakci & Arman, 2019).

Relationship of Rehabilitation Technologies with Neural Systems

Previously there was the idea that the nervous system was stable and did not change, but in recent years it has been proven that the nervous system has a dynamic structure. Neuroplasticity is the name given to all of the changes in neural organization that occur in the central nervous system throughout an individual's lifetime (Braun & Wittenberg, 2021). The use of technological devices and applications in rehabilitation is based on the principle of motor recovery and neuroplasticity. For this reason, it is seen that the technological approaches used today are mostly concentrated in the fields of cognitive, neurological and pediatric rehabilitation. The neuroplastic property of the central nervous system can be used to fully or partially restore lost function with appropriate rehabilitation programs. Plasticity basically occurs in three types. The first is associated with development in the prenatal period. The second occurs during development after birth. The third type refers to neuronal changes that are present after development. It is shaped by the experiences that occur in the organism (Alia et al., 2017).

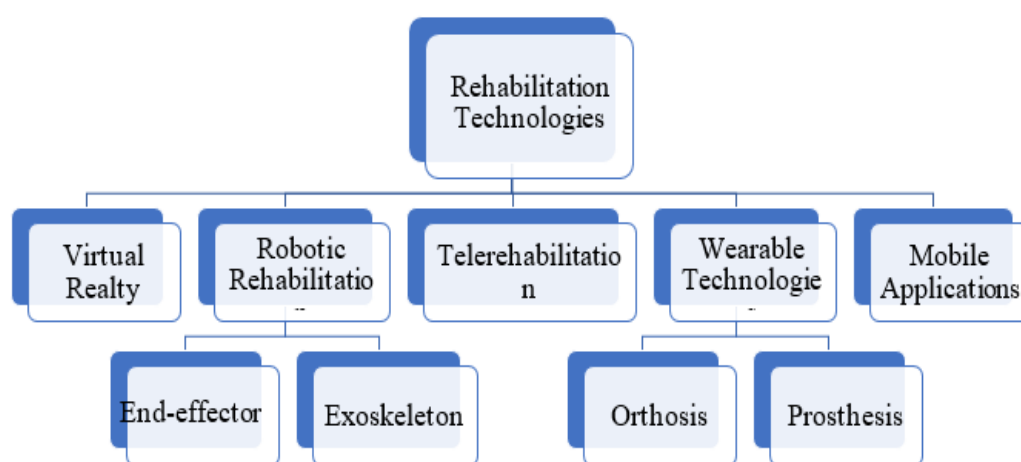
There are basic principles of plasticity that emerge with experience. For example, not using a certain brain function can lead to functional impairment, while training for that function can lead to improvement. For plasticity to occur, the activity must occur at certain repetitions, intensities and at certain times. Attention and interaction are also necessary for plasticity to occur (Kleim & Jones, 2008).

Technologies Used in Rehabilitation

Technological approaches used in Physiotherapy and Rehabilitation and Occupational Therapy vary according to the diagnosis, functional level, needs and potential of the individual. Rehabilitation technologies can be used alone or multiple applications can be used together. The most common example of this is virtual reality applications. Virtual reality applications can be used only through the screen or different interference devices, or they can be integrated into robotic devices or wearable devices to increase motor learning and interaction (Cheung et al., 2014). Figure 2 shows the technological approaches commonly used today.

Figure 2

Common Rehabilitation Technologies and Therapy Approaches (Braun & Wittenberg, 2021)



Virtual Reality

Virtual reality, also called virtual environment, is a three-dimensional computer-based simulation that creates a sense of being in any space and enables the perception of various information such as visual, auditory, etc. by the sensory organs. In virtual reality, the user is surrounded by a computer-generated 3D representation. The user can move in the virtual world, see, reach, grasp and reshape it from different angles (Tierl et al., 2018).

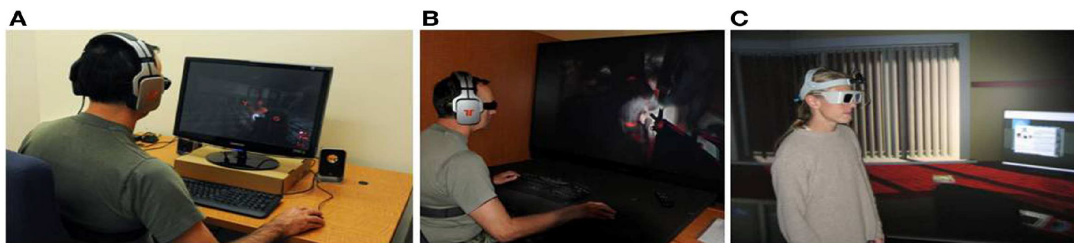
The virtual environment aims to take the user out of the physical environment and into an artificial world. The virtual environment can expose the user to visual stimuli through the screen, auditory stimuli through the audio device, haptic (contact), smell and even taste stimuli. The virtual reality device can enable the individual to be reflected in the environment from an egocentric (first person perspective) or allocentric (third person perspective) point of view. In the allocentric perspective, there is a reflection of the person called "avatar" that represents the person in the virtual environment and reflects the interaction, while in the egocentric perspective, the individual can interact with their own point of view in the virtual environment (Tarakci & Hajebrahimi, 2019).

There are hardware and software tools in systems that create virtual reality. These are hardware that provides visual, auditory or tactile stimulation and connects the user to the virtual environment, monitoring and interaction devices (keyboard, mouse, joystick, etc.) that transfer the user's activities to the virtual environment, display systems and software systems (Tarakci & Hajebrahimi, 2019).

The effectiveness of factors such as the number of senses stimulated in virtual reality applications and the level of interaction is called immersion. The immersion level determines the level of the user's involvement in the virtual environment, in other words, the level of isolation from the real environment. Immersion levels are generally classified into three different levels. Systems that provide a virtual environment at the basic level such as monitor, keyboard, mouse are referred to as non-immersive systems. There are also semi-immersive systems that use larger and higher resolution screens to increase visual stimulation and immersive systems that use screens or devices that completely cover the user's field of view (Figure 3) (Baus & Bouchard, 2014; Slater & Wilbur, 1997).

Figure 3

Immersion Levels in Virtual Reality A: Non-immersive VR system, B: Semi-immersive VR system, C: Immersive VR system (Baus & Bouchard, 2014)



The Use of Virtual Reality in Rehabilitation

Virtual reality applications are a brain-computer interaction method that provides many sensory and motor activities in a virtual simulation environment. Repetitive activities, which are the basic principle of neuroplasticity and motor learning mechanisms in traditional rehabilitation applications, are integrated into the virtual reality system and presented as simulations or video games. In this way, it is ensured that the individual's motor skills are developed and activities are performed with plenty of repetition. In addition, studies have shown that it plays a more motivating role compared to traditional rehabilitation and exercise practices, allowing activities to be performed for longer periods of time (Hao et al., 2022; Maier et al., 2019). Virtual reality applications have been shown to be effective in improving motor functions in both adults and children and adolescents (Kiani et al., 2023; Ravi et al., 2017).

Virtual reality is used in the rehabilitation of many neurological diseases such as stroke, head trauma, spinal cord injury, Parkinson's, MS, cerebral palsy, spina bifida, as well as in orthopedic rehabilitation for sensory development such as muscle strengthening, balance coordination development and proprioception. In addition, there are studies showing that it has been used in the field of cardiopulmonary rehabilitation in recent years and has positive clinical results such as increased physical capacity and endurance (García-Bravo et al., 2020; Tarakci & Hajebrahimi, 2019). Virtual reality first emerged with the video game industry. Over time, with its use in the field of rehabilitation and increasing scientific evidence of its effectiveness, the number of games with rehabilitation and educational content has also increased. Today, games with different interactions such as activities of daily living, different movement and activity trainings, cognitive trainings have emerged for rehabilitation purposes. The main companies that commercially produce and develop video games and virtual reality devices are Microsoft Kinect, Nintendo Wii, Oculus Rift, Razer Hydra, HTC Vive (Baus & Bouchard, 2014; Braun & Wittenberg, 2021; Tarakci & Hajebrahimi, 2019).

Figure 4

Use of virtual reality in rehabilitation (Stevens Institute of Technology, 2021)



Robotic Rehabilitation

Disability caused by neurological disorders or diseases requires long-term health care, pharmacological and rehabilitative treatments. Rehabilitation is critical to prevent or reduce morbidity in the later stages of the disease (Gardner et al., 1999). Diseases such as stroke, Parkinson's, spinal cord injury, cerebral palsy and MS require similar rehabilitation interventions to address problems such as motor impairments, reduced mobility and independence (Krebs et al., 2008).

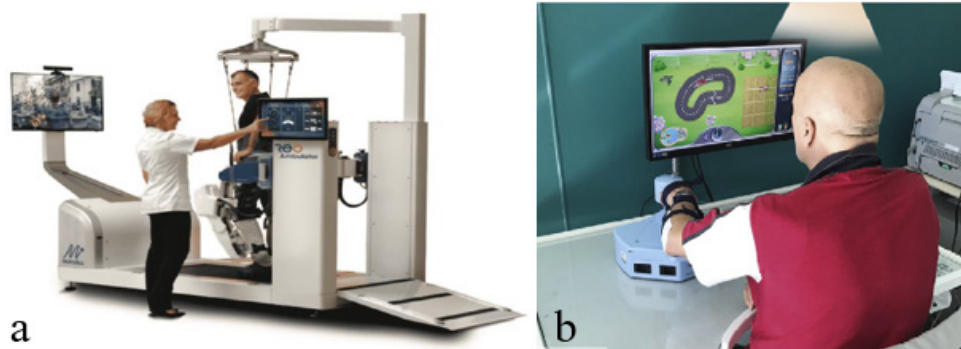
The main aim of neurological rehabilitation is to provide normal movement by improving muscle strength and coordination and sensory skills. In doing so, it is aimed to make normal movement permanent by providing cortical reorganization by supporting neuroplasticity. The most important motor learning principles used to ensure neuroplasticity are based on the repetition of purposeful activities in different ways and in large numbers (Kilinc et al., 2019).

Robotic rehabilitation is a current rehabilitation approach that is frequently used in the field of neurological rehabilitation, especially in the last two decades with rapid developments in technology, mechanical, computer, biomedical engineering and health. It is an application that allows the application of different and multiple repetitive exercises necessary for the stimulation of neuroplasticity, especially with motor learning principles (Demirbas, 2019; Kilinc et al., 2019). Robotic devices have many positive effects such as an objective assessment, enabling early patient participation in rehabilitation, spasticity inhibition, task-oriented training, preventing compensation, supporting neuroplasticity development, high dose and intensity training, cognitive rehabilitation, patient motivation, providing feedback to the patient and facilitating the work of physiotherapists and occupational therapists (Laut et al., 2016). It also has limitations such as high cost and the use of patients with certain functional and cognitive levels.

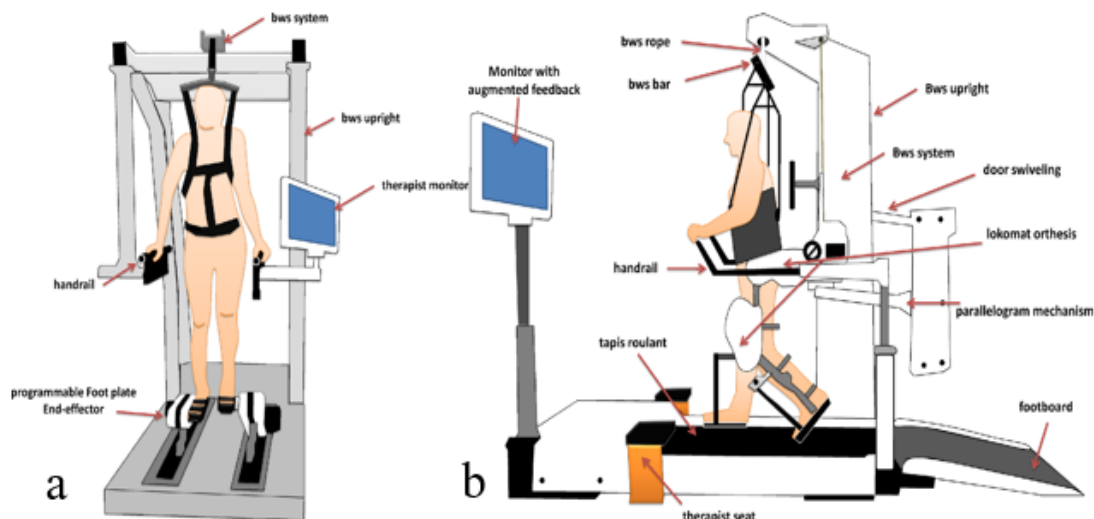
Robotic Rehabilitation devices used in the field of rehabilitation are divided into two as upper extremity robots and lower extremity robots according to the body parts used, and are divided into two as end effector and wearable robot systems according to the production method (Figure 5 and Figure 6).

Figure 5

a. Lower limb robot system (Kose, 2021) b. Upper limb robot system (Jakob et al., 2018)

**Figure 6**

a. End effector robot system, b. Exoskeleton type robot system (Calabrò et al., 2016)



Degrees of freedom (DOF), which is used to express the extent to which joint movements are allowed in robotic rehabilitation devices, determines the axes and planes in which movement occurs (Stegall et al., 2013). For example, a robot has a DOF of 1 if it can only move in one plane, such as hip abduction-adduction. If it performs flexion-extension to the knee and ankle joints in addition to the hip joint, it has a DOF of 3. The increase in the DOF value means that the effectiveness of the robot and its support for movement increases. In general, robotic rehabilitation devices can be used in active modes by supporting movement or creating resistance and passive modes where the device performs the movement completely. In addition, robotic devices can be used with virtual reality systems as a more effective and motivating method (Laut et al., 2016; Weiss et al., 2014).

End-effector Robotic Systems

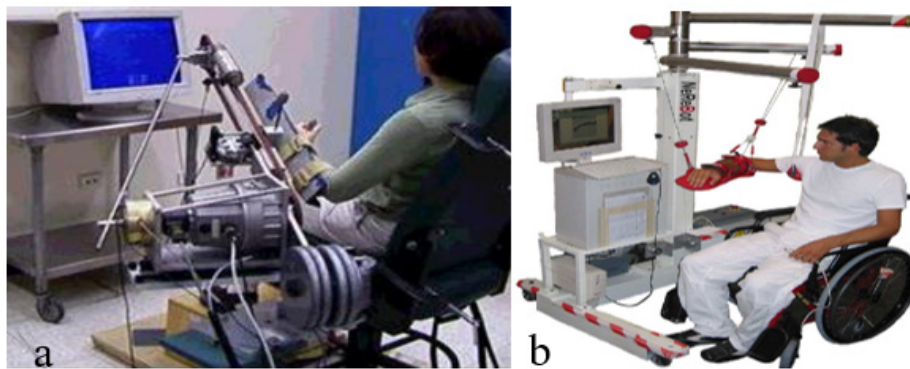
Upper limb end-effector robots are operated by means of a manipulandum held by the user, while lower limb end-effector robots are operated by means of an interface on the feet or legs. The manipulandum is connected to a robotic arm that transmits forces to the user and contains motion sensors. Since the forces and measurements take place on a single interface, it can be easily adjusted for different users without major changes to the

system (Colombo et al., 2005; Mehrholz & Pohl, 2012).

Sensory and motor training using a robotic device is realized through video games controlled by the movement of the manipulandum. The user tries to perform tasks such as drawing shapes or moving along a plane by moving an icon on the screen with the manipulandum. If the user is unable to perform the task, auxiliary force is provided by the robot through the manipulandum (Fasoli et al., 2003; Ferraro et al., 2003). In addition, in some robotic devices, the movements of the manipulandum are converted into kinematic data through sensors, allowing the user's motor functions to be evaluated (Krebs et al., 1998). Arm-Guide, EEULRebot, INmotion, GENTLE/S Haptic Master, NeReBoT, Bi-Manu Track are different end effector robotic device systems used in upper extremity rehabilitation.

Figure 7

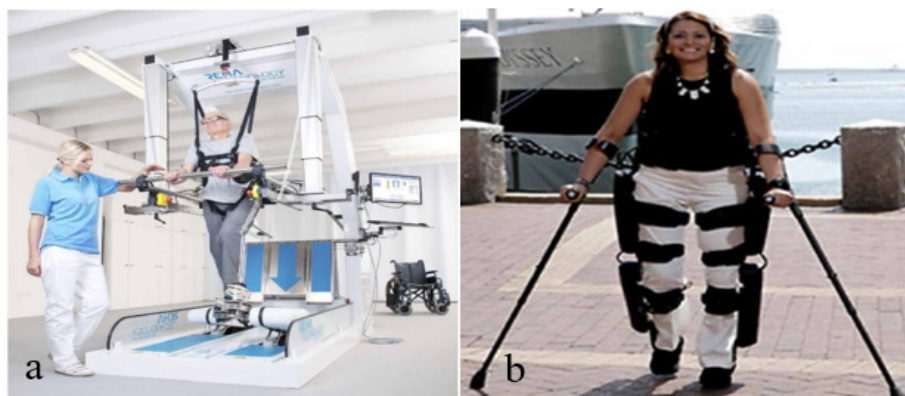
a. Arm-Guide (Hidler et al., 2005), b. NeReBoT (Rosati et al., 2007)



End effector robots used for lower extremity rehabilitation are less complex compared to upper extremity movements and are widely used for gait training (Low, 2015). For the lower limbs, robotic systems with force and torque sensors that allow simulation of walking and stair climbing activities are used. At the same time, data can be obtained through these devices that allow the evaluation of gait performance. Especially in neurological and geriatric individuals, it is possible for the therapist to provide walking training safely and with minimal effort against the risk of falling (Hesse et al., 2012; Schmidt et al., 2005). GT, G-EO System, Lokohelp, Rewalk are different end effector robotic device systems used in lower extremity and gait rehabilitation.

Figure 8

a. G-EO System, b. Rewalk (Goncalves et al., 2020)



Exoskeleton Robotic Systems

Unlike end effector robots, exoskeleton-type robots move directly on the user's specific joints. They are generally more difficult to design and build as they need to be adjustable to users of different anthropomorphic sizes and need to be connected to the limb at multiple points. Exoskeletons designed for the upper limb are heavy as they connect to different segments of the user's limb. This requires users to use compensatory muscle strategies during movement (Lum et al., 1999, 2006).

Exoskeletons have the ability to resist or assist movement by applying mechanical force to limb segments. Each joint can move independently of the other joints and isolated or combined joint movements can be performed (Kilinc et al., 2019). Exoskeletons used for lower extremities can have different DOF values from 2 to 8. They are especially used for gait training, balance training and clinical evaluation. There are also body weight support systems in the devices used for lower extremities (Roy et al., 2007, 2013). Hybrit Arm Orthosis, MIT Manus, ARMin, MIME, CLEVERarm, Armeo Power, Asist-On are exoskeleton robotic devices frequently used in upper extremity rehabilitation; Lokomat, ReoAmbulator, LOPES, Anklebot, ALEX, ICRO are exoskeleton robotic devices frequently used in lower extremity rehabilitation.

Figure 9

a. MIT-Manus (Hidler et al., 2005), b. Armeo Power (Sicuri et al., 2014)

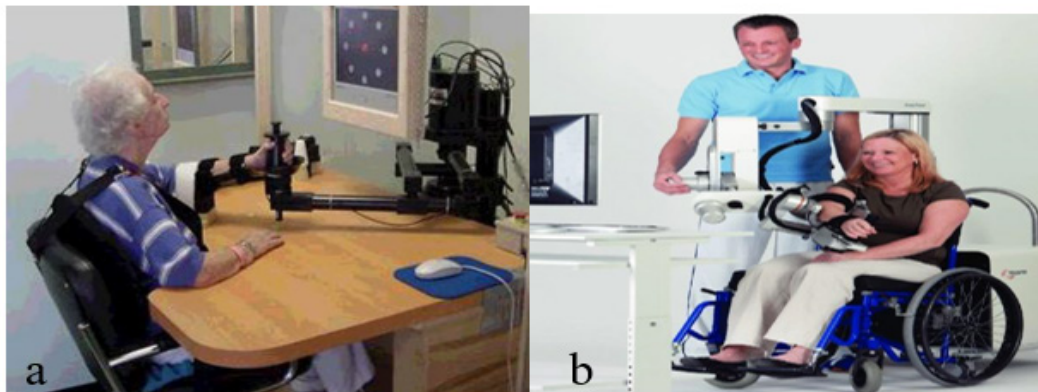
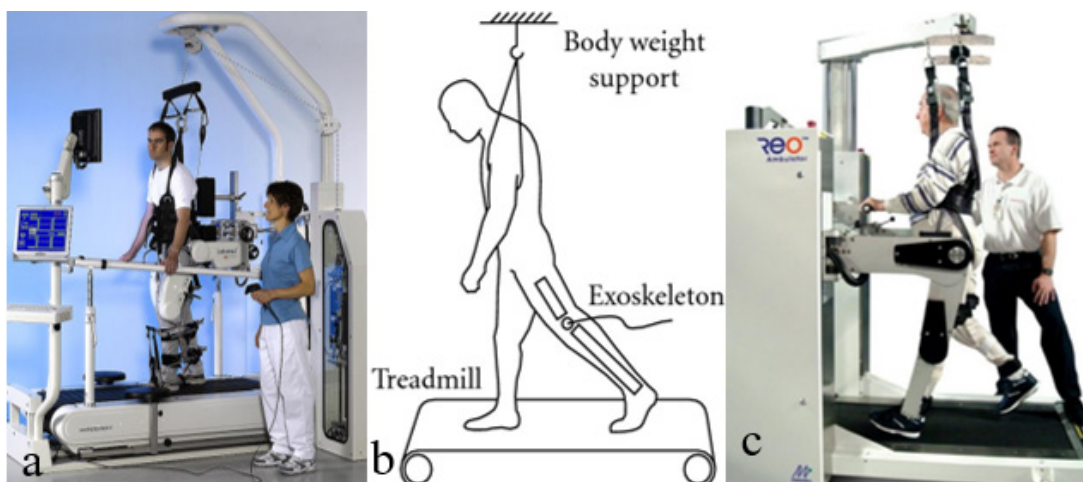


Figure 10

a. Lokomat (Lünenburger et al., 2007), b. Body Weight Support, c. ReoAmbulator (Díaz et al., 2011)



Telerehabilitation

Telemedicine is the remote realization of medical evaluation and treatment methods in a digital environment through technology. Using this technology, clinicians can remotely assess patients and direct treatment. Telemedicine applications are increasingly used today with the development of information technologies. Telerehabilitation, one of the prominent areas of telemedicine in recent years, is the provision of remote rehabilitation services through information and communication technologies (Flodgren et al., 2015; Peretti et al., 2017).

Telerehabilitation has many advantages for all rehabilitation specialties. In particular, it contributes to reducing the long waiting time for rehabilitation services and the necessity of transportation to the clinic. It also reduces the economic burden of health services and the number of days back to work (Sarsak, 2020). Diagnosis, assessment, intervention, goal setting, patient and family education, supervision and consultation are among the services provided within the scope of telerehabilitation (Galea, 2019; Richmond et al., 2017).

Telerehabilitation applications are divided into 3 groups: image-based technologies, sensor-based technologies and virtual reality technologies. Physiotherapists and occupational therapists use these tools to provide repetition, feedback, active participation, guidance and motivation, which are the basic requirements of motor learning (Russell, 2009). Image-based telerehabilitation technologies are realized through video conferencing and are historically considered to be the oldest telerehabilitation method (Delaplain et al., 1993).

With sensor-based technologies, motion data collected by sensors such as accelerometers and gyroscopes and data such as electrocardiogram, blood pressure and blood oxygen content can be monitored (Peretti et al., 2017). In virtual reality-based telerehabilitation systems, three-dimensional virtual environments are created by the computer for the patient to perform the desired movements and motor responses. Rehabilitation professionals can modify these virtual environments in line with the desired treatment goals (Holden, 2005).

When the literature is examined, there are studies showing that telerehabilitation has been successfully applied in neurological, orthopedic, cardiac and pulmonary rehabilitation. In addition, the recent Covid 19 pandemic has affected the whole world as it is a highly contagious disease, putting a serious burden on health systems and causing serious changes in the way of life. The COVID-19 pandemic has brought the importance of telerehabilitation practices to the forefront (Isernia et al., 2022; Kahraman, 2020; Knepley et al., 2021; Suso-Martí et al., 2021).

Mobile Applications

The use of smartphones, which emerged with the developments in technology, has increased significantly in recent years. It is known that there are approximately 3.4 billion smartphone users worldwide. Mobile applications that enter our lives with smartphones offer many different services such as entertainment, communication and information (Derakhshanrad et al., 2021; Namwongsa et al., 2018). Today, one of the most frequently used areas of mobile applications is the field of health. It is seen that the applications offered for use with smartphones and devices are mainly developed for fitness, nutrition, health tracking, wellness, medical education and diagnosis. It is also seen that mobile

applications are increasingly used in the field of rehabilitation. Mobile applications used for patient follow-up and evaluation, especially in rehabilitation services, do not seem to be suitable for use for every risk group yet (Oskay et al., 2019).

In the field of rehabilitation, goniometer applications are most commonly used to measure posture and body positions. Mobile applications that are compatible with the objective measurement methods used in the clinic and have validity and reliability have been created (Milani et al., 2014). Applications that can make measurements through sensors in mobile devices can provide information to the user and health professionals by recording many parameters such as step counting, weight, blood pressure, physical activity level, calorie expenditure, heart rate, ECG data (Antypas & Wangberg, 2012).

There are applications that enable the creation and follow-up of the exercise program that patients need, evaluate parameters such as pain and effort, and provide information to the clinician (Bhachu et al., 2014; Van Reijen et al., 2017). As a result, mobile applications used in the field of rehabilitation are used for patient follow-up and evaluation purposes by facilitating the rehabilitation process of patients and clinicians with the data obtained with smart devices.

Evidence for the Use of Technology in Different Rehabilitation Fields

There is a great deal of scientific research in the literature on the use and effectiveness of rapidly developing technology in rehabilitation. In this section, a summary of the literature on the use of technological developments in different diseases and rehabilitation areas is presented. Various studies have been conducted for many different diseases with the virtual reality-based video game model, referred to as exergames in the literature, and compared with traditional rehabilitation approaches. It has been reported that exergames can provide moderate to vigorous exercise and increase the level of physical activity (Benzing & Schmidt, 2018; Klompstra et al., 2014).

Studies, especially in children and young people, show that exercises with exergames increase cardiorespiratory fitness (CRF) and physical activity levels. In addition, participants reported that the video game-based exercise method was more motivating and exercise intensity was perceived to be lower compared to traditional exercise practices (Glen et al., 2017; McDonough et al., 2018).

The prescription use of exergames in patients with heart failure has been associated with significant improvements in energy expenditure and functional capacity based on the 6-minute walk test (6MWT), indicating promising results for clinical application. Exergames has shown that metabolic equivalents (MET), heart rate and oxygen consumption (VO₂) can be measured to calculate exercise capacity/CRF (Gomez et al., 2018; Klompstra et al., 2014).

In studies conducted with Nintendo Wii® in individuals with cerebral palsy (CP), it was reported that motor skills increased. In studies conducted with Xbox® Kinect, improvements in gait endurance, upper extremity functions and gross motor skills were reported. There is a strong level of evidence that functional balance and functional mobility improve in children with CP with training with the IREX® system, which is specially designed for rehabilitation (Do et al., 2016; Glegg et al., 2014). In a study that examined the effectiveness of robotic rehabilitation and included 18 individuals with CP, the participants were divided into two groups. The treatment group received conventional physiotherapy and robotic rehabilitation, while the control group received

only conventional physiotherapy. It was found that the functional independence results of the patients in the robotic rehabilitation group were higher than the other group (Gilliaux et al., 2015). In another study with 67 participants with CP and a single group, each patient received robotic rehabilitation sessions at least once a week. In the functional independence assessment, a significant difference was found between the measurements at the beginning and end of treatment (van Hedel et al., 2016).

In the literature, there are studies showing that robotic rehabilitation for the lower extremity improves balance, gait parameters and lower extremity muscle strength (Dewar et al., 2015; Tarakci et al., 2020). There are studies showing that upper extremity robotic rehabilitation applications increase motor control, motor activity and function, and decrease pain and spasticity (Takahashi et al., 2016; Tomić et al., 2017). However, some studies have reported that the effectiveness of upper extremity robotic rehabilitation is insufficient and more studies are needed (Taveggia et al., 2016; Veerbeek et al., 2017).

A 2021 review study showed that telerehabilitation had better outcomes compared to face-to-face rehabilitation in patients with low back pain, osteoarthritis, multiple sclerosis and knee-hip arthroplasty compared to control and waiting groups (Seron et al., 2021). In a review study examining the clinical outcomes of telerehabilitation, it was reported that 51% of the results were clinically significant and that telerehabilitation applications enabled more frequent communication with patients (Hailey et al., 2011).

In several studies examining telerehabilitation practices applied to Parkinson's patients, there is evidence that patients' cognitive skills, especially attention, logical, long-term memory and executive functions, have improved (Dias et al., 2016; Quinn et al., 2019). There are studies showing that telerehabilitation has similar efficacy with traditional and face-to-face rehabilitation practices in individuals with stroke (Chen et al., 2015; Schroder et al., 2019). There are studies in the literature showing that telerehabilitation is feasible and reliable in pulmonary rehabilitation and provides similar benefits to face-to-face rehabilitation in reducing dyspnea and morbidity, improving functional capacity and quality of life (Liu et al., 2014; Tsai et al., 2017).

In conclusion, it is obvious that technological developments have brought new ways and applications to rehabilitation approaches today. It is seen that technological applications contribute to more effective access of patients and health professionals to the gains aimed to be achieved through rehabilitation. However, clinical and scientific research shows that there is a need for much more studies on the type, frequency, quality, effectiveness and applicability of technological approaches used in the field of physiotherapy and rehabilitation and occupational therapy.

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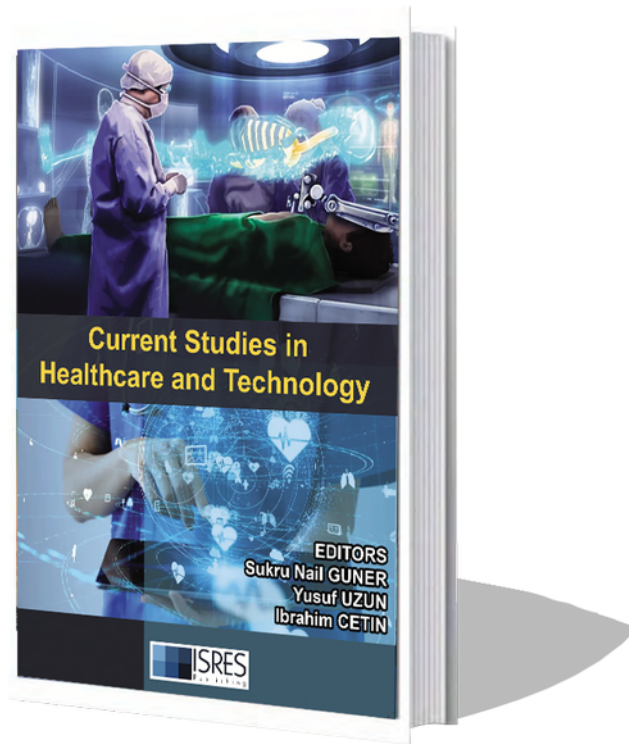
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