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New technologies used in the rehabilitation of knee pathologies

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Abstract

Background. Research into human movement dysfunction is receiving increasing attention as the proportion of older adults and the number of obese people in the world's population continues to rise. Compared to the other joints in the lower limb, the knee joint is very delicate and susceptible to injury. Knee deficits are a prevalent physical ailment that substantially influences the day-to-day functionality and emotional welfare of those who suffer from them. Supporting the body weight, helping maintain lower limb balance, and absorbing shock while the body is in motion are the primary factors contributing to these deficits. Movement biomechanics is an essential subfield of biomechanics that investigates how bones, muscles, ligaments, and tendons coordinate with one another throughout different types of human movement.

Aims. The purpose of this review is to devise and investigate novel approaches to the use of mobile devices in knee rehabilitation. This research investigates how mobile devices like smartphones and tablets are used in rehabilitation. Our primary emphasis will be on mobile applications that provide individualized workouts, continuous monitoring, and immediate feedback to patients.

Conclusions. Undoubtedly, the technology will continue to develop and grow over time and be integrated with many other electronic health systems and devices. As a direct consequence of this advancement, physiotherapists will have more opportunities to assist in designing and developing exoskeletons that may be used throughout rehabilitation.

Keywords: new technologies, rehabilitation, knee, pathologies.

Introduction

Rehabilitation is the care given to people who have lost the ability to carry out activities of daily living. Some of the most common causes are injuries and trauma, stroke, major surgery, severe infections, adverse reactions to medical treatment, specific congenital disabilities and genetic disorders, disabilities, and chronic pain. Thus, monitoring and rehabilitation through physical therapy are necessary to improve people's quality of life. As the number of people needing rehabilitation increases, so does the demand for therapy (Bae et al., 2012; Sengchuai et al., 2022).

The main obstacles to effective physical therapy are lack of consistent participation due to insufficient training of experts (doctors and physiotherapists), lack of motivation to practice, inability to monitor, follow and control the rehabilitation programme when patients leave the hospital, and inconveniences such as travel. In addition, the number of practical tools, as well as physiotherapists and doctors, is insufficient. Physical rehabilitation exercises often need to be done where patients can be monitored and under continuous professional supervision. However, rehabilitation activities can be carried out outside the hospital if adequate monitoring is provided. This could reduce the length of rehabilitation time and the frequency of injuries during out-of-hospital rehabilitation. Another benefit is the ability to quantify and evaluate the effectiveness of each patient's rehabilitation process. In particular, during the COVID-19 pandemic, the amount of therapeutic exercise performed in the hospital has decreased significantly due to social distancing and hospital safety policies. As a result, to meet this requirement, some would prefer to do the exercise through a telemedicine system (Sengchuai et al., 2022; Kilova et al., 2021).

With the global increase in the elderly population and obesity rates, there is a growing emphasis on research into human movement dysfunction. The knee joint is particularly sensitive and vulnerable to the lower limb joints. Knee deficiencies are common physical problems that significantly impact people's daily functioning and mental wellbeing. These impairments are primarily influenced by supporting body weight, assisting lower limb

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balance and shock absorption during movement. Movement biomechanics, a crucial branch of biomechanics, examines the coordination between bones, muscles, ligaments and tendons during various human movements. According to Chhabra and colleagues' research from 2001, the knee joint is able to sustain significant stresses because of the complex interaction that occurs between its component parts. According to Zhang et al.'s research from 2020, there is a pressing need to investigate the biomechanics of the movement of healthy and sick knee joints in order to help or rehabilitate human locomotor function.

In addition, we would like to emphasise the significance of incorporating innovative technology into physical activities (Szabo, 2021a) in order to facilitate the improvement of coordination (Szabo et al., 2021), as well as balance (Szabo, 2021b), and overall rehabilitation (Szabo, 2022; Szabo & Neagu, 2022).

This review *aims to develop and explore innovative ways of using mobile devices in knee rehabilitation.* With this review, *we aim to explore how mobile devices such as tablets and smartphones are used in rehabilitation. We will focus on mobile apps that provide personalized exercises, monitoring, and real-time patient feedback.*

New approaches to knee rehabilitation

Smart and Connected Health (SCH) refers to digital healthcare solutions or systems that are fully connected and can operate remotely. The National Science Foundation (NSF) and the National Institutes of Health (NIH) in the United States started an initiative in 2013 called "Smart and Connected Health" (SCH: Connecting Data, People and Systems) to ac celerate the discovery and integration of novel methods to the use of information technology (1). Their goal was to create the next generation of interdisciplinary research to facilitate the formation of new scientific partnerships and the work of current scientific collaborations on breakthrough "smart" concepts (Navaz et al., 2021).

The concept of eHealth encompasses various applications that use modern information and communication technologies (ICT) to provide treatment and care to patients. As such, eHealth is a broad term encompassing many ICT-based applications designed to process information electronically. Since the medical data included on the eHealth card may be conveyed straightforwardly, this information can be transferred to facilitate the patient's treatment and care procedures. This data contains information about medical emergencies, treatment plans, drugs, computerised patient files, and telemedicine applications. The transmission of this medical data is carried out employing a telematics network. In a nutshell, "a new term used to describe the combined use of electronic communications and information technology in the health sector" (Safi et al., 2018) is how "e-health" is defined.

The use of linked structures, technology solutions, and physical places for interaction are all part of recent healthcare industry efforts to achieve stability, security, sustainability, and high-quality value. Incorporating cutting-edge medical technology and digital solutions is essential to these forward-thinking designs and models. However, the effective implementation of breakthrough healthcare technology, particularly digital ones, is contingent upon the approval of healthcare professionals such as physicians and nurses. These people have direct contact with emerging technology and the processes involved in their deployment, while patients are seen as clients. In order to ascertain whether or not these communities stand to gain from these advances, it is essential to recognise and lessen any opposition they may face. This may be accomplished by increasing public knowledge of the technologies in question and persuading prospective users of their advantages.

Consequently, introducing new health technologies in healthcare settings should also consider psychological signs that lead to the growth of acceptance, encouraging a scenario in which all parties benefit equally. Both medical personnel and their patients should be aware of resistance to new treatments or technology. After they have been identified, these types of resistance may be conquered using treatments that have been carefully designed and selected (Safi et al., 2018).

Within the smart cities concept, the application of computerized tech, particularly artificial intelligence, has represented a focal point of development, and healthcare distribution is no omission. According to Deloitte, they have linked health services, also known as technology-enabled care (TEC), including telehealth, telemedicine, m-health, digital health, and e-health. Telehealth and telemedicine also fall under this category. Therefore, "smart connected health" (SCH) is a brand-new and exciting field of research that draws from a broad spectrum of fields, including medical informatics, public health, big data, bioengineering, the telecommunications sector, and several others. CHS is adaptable enough to be employed in a widespread spectrum of critical health scenarios, each of which may need transactions in health that are resource-aware, time-limited, structured, and stable amongst a wide variety of stakeholders. CHS is flexible enough to be employed in these situations because it can be utilised in various critical health scenarios. CHS is revolutionizing the healthcare structure of the following generation, which will have substantial possible privileges, such as accelerating procedure and experimenting with procedures, lowering the expense of medical visits, efficiently responding to a diversity of emergencies and the proliferation of pandemics, and strengthening the attribute of convalescent healthcare (Chen et al., 2018). CHS also has the potential to improve the quality of patient care. In addition, several new technologies have substantial untapped potential to revolutionise specific wellbeing and societal care facets. In addition, the usage of smartphones and tablets is becoming more popular all over the globe, regardless of age, which has led to significant growth in the proportion of opportunities for mobile health apps over the last few years, along with a large number of fitness and wellness apps. Patients and caretakers now have admission to clinical data in real-time due to the advent of wearable "biosensing" equipment. These gadgets, which include automated blood pressure monitoring and glucose sensors, are just two examples of these crucial breakthroughs. Therefore, via the utilisation of modern digital technologies, CHS can authorize convalescents and healthcare professionals to have more control over their wellbeing, conveniently benefit from online information, communicate their ideas and worries to their doctors, and locate suitable help and action (1). Insufficient funding for research and development, especially in translational investigation and technology, prevents new technologies from emerging on time. The availability of funding through programmes such as Small Business Innovation Research (SBIR) is conditional on the technology reaching a stage where it becomes eligible for such funding. In addition, SBIR funding often requires working with small companies instead of large companies with more significant resources to bring technology to market more efficiently (2).

The dynamic shift in demographics and advances in critical care treatment in the United States has led to a growing demand for solutions that facilitate wellness management and rehabilitation outside traditional clinical settings. To be effective, interventions targeting wellness and rehabilitation must be comprehensive, addressing biological functions at the cellular level and incorporating community support at the individual level. Delivering successful rehabilitation programs has become increasingly complicated due to the growing number of people with multiple medical conditions and disabilities and limited access to healthcare providers (Ma et al., 2014). However, recent technological advances, such as wearable sensor systems, have the potential to significantly increase the effectiveness of rehabilitation interventions and help reduce health disparities (Rodgers et al., 2019).

Virtual reality therapy

The knee joint is complex and significant in the human body. When a knee joint injury occurs, it directly impacts the functional abilities of the knee joint, resulting in limited motion and muscle atrophy around the knee joint, known as arthrogenic muscle inhibition (AMI) (Reddy et al., 2021). The injury can lead to the accumulation of fibrous adhesions due to the deposition of serous fibrous exudate and fibrin in the knee joint cavity. Prolonged immobilization may further contribute to problems such as muscle atrophy, osteoporosis, nutritional disorders, atrophy and fibrosis of the articular cartilage. Immobilization also causes drying and adhesion of the synovial sacs, leading to stenosis in the joint cavity. Clinical studies have confirmed a negative correlation between the duration of joint immobilization (1 to 3 months) and recovery of knee flexion function. Unfortunately, many patients may not benefit from early rehabilitation after surgery or joint trauma, leading to a high incidence of knee joint dysfunction. Post-operative immobilization of the lower extremities is the leading cause of knee joint adhesion, and this dysfunction significantly affects the patient's ability to perform daily activities (Li, 2022).

The importance of early functional training after injury surgery has gained recognition in the rehabilitation field in recent years. However, traditional rehabilitation training systems based on virtual reality technology can lead to patient anxiety due to the need to face a different virtual world daily, limiting their effectiveness. In response to this challenge, augmented reality (AR) has been introduced to the rehabilitation field. AR systems offer advantages such as three-dimensional registration, the combination of virtual and natural elements and real-time interaction, making them widely used in various industries and fields such as the military, cultural heritage preservation and gaming. By integrating AR technology with the principles of rehabilitation medicine, a complex scenario of virtual and real environments can be created for the patient based on the physiological structure and movement of the knee joint, facilitating the recovery of damaged joints. In rehabilitation therapy, repetitive movement training based on the patient's daily activities can stimulate the involvement of residual function neurons, encouraging the brain's nerve center to correct and improve the quality of movements repeatedly. This contributes to the structural and functional recovery of injured joints. In addition, rehabilitation training and assessment can reinforce each other. By analyzing the patient's training data, underlying behaviors can be identified, and an intelligent assessment of the patient's training effectiveness and rehabilitation progress can be provided. This information serves as a reference and basis for formulating the next step of the training plan. In short, AR technology has great potential for post-operative bone and joint rehabilitation. Some researchers have successfully applied RA-based rehabilitation assessment and training systems for specific joint injuries, such as ulna-radial deviation of the wrist joint (Plancher et al., 2020). However, there is limited research on the application of RA in ankle rehabilitation training, warranting further investigation in this area (Li, 2022).

Virtual Reality (VR) is an engaging and motivating tool that can be used to modulate neural behaviour in rehabilitation. It offers the ability to create virtual environments, ranging from simple two-dimensional visuals to more complex three-dimensional games and functional environments, which can be enhanced with haptics, electromyography, electroencephalography and fMRI. These virtual environments can potentially address the need for effective rehabilitation training strategies that improve functional skills and real-world interactions. Efforts have been made to investigate whether motor learning in VR can be transferred to the physical world, vital for setting measurable goals in VR interventions. However, it is essential not to focus only on reducing motor deficits without considering the influence of perceptual factors in the virtual environment. Neglecting these factors may hinder task transfer and the overall rehabilitation process. Increasing evidence suggests that VR facilitates the integration of information from different sensory pathways and involves executive processing, allowing the perception of multimodal information (Keshner & Fung, 2019). Therefore, VR can be designed as a rehabilitation tool to target the perception-action system, which plays a vital role in motor planning, learning, performance and execution. By considering the perception-action system and incorporating it into VR interventions, we can harness the potential of VR as a powerful tool to enhance the rehabilitation process and support motor skill development (Keshner & Lamontagne, 2021).

VR technology has also proven to be a promising tool for improving rehabilitation outcomes. When various technical devices (e.g. head-mounted displays, desktop computers, motion capture and tracking systems, motion-sensing gloves) are implemented, it can provide, through different levels of immersion, realistic experiences by creating and interacting with virtual environments (VE) that closely resemble everyday environments. To date, a wide range of studies have tested and demonstrated the effectiveness of, for example, VR-based treadmill training for the lower extremities to reduce fall risk and improve gait and balance (Zanatta et al., 2023).

Electric current therapy

Immobilization or range of motion (ROM) limitation can induce joint contracture due to pain. This contracture can be influenced by two anatomical components around the joint: arthrogenic and myogenic components. It is believed that arthrogenic components, particularly those of the joint capsule, play an essential role in the development of joint contractures. Previous research has revealed that joint capsule fibrosis and overexpression of type I collagen may develop and advance after one week of immobilization. Additionally, myofibroblast increase has been linked to this fibrosis (Zhou et al., 2018), notably in the posterior knee capsule (Rodríguez-Sanz et al., 2020).

The field of rehabilitation has made use of several physical treatments that are founded on electrical or electromagnetic stimulation. In physical rehabilitation, the treatment known as capacitive-resistive electrical transfer, or CRet, has been utilized to repair injuries to muscles, bones, ligaments, and tendons. Applying electrical currents with radio frequencies ranging from 300 kHz to 1.2 MHz is the basis for the CRet treatment modality, a non-invasive kind of deep electrothermal therapy. This treatment has the potential to enhance haemoglobin saturation as well as create warmth in deep muscular tissues. The physiological consequences connected with this kind of physiotherapy are generated by applying an electromagnetic field with a frequency of around 0.5 MHz to the human body. This type of physiotherapy is known as transcranial magnetic stimulation (TMS). This method has been connected to better profound and inconsequential blood circulation, vasodilation, greater temperature, removal of excess fluid, and heightened cell proliferation (Hernández-Bule et al., 2014). Other effects include increased cell proliferation. Other responses, such as more significant cell proliferation, are thought to be primarily connected to current flow (Rodríguez-Sanz et al., 2020). On the other hand, other backlashes, such as increased blood perfusion, are understood to be correlated with higher temperatures.

Neuromuscular electrical stimulation, often known as NMES, is a treatment method that is used to address quadriceps weakness after surgical procedures. As a therapeutic method for aiding strength restoration, neuromuscular electrical stimulation has shown varied efficacy. When referring to rehabilitation after ACL repair, it has been discovered that NMES seizures lasting between four and six weeks benefit the recovery of quadriceps strength and functional performance compared to therapy that does not include NMES (Snyder-Mackler et al., 1995). However, other trials connected to the ACL found that NMES therapies applied at comparable time intervals did not result in any post-operative strength benefits. In every one of the experiments mentioned above, the researchers employed variable treatment settings that might affect the results (Conley et al., 2021).

Several studies on patients with patella-femoral pain syndrome have recognized the efficacy of EMG-BF in combination with conventional quadriceps muscle training for improving symptoms and muscle strength (Conley et al., 2021). Studies also indicate increasing recovery of knee extension and range of motion and more outstanding EMG production using biofeedback after knee surgery (Wise et al., 1984).

Biofeedback is an instrument that uses myoelectric signals to help retrain muscles and, relying on the diagnosis, could be applied to reduce or improve muscle activity (Bonnette et al., 2020). Many studies have endorsed biofeedback for rehabilitating neural and musculoskeletal systems over the past decade. In early studies, researchers spotlighted the quadriceps, head and knee. However, there is ample evidence that biofeedback is used for other orthopedic injuries in various settings. In 1990-1991, Drapper and Ballard studied the effect of EMG-BF on quadriceps muscle function after ACL reconstruction and reported that biofeedback was more effective than ES alone in facilitating recovery of knee extension (Wise et al., 1984).

Exoskeletons and robotic technology

A robot exoskeleton is a mechanical device that can be worn on the limbs of the human body. It consists of links or segments that are attached to the limbs to provide support and assistance (Nycz et al., 2016). Recent research on lower limb exoskeletons has demonstrated their potential applications in various fields, particularly in rehabilitation and power-assisted exercise. These devices have shown promise in assisting people with their physiological activities and can potentially become valuable assistive devices in improving human capabilities (Changcheng et al., 2022).

Exoskeletons made of robotic material have the potential to improve human mobility by enhancing the capacity to apply torques to the joints of the lower extremities in a manner that is suitably timed and scaled. Exoskeletons have been made for people who are healthy to wear to enhance their gait economy and help them carry burdens, and they have also been designed for persons with impairments to assist mobility and improve rehabilitation. Exoskeleton-assisted gait rehabilitation research has primarily been conducted on adults after a stroke or spinal cord injury; however, motorized exoskeletons may provide a novel option to the therapies now available for gait abnormalities in children with cerebral palsy (Lerner et al., 2017).

A robot exoskeleton's passive user control mode involves transmitting forces to actuate the lower limbs, allowing individuals who cannot walk without external assistance to follow a planned rehabilitation trajectory slowly, smoothly and safely (Yan et al., 2015). The control mechanism for this mode uses pre-planned gait patterns, which can be based on recorded data or the typical gait of a healthy individual. These specified gait patterns serve as desired trajectories for the robotic exoskeleton during gait training. Effective control strategies are crucial for achieving consistent and repetitive gait training. Position-tracking controllers are commonly used in robotic exoskeletons in passive mode for rehabilitation. For example, a lower limb orthosis can use position patterns derived from clinical gait analysis of healthy individuals, implementing a PD control strategy to restore a natural gait. A hierarchical control system can be used, combining a low-level PID controller for setting the desired torque and a high-level controller for generating torque references. However, linear PD/PID-based controllers designed for error tracking can affect the performance of nonlinear robotic exoskeleton systems. A fuzzy neural controller based on a robust quadratic linear controller has been proposed for passive assist gait training to overcome the challenges generated by external disturbances and inertial uncertainties. Simulation results showed promising gait tracking results using this approach (Changcheng et al., 2022).

The use of assistive exoskeletons and robotic devices in rehabilitation and therapeutic training is widespread, especially for people with neuromuscular diseases or those recovering from conditions such as stroke. These devices play a crucial role in maintaining and regaining limb function. However, a significant limitation of current devices is achieving proper joint alignment and fit. Joints are complicated and complex structures, and their axes of rotation change throughout the range of motion. Traditional joint modelling techniques are based on measured motion kinematics muscle and bone contact forces (Jayaraman et al., 2020). However, these modelling approaches often simplify assumptions that may not hold in medical practice. In addition, diseases, conditions and injuries can lead to variations or abnormalities in joint kinematics, muscle responses and reaction forces, further complicating joint motion modelling. The effectiveness of exoskeletons and wearable robotic devices relies on achieving proper alignment and fit between anatomical joints and those of the device. A misalignment brought on by illness or injury may bring about strain on the soft tissues and potential dislocation of the joints. Even though the knee joint's axis rotates concerning the knee joint's angle, it is usual practice to construct a revolution or hinge joint for an exoskeleton that spans the knee joint. This is done even though the knee joint itself is mobile. It is possible to experience pain and even sustain an injury if the complicated mobility of the joint in the exoskeleton's design is not respected. As a result, it is of the utmost importance that future exoskeleton systems are capable of executing the intricate three-dimensional motions shown by the anatomical joints that correspond to, such as the knee joint.

The difficulty still exists today in ensuring that the exoskeleton's design is compatible with the anthropometric features of the people wearing it. Methods such as passive gliding may be used to obtain correct alignment between the exoskeleton and the anatomical joints. Quantitative performance measurements have also been used to study the interaction between humans and devices. Assessing kinematic compatibility may be accomplished, for instance, by measuring the relative motion of the human and the exoskeleton during gait and formulating a prediction methodology for human joint motion in terms of exoskeleton angular motion. Both of these methods are helpful. In order to achieve precise measurements using this method, it is often necessary to do marker insertion, post-processing, and matching with human body models. Task-based therapy training has also benefitted from robotic equipment, further highlighting the significance of appropriate joint alignment and fit in reaching good rehabilitation results (MajidiRad et al., 2022).

In human-robot interaction (HRI), computational models of active orthoses have evolved as an option to lessen the hazards associated with direct human exposure to robot counterparts. This has occurred as a result of the increasing complexity of human-robot interactions. These models have shown encouraging results in assisting knee mobility while HRI is being performed. The functional range of motion of the lower extremities may be determined by employing musculoskeletal models, which makes this identification feasible. The synthesis process may be optimised with the use of this information, and the proper exoskeleton measurements, segments, and joints can be determined using that knowledge. The use of computational models enables the replication of measurable limb motions without the need to align a human joint to the equivalent joint of an exoskeleton. This is one of the advantages of utilizing computational models. This is especially helpful for the knee joint, which is challenging to articulate and is susceptible to damage. Researchers can investigate the impact of exoskeletal joint misalignment if they construct a musculoskeletal model tailored particularly for the knee joint. Analytical and magnetic resonance imaging (MRI) methods have been used in previous research to analyze biological joints and pin-based exoskeletal joints. Different motion trajectories have been used to analyze these systems' kinematics. Although there are studies that have been conducted on the axis of motion of the knee joint in a variety of people, further study is required to get a complete knowledge of the sensitivity of exoskeleton design and to build more dependable coordination between the human exoskeleton (MajidiRad et al., 2022).

Using smartphones

Recently, mobile apps have started to play an essential role in monitoring and motivating patients to engage in their health (Higgins, 2016). Mobile Health (mHealth) apps aim to improve patient engagement and self-management capabilities in patient-centered healthcare models (Stauber et al., 2020).

Barriers to adherence are multifactorial, and patients often underestimate the importance of rehabilitation due to inadequate education or poor communication. This is problematic because patients are expected to exercise independently for most of the rehabilitation period (Jack et al., 2010). Patients from low-income households may face more significant barriers to rehabilitation due to limited access to rehabilitation facilities, inability to manage co-payments and low health literacy. Accessibility is also a struggle for patients with high family or work responsibil ities who live alone and/or experience turning off amounts of pain. Finally, psychological barriers such as poor self-efficacy, fear avoidance behaviors, and stress can also prevent adherence (Bell et al., 2019).

Physiotherapy rehabilitation is usually recommended to support the recovery or long-term management of a musculoskeletal condition. Standard care for rehabilitation of knee conditions involves exercise programs and the provision of information. However, current rehabilitation delivery methods struggle to keep up with high patient volumes and the length of treatment required to maximize recovery. Therefore, the development of new interventions to support self-management is strongly recommended. Such interventions should include information provision, goal setting, monitoring, feedback and support groups, but the most effective delivery methods are poorly understood and require further research. Finally, treatments need to be personalised, i.e., targeted to individual needs, to improve the prospects for rehabilitation (Spasić et al., 2015).

With the development of technology, more people are using their smartphones to record measurements because they are easy to carry around. In recent years, several different applications for measuring angles have been created for use on smartphones. These encompass accelerometers, gyroscopes, magnetometers, and (photo) snapshots that calculate joint angles. Their validity and reliability have all been well investigated. The Japanese mobile application "Grid Line Photography App Professional" (APP, Naradewa Inc) was created to measure angles in 2017. Taking a picture of the scene with a smartphone and locating three spots at random on the picture allows one to calculate the angle between two parallel lines. It is simple to use because of its familiarity since taking a snapshot near a joint and finding its three points is comparable to the common practice of measuring joint angles using a UG. This is because the two processes are similar. Nevertheless, the reliability of the measurements produced by the APP depends on the image being taken in a direction perpendicular to the plane that contains the axis of movement of the joint. In inclusion, the evaluation will be off if the three locations necessary to estimate the joint angle precisely are not precisely detected on the image (Ishii et al., 2021).

Smartphone motion sensors can passively capture steps taken and other mobility values and can present a reliable means of assessing patient recovery after total hip or knee arthroplasty (THA or TKA) or other orthopaedic procedures (Case et al., 2015). Potential advantages over traditional pedometers include better compliance with use, greater ease, and the ability to collect data over more extended periods in larger cohorts. Smartphones also offer the possibility to collect other relevant information such as distances covered, steps taken or duration of activity (Lyman et al., 2020).

With the advancement of electronic technologies and their integration with wearable devices, core systems have been widely applied in medicine, especially for tracking rehabilitation actions. A study conducted by Bahadori et al. (2018) indicated that both an accelerometer and gyroscope were used in five of the studies that were conducted in order to examine the evidence of wearable devices supporting their usefulness in facilitating rehabilitation following total hip replacement and TKR surgeries. Friedman et al. employed a wearable sensor device (magnetometer) to correctly record daily wrist and finger usage to objectively evaluate the long-term rehabilitation process for cerebrovascular illness (such as stroke). This allowed them to examine the rehabilitation process for cerebrovascular disease objectively. Wireless inertial sensors were fitted to shoes by Mariani and colleagues in order to quantify the distance between the heel and the toe for gait analysis. They developed separate 2-D and 3-D models for motion sensing and three additional models for predicting patient gait rehabilitation information, and they did so without being constrained to a particular site and experimental setting for data collecting (Huang et al., 2022).

In recent years, inertial measurement units, sometimes known as IMUs, have seen increased use to identify human postures and gaits. The sensors can be readily integrated with various wearable devices and the Internet of Things for various applications due to their cheap cost, simplicity of use, and lightweight. IMUs can potentially be used to detect posture for applications ranging from athletics to healthcare (Huang et al., 2022).

Patient-reported outcome measures (PROMs) can also be efficiently collected using smartphones. It is possible to conduct surveys whenever necessary and at any frequency when using a website or application that is compatible with mobile devices (Lyman et al., 2020).

Knee replacement patients now have access to a newly created instructional software specifically designed to help them while they are undergoing treatment. The app provides information regarding the post-operative recovery period, such as advice on good food and physical exercise following surgery, as well as information about medicines. In addition to that, the app has the PROMIS® measurements of physical function as well as pain interference. Patients are given the opportunity to react to these measurements at the times that have been pre-defined for the measurement. Currently, PRO scores are only displayed in the health professional dashboard. Utilizing this information, we can follow individual patients' and groups of patients' progress during the healing period. Patients could access and monitor their PRO scores if the app included a PRO feedback report and was integrated within the app. This information might make patient participation easier and increase communication with medical experts; moreover, the PRO feedback report could assist patients in addressing health problems and concerns based on PRO ratings (Fischer et al., 2020; Santana et al., 2014).

Patients who use the app can have an automatically created PRO feedback report made for them, and patients can also check their PRO findings instantly through their smartphones. This raises problems concerning the kind of information that patients might find helpful and the structure that a report needs to take to be simple to comprehend and assess (Fischer et al., 2020).

Use of Artificial Intelligence

Compared to other industries, healthcare has relatively slowly adopted artificial intelligence. The delivery of healthcare depends on a large number of factors, of which the most difficult to replicate is the experience and intuition of the physician and the logical interpretation of the patient's condition by correlating the available

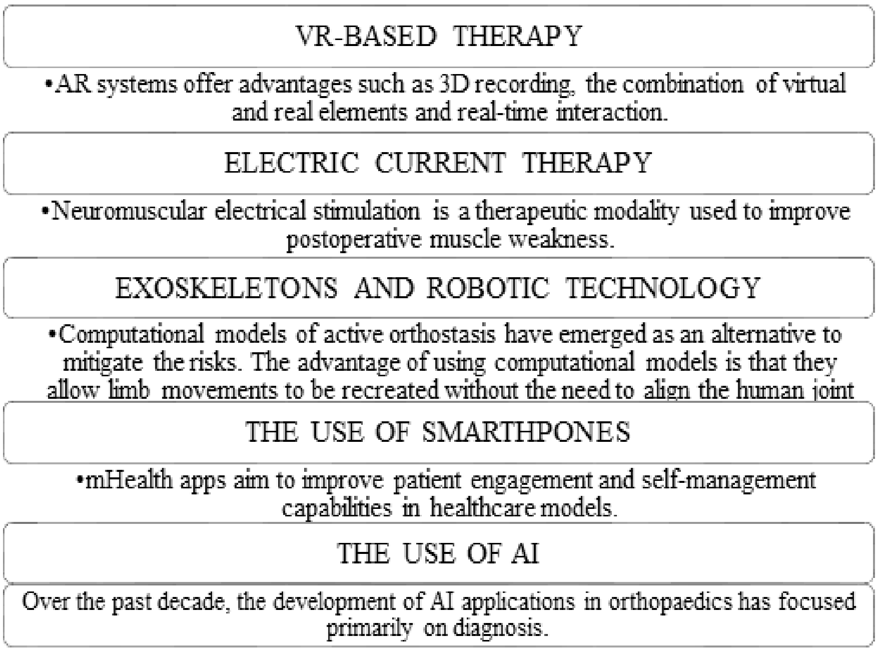

Fig. 1 – New approaches to knee rehabilitation.

clinical examination with radiology and other investigative reports. The diagnostic process is so complex that we never hope to reproduce it in a machine. The incredible complexity of healthcare delivery is, strangely enough, what makes it such fertile ground for the application of artificial intelligence. Nevertheless, technology is now changing how doctors interact with their instruments, how the instruments provide information to doctors, and how the resulting interpretation is used to help the doctor and patient make an appropriate treatment choice (Woodson, 2019; Poduval et al., 2020).

In medicine, AI can be applied either virtually using computers or physically using robots. In the last decade, the development of AI applications in orthopaedics has focused primarily on diagnosis, mainly image interpretation. In a recent research, conducted by Chen & Asch (2017), it was proven that a convolutional neural network (CNN), which is an example of a machine learning algorithm, outperformed general orthopaedic surgeons when it came to identifying and categorising proximal humeral fractures, while performing comparably to specialised shoulder surgeons. In a similar investigation, a CNN was developed to interpret hand, wrist and ankle radiographs with an accuracy equal to that of senior orthopaedic staff (Corban et al., 2021).

In orthopedic sports pathology, nearly half of all injuries involve the knee. Of these injuries, anterior cruciate ligament (ACL) tears are expected, with non-contact ACL injuries accounting for up to 78% of all sports-related knee pathologies. Although common, diagnosing clinically significant ACL injuries can be challenging for clinicians. ML can facilitate this by addressing the variability of specific clinical tests, such as pivot shift while improving the diagnostic accuracy of magnetic resonance imaging (MRI). However, along with improving diagnosis, AI can provide more robust solutions to other issues related to ACL tear management. Specific issues are well suited to machine learning methodologies, such as accurately predicting people at risk of ACL injury or damage, recognizing complicated anatomical landmarks intraoperatively, and improving post-operative pain management and rehabilitation regimens (Corban et al., 2021).

Conclusions

1. Smartphones are finding a growing number of applications in rehabilitation, including treating and recovering knee diseases. There is reason to be optimistic about using technology to strengthen rehabilitation programs for knee diseases. It is vital for the whole area of rehabilitation and recovery, particularly in terms of a better knowledge of long-term recovery, and it may be helpful to individuals of all ages, particularly children and adolescents.

2. It has lately found standard practice in many therapeutic specialties, such as neurology, orthopedics, and gerontology, to use exoskeletons to assist patients directly as they work toward recovery.

3. There is no question that, over time, technology will continue to evolve and advance and become connected with many other electronic health systems and gadgets. Physiotherapists will have more possibilities to be/become involved in the design and evolution of exoskeletons for application in the rehabilitation process as an outcome of this development.

4. Telemedicine enables doctors and other medical professionals to devise individualized patient treatment plans more swiftly.

5. Mobile health applications allow patients to take control of their care and enhance the quality of their experience.

Conflict of interests

Nothing to declare.

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