



Role of Telerehabilitation in Upper Extremity Rehabilitation of Parkinson's Patients: Review of the Literature

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ABSTRACT

Parkinson's Disease (PD) is one of the most common neurodegenerative diseases that mostly affect motor function. Upper extremity dysfunction occurs in these patients from the early stage and negatively affects the activities of the individual such as reaching, grasping, and writing, which are frequently used in daily life. The fact that PD is a chronic neurodegenerative disease increases the need for long-term rehabilitation of individuals. On the other hand, long-term rehabilitation service leads to high costs for both health institutions and patients. Telerehabilitation applications enable physiotherapy and rehabilitation services to be applied more practically, at lower costs, and by saving more time. Considering that Parkinson's patients mostly consist of the geriatric population, the increase in diseases such as the emerging Covid-19 epidemic has made it more difficult for patients with PD to reach rehabilitation. This situation has accelerated the emergence of rehabilitation services that can be an alternative to the rehabilitation services used in the clinic. Due to the limited physiotherapy and rehabilitation services provided in hospitals or clinics for patients with Parkinson's, therapists focus more on developing transfer-oriented skills such as balance and walking, and they often cannot find enough time for upper extremity training. Therefore, telerehabilitation applications appear as an advantageous option for upper extremity training. Telerehabilitation is defined as the transmission of rehabilitation services to long distances by using various communication technologies. Recently, telerehabilitation approaches have been frequently preferred in many neurological disease groups such as stroke, Multiple Sclerosis, and PD. In this review, it is aimed to discuss the telerehabilitation approaches used in the upper extremity rehabilitation of patients with PD.

Keywords: Parkinson disease, upper extremity, telerehabilitation

Parkinson Hastalarının Üst Ekstremitte Rehabilitasyonunda Telerehabilitasyonun Yeri: Literatürün Gözden Geçirilmesi

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Öz

Parkinson Hastalığı (PH), çoğunlukla motor fonksiyonu etkileyen en sık karşılaşılan nörodegeneratif hastalıklardan biridir. Üst ekstremitte fonksiyon bozukluğu bu hastalarda erken evreden itibaren ortaya çıkmakta ve bireyin günlük hayatta sıklıkla kullandığı uzanma, kavrama, yazı yazma gibi aktivitelerini olumsuz yönde etkilemektedir. PH'nin kronik nörodegeneratif bir hastalık oluşu bireylerin uzun süreli rehabilitasyona olan ihtiyacını arttırır. Diğer taraftan, uzun süreli uygulanacak olan rehabilitasyon hizmeti hem sağlık kuruluşları hem de hastalar için yüksek maliyetleri beraberinde getirir. Parkinson hastalarının çoğunlukla geriatrik popülasyondan oluşması göz önünde bulundurulduğunda, günümüzde ortaya çıkan Covid-19 salgını gibi hastalıkların artması PH'li bireylerin rehabilitasyona ulaşmasını daha fazla zorlaştırmıştır. Bu durum klinikte kullanılan fizyoterapi ve rehabilitasyon hizmetlerine alternatif oluşturabilecek rehabilitasyon hizmetlerinin gündeme gelmesini hızlandırmıştır. Diğer taraftan Parkinson hastaları için hastane ya da kliniklerde uygulanan fizyoterapi ve rehabilitasyon hizmetlerinin sınırlı olması nedeniyle, terapistler denge ve yürüme gibi transfere yönelik becerileri geliştirmeye daha fazla odaklanmakta ve çoğunlukla üst ekstremitte eğitimi için yeterli zamanı bulamamaktadırlar. Tüm bu nedenlerden dolayı telerehabilitasyon uygulamaları, üst ekstremitte eğitimi için avantajlı bir seçenek gibi görünmektedir. Telerehabilitasyon, çeşitli iletişim teknolojileri kullanılarak uzak mesafelere rehabilitasyon hizmetinin iletilmesi olarak tanımlanmaktadır. Son zamanlarda yaygınlaşmaya başlayan telerehabilitasyon uygulamaları, fizyoterapi ve rehabilitasyon hizmetlerinin daha pratik, daha düşük maliyetli ve zamandan daha fazla tasarruf edilerek uygulanabilmesine olanak sağlamaktadır. İnme, Multipl Skleroz, PH gibi birçok nörolojik hastalık grubunda telerehabilitasyon yaklaşımları son yıllarda sıklıkla tercih edilmektedir. Bu derlemede, PH'li bireylerin üst ekstremitte rehabilitasyonunda kullanılan telerehabilitasyon yaklaşımlarını ele almak amaçlanmıştır.

Anahtar sözcükler: Parkinson hastalığı, üst ekstremitte, telerehabilitasyon

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Introduction

Parkinson's disease (PD) is the second most common neurodegenerative disease after Alzheimer's disease and is the most common movement disorder in neurology clinics ^{1,2}. The disease, which mostly affects motor functions, affects 1-5% of individuals aged 65-69 and 1-3% of individuals over 80 years of age ³. Impairment of functional skills of the upper extremity in PD is related to both the inability to plan voluntary and complex movements, and the impairment of planning simultaneous motor and cognitive skills ^{4,5}. The bradykinesia, hypokinesia, tremor, and rigidity seen in the clinical picture in PD cause the impairment of motor skills in the upper extremity over time ^{6,7}, and patients with PD become increasingly dependent on their daily living activities ⁸⁻¹⁰.

Currently, medical treatment and surgical approaches are frequently used among the treatment options of PD. Physiotherapy is preferred in the treatment of progressive functional losses together with medical treatments. Recently, with the demonstration of neuromodulatory and neuroprotective effects of exercise in neurodegenerative diseases, the importance of physiotherapy in PD has increased ¹¹⁻¹³. In human and animal studies, it has been shown that the release of neuroprotective growth factors increases with exercise, and thus dopaminergic neuron loss may decrease ¹³⁻¹⁵. In addition, it has been stated that the sensitivity of dopaminergic receptors may increase with exercise training, thus improving the motor functions of patients with PD ¹⁶. Based on this information and considering that PD is a progressive chronic disease, it is of great importance to gain exercise habits with physiotherapy from an early period. ¹⁷

On the other hand, this process, which requires the patient to be followed throughout his/her life, brings with it some problems. The first is the financial burden it creates on the health system and the patient ¹⁸. Another problem is the difficulty of patients' access to physiotherapy services ¹⁹. Most of the working patients have difficulty in obtaining the necessary permission to go to the physiotherapy centers during working hours or have problems in reaching the physiotherapy centers. Patients who have difficulty in using public transport due to balance and walking difficulties have to travel with the accompaniment of the company of another person. For patients with advanced activity limitations, the use of public transportation becomes impossible. As a result, the transportation problem in PD becomes one of the most important problems preventing physiotherapy and rehabilitation.

In recent years, telemedicine and telerehabilitation approaches have come to the fore to make medical and rehabilitation services more accessible. The importance of this approach has increased significantly with the World Health Organization declaring the COVID-19 pandemic on March 11, 2019 ²⁰. Especially due to the pandemic, many patients with PD spend more time at home and limit their activities due to the fear of COVID-19 virus transmission.

In this case, telerehabilitation approaches have become a more important option for patients compared to the past.

This review aims to draw attention to the increasing importance of telerehabilitation applications and present the telerehabilitation approaches applied in upper extremity education of PD by examining them in the light of the literature.

Telerehabilitation

In recent years, with the increase in the demand for rehabilitation services, the increase in cost and time loss pose a risk in terms of the sustainability of health services ²¹. As a result of technological developments and widespread use of the internet, the use of technology in rehabilitation is increasing and has become an important option ²². In addition, technological solutions can increase patients' participation in treatment. It can also reduce the workload of hospitals, physiotherapy departments, and other rehabilitation centers ^{21,23}. Telerehabilitation, one of the leading technological rehabilitation applications, is an efficient method that can be used in all the fields where the rehabilitation process is required ²⁴.

Telerehabilitation is defined as the transmission of rehabilitation services over long distances using electronic information and communication technology ^{11,25}. Telerehabilitation covers the services provided by many health disciplines such as physiotherapy, occupational therapy, and biomedical engineering. It can also be used in all rehabilitation activities, including diagnostic patient assessment, rehabilitation interventions, education, and monitoring patient performance ^{26,27}. In particular, it allows patients who have difficulty accessing due to economic, geographical, or physical inadequacies to benefit from rehabilitation services ^{24,25}. In addition, telerehabilitation provides continuity in rehabilitation by reducing travel time and cost ²⁸. Considering the epidemic diseases such as Covid-19 that emerged in 2019 and affected the whole world ²⁹, it is expected that telerehabilitation will gain importance day by day for patients who need long-term physiotherapy such as PD.

Telerehabilitation Applications

Many technological tools are used for telerehabilitation applications ³⁰. Telerehabilitation approaches in neurological diseases continue to get stronger day by day ³¹⁻³³. In this section, telerehabilitation technologies that differ in various aspects such as the mode of communication, the way or technology of data transmission will be described.

1- Messaging or phone call based telerehabilitation

Messaging has been the basis of communication in many fields for many years ³⁰. While the message used to be sent by mail in written form or report, nowadays it can be transmitted more practically and quickly by being transferred to the digital environment. In addition, thanks

to the increase in mobile use, voice or written conversations can be made with the patient, thus the rehabilitation process can be followed instantly³⁰. The most important disadvantage of telerehabilitation applied in this way is that only written or voice communication can be contacted with the patient, so the therapist is difficult to control whether patients perform exercises³⁴.

2- Videoconference-based telerehabilitation

Videoconference-based telerehabilitation, which is often performed using an internet network via telephone or computer, provides a real-time one-to-one treatment environment for the patient and therapist^{27,35}. This method was first used to track physiotherapy consultations of soldiers via satellite communication by Delaplain et al. in 1993 at the Tripler Army Medical Center in Hawaii. Thus, it has been seen that the physiotherapy service can be followed from very long distances³⁶. Videoconference-based telerehabilitation technologies are currently the most commonly used type in the rehabilitation of individuals with neurological diseases³⁷⁻³⁹. In particular, this type of telerehabilitation has become more applicable with the proliferation of smartphone and video calling technology.

3- Virtual reality-based telerehabilitation

Virtual reality (VR) applications are used in this type of telerehabilitation application⁴⁰. VR applications increase the sense of reality in the individual with enriched virtual environments where sensory inputs are increased. Thus, it provides the opportunity to do activity training with a rich variety of tasks in different environments. VR applications vary according to the technology used. Immersion affects the experience in VR and affects the user's sense of presence. For this reason, it is often used in VR classification. VR technologies can be broadly grouped into three categories: non-immersive, semi-immersive, or fully immersive. Fully immersive VR consists of complex virtual environments including multiple senses such as touch, sound, and motion, as well as a head-mounted display, while environments created with only a two-dimensional screen are known as non-immersive VR⁴¹. Apart from these applications, another virtual application that has become widespread recently is augmented reality. In this application, exercises can be performed safely and easily by placing virtual objects in a real environment that the individual can watch online⁴². To use VR as part of telerehabilitation, the therapist either presets the program to suit the patient or follows the patient's session online. In addition, the therapist can simultaneously intervene in the system and/or access data about the details of the sessions via an internet platform^{33,43}. Thus, the therapist can follow the flow of the treatment or make changes to the program at any time.

One of the most important advantages of VR applications is that it is motivating⁴⁴. During the sessions, games and exercises are combined to provide an enjoyable environment for the individual. Thus, the tiring and boring repetitions of traditional physiotherapy sessions are replaced by highly repetitive and enjoyable

sessions with high motivation. VR also has some disadvantages. Head-mounted displays, which are generally used in immersive virtual reality applications, may cause complaints such as headache, nausea, vomiting, and fatigue in the individual⁴⁵. Moreover, it is another disadvantage that these systems require expensive equipment³⁰.

4- Web and mobile application-based telerehabilitation

The widespread use of smartphones has enabled them to be included in the telerehabilitation process. Various phone applications or internet-based platforms are increasing day by day^{47,48}. Such applications can be used for evaluation as well as treatment⁴⁷. Practices can consist of standard exercise modules or include various behavior change techniques, including patient-appropriate goal setting, graded tasks, and performance feedback⁴⁹.

5- Integrated system-based telerehabilitation

Three-dimensional evaluation and the treatment of motion can be performed using only sensors (accelerometer, gyroscope, kinect, etc.)²⁷. For example, the accelerometer, which is one of the most commonly used sensors in telerehabilitation, records the movements of the individual at home by three-dimensional coding. Thus, the physiotherapist can obtain information about a patient's exercise status by accessing this information^{50,51}. In addition, this type of sensor can be integrated into other telerehabilitation models²⁷.

Integrated systems are composed of various systems that combine multiple sensors and technical interfaces³⁰. These systems can provide the therapist with summary information about the exercise, as well as more detailed information saved in the cloud system^{30,52}. In addition, rehabilitation can be followed multidimensionally by combining tactile or visual responses, artificial intelligence, and high data storage capacity⁵³. Thus, the therapist can access information at any time and follow up more detailed exercises in the home environment. Integrated systems have some disadvantages as well as advantages. Some of the disadvantages are that systems often require the assistance of one person to set up and use, and are costly equipment^{46,54,55}. Although these disadvantages limit the patient population, it is thought that technologies that are easy to use and developed with less cost will increase in the near future.

Telerehabilitation In Upper Extremity Rehabilitation Of Patients With Pd

Patients with PD experience activity limitations in the functional skills of the upper extremity such as reaching, grasping, and writing from an early stage¹⁰. Due to the limited rehabilitation period in hospitals and clinics, therapists focus more on improving balance and walking skills in treatment and often ignore upper extremity training. Therefore, telerehabilitation is an important option for upper extremity training⁴⁶.

The telerehabilitation system allows remote monitoring of patients' exercise programs using technological systems²⁸. When the literature is examined, it is seen that

telerehabilitation approaches are used to improve balance and gait, increase daily living activities and quality of life, and improve upper extremity skills in many neurological disease groups^{31,32,56}. The first study on telerehabilitation in PD was conducted by Hubbel et al. (1993) in the 1990s. In the study, it was shown that motor assessment could be done from long distances in PD. It was also stated that patients could receive better health care by using telerehabilitation approaches⁵⁷. In the following years, we see that many studies have been carried out on the telerehabilitation-based evaluation and the treatment of PH. However, the vast majority of these studies were done in the 2000s⁵⁸⁻⁶². On the other hand, studies on telerehabilitation of the upper extremity in PD are very limited^{33,34,46,59,63,64}.

Vanbellingen et al. (2017) studied the home-based treatment program in PD. In the home-based training program, in which two different exercise programs (dexterity training and theraband training) were compared, patients were called by phone and asked whether they had any questions about their exercises after the first week of the training. The patients were then asked to continue the program for one month. As a result of the study, it was found that there was an improvement in fine motor skills in both groups. The researchers stated that exercise supervision only at the end of the first week was a limitation because the current method has made it difficult to control whether all patients performed their exercises as prescribed in the booklet. In future studies, they suggested that the exercise program should be followed with online monitoring-based applications³⁴.

Table 1. Types of Telerehabilitation Used in the Current Studies on Upper Extremity Rehabilitation of Patients with PD

	Objective	Number of patients	Type of telerehabilitation
Cikajlo et al. (2021)	To build a telerehabilitation system with virtual pick and place tasks for small-scale hand movements in PD	28 (H&Y stage II-III)	Non-immersive Virtual reality-based telerehabilitation
Isernia et al. (2020)	To test in PD patients the efficiency and efficacy of the Human Empowerment Aging and Disability (HEAD) program	31 (H&Y stage ≤ II)	Integrated system-based telerehabilitation using virtual reality
Voola and Hema S. (2020)	To find the effectiveness of telerehabilitation on manual dexterity and its impact on quality of life in clients with Parkinson's Disease	45 (H&Y stage I-IV)	Videoconference-based telerehabilitation
Vanbellingen et al. (2017)	To investigate the effectiveness of a home-based dexterity program on fine motor skills	103 (H&Y stage I-IV)	Phone call-based telerehabilitation (only at the end of the first week)
Cikajlo et al. (2018 and 2017)	To design intensive target-based physiotherapy for upper extremities suitable for telerehabilitation services and examine the clinical meaningfulness of the exergaming at an unchanged medication plan.	28 (H&Y stage II-III)	Non-immersive Virtual reality-based telerehabilitation

H&Y: Hoehn and Yahr

In subsequent years, Voola and Hema S. (2020) implemented the same treatment program as the previous study via videoconference. As a result of the study, it was shown that fine dexterity and quality of life increased in both groups. While face-to-face follow-up of the patients during the treatment was shown as an important advantage, it was stated that the poor network connection and the need for caregiver assistance were the most important difficulties in this study. On the other hand, the researchers stated that telerehabilitation applied via videoconferencing could be an alternative form of service delivery in the treatment of patients with PD by cost-effectiveness and reduced transportation issues⁶³.

Cikajlo et al. (2018 and 2017) studied a virtual reality game called "Fruit Picking" through telerehabilitation for upper extremity treatment of patients with PD. The virtual game aimed to collect virtual apples before falling off the tree and place them in the basket in the lower part of the screen. Each exercise session was stored on a computer by a system accessible to the therapist. Thus, the system

provided the therapist to review data remotely and plan/follow the exercise-based therapy. According to the results of the study, it was found that upper extremity motor function improved. The quality and accuracy of the exercises could not be observed because there was no control group and the sessions could not be done face to face, which were the limitations of the study. In addition, it was stated that there is a need for studies that compare telerehabilitation versus the conventional approach^{46,64}. In the following years, Cikajlo et al. (2021) conducted another study with a control group. They studied a virtual reality-based telerehabilitation program to increase upper extremity function in patients with PD. While the hospital outpatient group applied the virtual reality exercises in the clinical setting, the home group receive the exercises through telerehabilitation at home. The goal of participants seated in front of the computer screen was to pick up and place 10 small virtual cubes lying around the virtual environment into the chest. They designed the telerehabilitation system as a client-server model. Thus, the therapist working remotely followed with data

synchronization occurring after the accomplished session. At the end of the study, it was shown that there was an improvement in both groups and that telerehabilitation could be an alternative to clinical applications. As the limitation of the study, it was stated that the telerehabilitation group was chosen according to the address and technical possibilities, and the number of individuals in the groups was low and unequal. In addition, it was stated that virtual reality application does not require special technical skills, but it was stated that running the application was not an easy task for patients with PD⁵⁹. Based on this study, it draws our attention that technical possibilities and technological knowledge are important factors for patients with PD to receive telerehabilitation services.

Isernia et al. (2020) developed a virtual reality application through telerehabilitation and used an internet platform (Human Empowerment Aging and Disability (HEAD) program) whose content was designed by physiotherapists, neurologists, and neuropsychologists³³. In the sessions, a series of tasks including both motor and cognitive activities were performed using a sensor that detects motion in front of the screen. In addition, the physiotherapist can complicate the program before each session⁶⁵. Initially, both the telerehabilitation group and the control group were involved in 1-month HEAD rehabilitation in the clinic. Then the telerehabilitation group continued a 3-month HEAD telerehabilitation, while the control group continued only the usual care condition. They found the positive influence of a multidimensional rehabilitation approach to be performed at home for patients with PD. The main limitations of the study are the small sample size and the non-randomness of the groups. On the other hand, it has been shown in the study that the HEAD program applied through telerehabilitation can be beneficial not only for the motor but also for the non-motor symptoms in PD. In addition, the ability to adjust the difficulty level by the therapist seems to be another advantage of the program.

Although telerehabilitation practices have been increasing in popularity recently²⁴, only 6 studies have been found involving the upper extremity training with telerehabilitation in PD. One of these studies applied telerehabilitation via calling phone³⁴, while another applied the same treatment via videoconferencing⁶³. The other three studies were performed using virtual reality-based telerehabilitation^{46,59,64}. In the last study, telerehabilitation in which virtual reality, an internet-based platform, and sensors are integrated was used³³. The last five years have seen significant advances in telerehabilitation of the upper extremity functions in PD, and the use of technology has increased with each passing year, and this trend is likely to continue. However, although each of the studies contributes to the next, it is noteworthy that there are limitations regarding the study design. According to the studies, the fact that telerehabilitation requires technical knowledge and there are problems with internet access made it difficult to implement telerehabilitation in PD^{33,46,59,63}. On the other

hand, it is seen that five of the studies were pilot studies and had a low sample size^{33,46,59,63,64}. At the same time, there is only one study that compared telerehabilitation with face-to-face interventions⁵⁹. It was shown that telerehabilitation could be an alternative approach to face-to-face clinical applications in this study. Therefore, studies comparing telerehabilitation approaches with clinical-based interventions are needed. There is only one study that was integrated and used virtual reality, sensors, and internet platforms³³. According to this study, it was emphasized that there is a need for more comprehensive studies using advanced technology in the upper extremity training of PD.

It is seen that studies about the telerehabilitation of the upper extremity in neurological diseases are focused on stroke patients⁶⁶. Advanced robotic devices, machine learning-based or artificial intelligence-based integrated systems are used for telerehabilitation interventions in these patients^{66,67}. Advanced technologies provide an environment where patients' independence is enhanced⁶⁷. Additionally, these technologies can provide the facility to the therapist in the follow-up and the management of patient performance during exercise sessions^{66,68}. As stated in the limitations of upper extremity telerehabilitation of PH, such technologies may be a solution in the future for problems such as the difficulty of using telerehabilitation systems and the inability to monitor patient performance.

It has been stated that the necessary technological equipment is not yet sufficient, especially in the rural areas of our country in terms of telerehabilitation technology⁶⁹. Additionally, the lack of studies examining the upper extremity telerehabilitation of PH shows that there is a need for studies in this area.

Conclusion

In this review of literature, we have shown that telerehabilitation for upper extremity function deficit in PD to be as effective as in face-to-face conventional therapies, if not better. Telerehabilitation holds significant potential to obtain successful rehabilitations and cost-efficiency. Additionally, it was emphasized that randomized controlled studies with larger samples are needed for more evidence on the clinical effectiveness of telerehabilitation programs in patients with PD having upper extremity dysfunction. Studies should be designed by analyzing the long-term gains of upper functions as a result of telerehabilitation interventions and the behavioral changes they may cause. On the other hand, the diversification and increase of telerehabilitation programs are promising in this field with the development of technology in recent years.

Conflict of interest

There is not a conflict of interest

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