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Original Article

The impact of motion capture camera-supported telerehabilitation gamification on upper extremity functions and quality of life in stroke and cerebral palsy patients

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ABSTRACT

Objectives: The aim of this study was to investigate the impact of a newly developed motion capture camera-supported telerehabilitation gamification software on upper extremity functions and quality of life (QoL) in patients with stroke and cerebral palsy (CP).

Patients and methods: Between November 14th 2022 and November 14th 2023, a total of 122 patients were included in the study, 90 with stroke (52 males, 38 females; mean age: 59.8±14.7 years; range, 23 to 80 years) and 32 with CP (17 males, 15 females; mean age: 11.7±2.8 years; range, 8 to 18 years). All patients received a telerehabilitation program, supported by motion capture technology, incorporated gamification elements to engage patients were conducted for 30 sessions. The patients were assessed by hemiplegic upper extremity functionality tests and QoL scales.

Results: Both groups showed statistically significant improvements in the upper extremity functions and QoL, as measured by Fugl-Meyer Assessment of Upper Extremity (FMA-UE) Scale (p<0.001), Action Research Arm Test (ARAT) (p<0.001), Nine-Hole Peg Test (9HPT) (CP: p<0.05, Stroke: [p<0.001]), Motor Activity Log-28 (MAL-28) (p<0.001), Stroke-Specific Quality of Life Scale (SS-QOL) (p<0.001) and Pediatric Quality of Life Inventory (PedsQL) (p<0.001).

Conclusion: Our study findings highlight the potential of motion capture camera-supported telerehabilitation gamification software in enhancing upper extremity functional outcomes and significant improvement in QoL for patients with stroke and CP.

Keywords: Cerebral palsy, gamification, quality of life, telerehabilitation, stroke.

The global demographic is increasingly outpouring into the senior category, with the proportion of chronic patients needing disability support and care reaching the highest figure ever. Aging and the rise in certain neurological illnesses are also strongly correlated.[1] Stroke leads to hemiplegia and upper extremity functions are severely affected.[2] It is estimated that 2019 was the year of 125,345 new cases of stroke in Türkiye; stroke prevalence was 1,080,380 (1.3%) and there were 48,947 stroke-caused deaths.[3,4]The latest breakthroughs in the medical field concerning stroke treatment have made it possible to witness a lowering of mortality rates among populations diagnosed with stroke. Still, on the other hand, the survival rates of those who experience disabilities have increased accordingly.[4]

Cerebral palsy (CP), a permanent movement disorder group which usually occurs in early childhood, could cause serious problems with motor function and daily living activities.[5] As children with CP age, mobility decreases, causing secondary musculoskeletal problems. Diminished walking ability, falls, less engagement and obstacles in performing daily living activities are some factors which make an individual's quality of life (QoL)

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decrease.[6] In individuals who do not remain in therapy, range of motion decreases and problems such as contractures and pressure sores occur due to immobilization. This situation aggravates the care burden, that ends in financial and emotional challenges for patients and their families and also, high treatment costs.[7] Both diseases, stroke and CP, have one thing in common: the patients require rehabilitation continuously.

The healthcare system's ability to provide rehabilitation services has not been able to cope with the vast patient inflow. Notably, such a situation has led to a cohort of different age and disease groups that have long-term, but necessary rehabilitation services struggle to retrieve them. Furthermore, a considerable number of individuals who have had a stroke and those who are diagnosed with CP are individuals with disabilities, and their access to specialized services, such as rehabilitation, has become increasingly difficult under current conditions. The two main hindrances which patients encounter are the lack of transport facilities and a shortage of healthcare professionals trained to provide tailored neurorehabilitation.

Although traditional rehabilitation measures are usually effective, they indeed have some critical downsides. Some of the examples are the accessibility and patient adherence issues, as well as the incomplete following of therapy sessions. The cutting-edge technology of telerehabilitation has been suggested to resolve these issues, enabling clinicians to deliver various therapies remotely.[8] Moreover, telerehabilitation is a reliable method which takes the patients out of the stress involved in the fact that they are living in either inadequate or isolated areas. On top of all these, it extends flexibility and comfort of the sessions, which are the main demands patients request.[9]

The integration of motion capture camera technology and gamification elements into telerehabilitation programs has the potential to further enhance patient engagement and therapeutic outcomes.[10,11] Gamification, which involves incorporating game-like features into rehabilitation exercises, has been shown to increase motivation and adherence by making therapy more enjoyable and interactive.[11] Wearable technologies and motion capture cameras, can provide real-time feedback and personalized adjustments to exercises, thereby improving the effectiveness of rehabilitation programs.[12]

In the present study, we aimed to investigate the efficacy of a newly developed telerehabilitation software program with motion capture camera-supported gamification on upper extremity functions and to evaluate the QoL of stroke and CP patients.

PATIENTS AND METHODS

Study design and study population

This single-center, case-control study was conducted at Erenköy Physical Therapy and Rehabilitation Hospital, Department of Physical Medicine and Rehabilitation between November 14th, 2022 and November 14th 2023 as a part of a government support program.[13] After development of the software, a patent application was made (Patent Application Number: 2024/000405). A written informed consent was obtained from patients and parents and/or legal guardians of pediatric patients. The study protocol was approved by the Üsküdar University Non-Interventional Clinical Research Ethics Committee (date: 30.09.2024, no: 613513421020-426). The study was conducted in accordance with the principles of the Declaration of Helsinki.

The number of patients who met the inclusion and exclusion criteria for telerehabilitation was determined through a power analysis and all the collected data were included in the study. A total of 122 patients were included in the study, 90 with stroke (52 males, 38 females; mean age: 59.8±14.7 years; range, 23 to 80 years) and 32 with CP (17 males, 15 females; mean age: 11.7±2.8 years; range, 8 to 18 years). The participants were enrolled in the telerehabilitation program during the study period. Inclusion criteria for stroke were as follows: age between 18 and 80, hemiplegic vascular stroke, Mini-Mental State Examination Score (MMSE) ≥24, modified Ashworth Scale 0-1-2-3, Brunnstrom Stage ≥3. Exclusion criteria were as follows: active chemotherapy, orthopedic limitation which interfere with participation to telerehabilitation sessions, major depression and severe dementia, modified Ashworth Scale 4-5. Inclusion criteria for CP were as follows: age between 3 and 18 years, Gross Motor Function Classification System (GMFCS) 1-2-3, modified Ashworth Scale 0-1-2-3, Brunnstrom Stage ≥3, having a diagnosis of hemiplegic CP, and not having any orthopedic operation or major surgery within the past six months. Eligible patients which accepted to participate telerehabilitation were referred to the telerehabilitation clinic. Demographic data of all participants were recorded at baseline. The study flowchart is shown in Figure 1.

Outcome measures

Upper extremity function tests: Disease-specific upper extremity function tests were administered, including the Fugl-Meyer Assessment of Upper Extremity (FMA-UE) Scale,[17] Action Research Arm Test (ARAT),[18] Nine-Hole Peg Test (9HPT),[19] and Motor Activity Log-28 (MAL-28).[20]

QoL assessments: Disease-specific QoL scales were completed by the patients. The Stroke-Specific Quality of Life Scale (SS-QOL) for stroke patients[21] and Pediatric Quality of Life Inventory (PedsQL) for CP patients and caregivers were used for the assessment.[22,23]All outcome measures were evaluated face to face at baseline and after the treatment.

The FMA-UE is a widely used, valid and reliable clinical measurement tool for evaluating motor functions in individuals who have experienced a stroke.[17] It is scored using a three-level ordinal system for each item (0: inability to perform the movement, 1: partial ability to perform the movement, 2: full ability to perform the movement). The maximum score for upper extremity assessment is 66, with higher scores indicating better motor

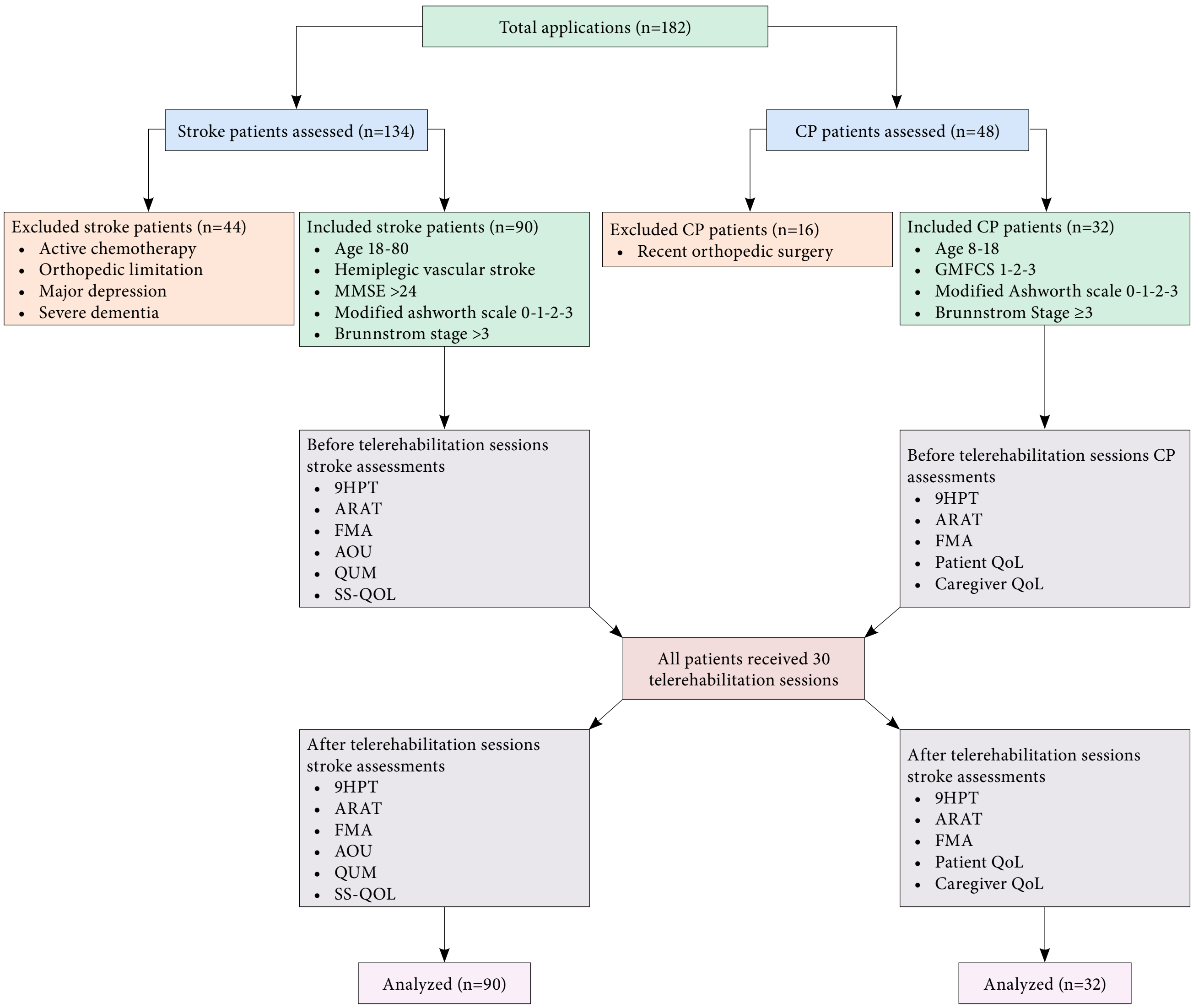

Figure 1. Participant flowchart.

CP: Cerebral palsy; MMSE: Mini-Mental State Examination Score; 9HPT: Nine-Hole Peg Test; ARAT: Action Research Arm Test; FMA: Fugl-Meyer Assessment; AOU: Amount of use scale; QUM: Quality of movement; SS-QOL: Stroke-Specific Quality of Life Scale; QoL: Quality of life.

function. Furthermore, the scale demonstrates high intra-rater (r=0.96) and inter-rater (r=0.95) reliability.[24] It is a reliable and valid test widely used to assess motor impairment of the paretic upper extremity in stroke patients.[25]

The ARAT is a valid and reliable assessment tool developed by Lyle[18] to evaluate upper extremity motor functions in individuals undergoing rehabilitation after stroke, traumatic brain injury or CP. The test comprises four subcategories: grasp, grip, pinch and gross arm movement, totaling 19 items. The assessment is conducted using an ordinal scale ranging from 0 (inability to perform the movement) to 3 (completion of the task with normal performance). The ARAT total score ranges from 0 to 57, with higher scores indicating better motor function.[18] The validity and reliability of the test have been extensively studied[26] and it has been widely used as an assessment tool in numerous studies for evaluating stroke patients.[27]

The 9HPT is a widely used neurological assessment tool designed to evaluate fine motor skills and manual dexterity. During the test, a board is placed in front of the participant, with pegs positioned in front of one hand and empty holes in front of the other. The participant is instructed to pick up the pegs one by one using only one hand and place them into the holes as quickly as possible, then remove them in the same manner. This process is repeated twice for each hand and the time taken is measured using a stopwatch. The final score is determined by averaging the completion times of the two trials for each hand. A shorter completion time indicates an improvement in motor skills.[19]

The MAL-28 is a validated and reliable scale in Turkish, designed to assess the frequency of upper extremity use and the quality of movement in daily living activities.[28] The MAL-28 consists of two subscales: the Amount of Use Scale (AOU) and the Quality of Movement Scale (QOM). Participants rate how frequently they perform predetermined daily living activities using the affected upper extremity (0=never use, 5=use at normal frequency) and evaluate the quality of movement. If a participant is unable to perform an activity, the reasons for non-use are recorded and the activity is excluded from the evaluation. Scores for both subscales are calculated separately, with average scores ranging from 0 to 5, providing insight into upper extremity usage frequency and movement quality.[20]

The SS-QOL is a validated and reliable measurement tool in Turkish, designed to assess QoL in individuals who have experienced a stroke.[29] It consists of 12 subdomains including energy, family roles, language, mobility, mood, personality, self-care, social roles, cognitive function, upper extremity function, vision and work/productivity, totaling 49 items. Each item is rated on a five-point Likert-type scale, with scores ranging from 1 to 5. Higher total scores indicate better QoL.[30]

The PedsQL is a valid and reliable tool developed to assess health-related QoL in children and adolescents aged between 2 and 18 years.[22] The scale includes parent-reported and self-reported forms tailored to specific age groups and evaluates four main domains: physical health, emotional functioning, social functioning and school functioning. Items are scored between 0 and 100, with either a three-point or five-point Likert-type scale depending on the age group. Higher scores indicate better QoL. The Turkish validity and reliability study of the scale was conducted by Memik et al.[23]

Telerehabilitation sessions

The telerehabilitation program involved ORBBEC FHD 108OP Astra Pro Plus (Orbbec Technology, Shenzhen, China) motion capture camera-supported gamification exercises tailored to individual patient needs. These sessions were conducted remotely between two distant healthcare facilities or allowing patients to engage in rehabilitation exercises from their homes.

Participants engaged in telerehabilitation sessions for 30 sessions. Each session included:

- Interactive exercises: Guided by motion capture technology, providing real-time feedback.
- Gamification elements: Incorporated game-like features to enhance motivation and engagement, also rehabilitation game levels were updated every session according to patient's progress.

In the telerehabilitation patient monitoring system, sessions were tracked and recorded daily. The patient is approached with a new game software that aims to move balls across the screen. While the patient is seated in front of a motion capture camera, they move their hemiplegic limb to carry out flexion, extension, abduction and adduction processes to pass the balls above the obstacle. In the meantime, session time, total number of balls that fell out, the height and width of the central obstacle, game level and errors were noted. When patients can shift balls above the obstacle quickly and without errors, they are introduced to a new obstacle that is higher and wider than the old one and the patient progresses to the next level of the game (Figure 2).

Statistical analysis

Study power analysis and sample size calculation were performed using the G*Power version 3.1.9.2 software (Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany). The effect size for CP patients was determined using data from a previous study involving a comparable patient population that utilized the FMA-UE.[14] The effect size was calculated using Cohen's d, applying the change in mean divided by the pooled mean ± standard deviation (SD) approach.[15] This computation resulted in an effect size of 0.7. Based on a significance level (α) of 0.05 and a statistical power of 0.95, a priori sample size estimation was performed using the t-test family and the Wilcoxon signed-rank test for means, indicating that a minimum of 30 participants was required for the study in CP patients.

Similarly, for stroke patients, effect size estimation was conducted using data from a study involving a comparable patient population assessed with FMA-UE.[16] The effect size was determined using Cohen's d, following the change in mean divided by the pooled SD approach.[15] This analysis yielded an effect size of 0.52. Maintaining a significance level (α) of 0.05 and a statistical

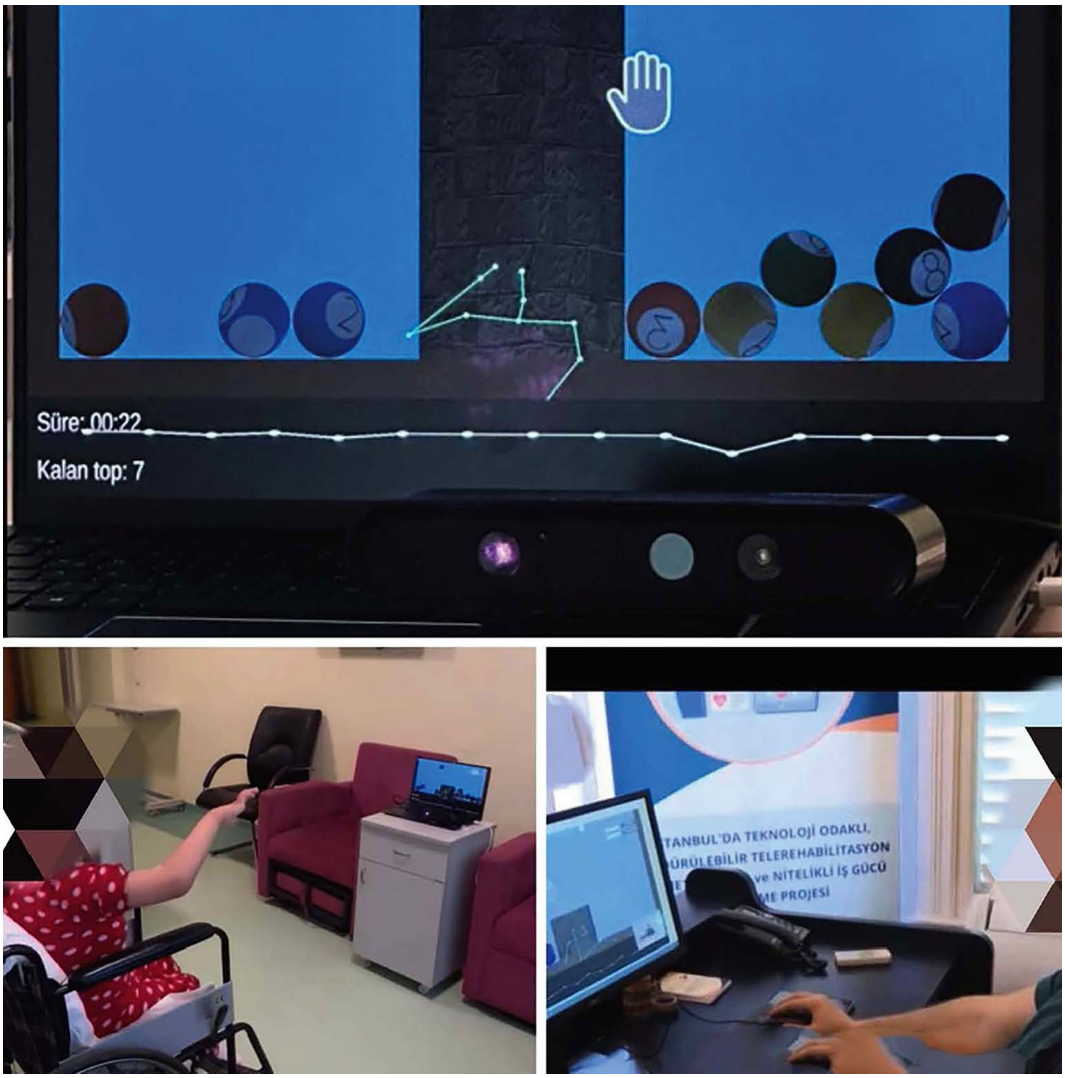

Figure 2. Images from the telerehabilitation sessions.

TABLE 1
Distribution of participants by demographic and clinical characteristics

	n	%	Mean±SD
Cerebral palsy			
Age (year)			11.65±2.83
8-12	20	62.5	
13-18	12	37.5	
Sex			
Male	15	46.9	
Female	17	53.1	
Total	32	100.0	
Stroke			
Age (year)			59.79±14.67
Under 65	53	58.9	
65 and older	37	41.1	
Sex			
Male	52	57.8	
Female	38	42.2	
Total	90	100.0	

SD: Standard deviation.

power of 0.95, a priori sample size calculation was performed using the t-test family and the Wilcoxon signed-rank test for means. The results indicated that a minimum of 53 participants would be required for the study in stroke patients.

The data were analyzed appropriately with statistical techniques to determine the significance of changes in functions of the upper extremity and QoL. Patient groups were considered separately due to the differences in the characteristics and age groups of hemiplegia induced by stroke and CP. This criterion-based approach helped us to objectively assess the influence of motion capture systematic camera-supported telerehabilitation gamification on CP and stroke patients.

Statistical analysis was performed using the IBM SPSS for Windows version 25.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in SD, median (min-max) or number and frequency, where applicable. The Kolmogorov-Smirnov test and Shapiro-Wilk test were used to evaluate the normality assumption. To compare two continuous dependent groups, the Wilcoxon signed-rank test was used. A p value of <0.05 was considered statistically significant.

RESULTS

In this study, as the nature of stroke and CP is different and both affect different age groups, each group was evaluated within themselves. Baseline demographic and clinical characteristics of the participants are summarized in Table 1.

A statistically significant improvement was observed in the 9HPT results of patients diagnosed with CP following telerehabilitation ($p<0.05$). The completion time for the 9HPT was found to be shorter after telerehabilitation compared to the pre-intervention period. Additionally, significant improvements were observed in the ARAT, FMA-UE and QoL scores of CP patients after telerehabilitation ($p<0.001$) (Table 2).

In the stroke group, improvements were observed in the 9HPT results following telerehabilitation, with a reduction in the test completion time ($p<0.001$). Additionally, significant improvements were observed in the ARAT, FMA-UE, MAL-28, and SS-QOL scores after telerehabilitation ($p<0.001$) (Table 3).

TABLE 2
Pre- and post-telerehabilitation measurements of patients with cerebral palsy

	Before telerehabilitation		After telerehabilitation		
Outcome measures	Median	Min-Max	Median	Min-Max	*p**
9HPT	35.62	0-173	34.12	0-153	0.010
ARAT	41.00	6-57	55.50	6-57	<0.0001
FMA-UE	50.50	20-66	66.00	24-70	<0.0001
Patients QoL	59.00	25-100	70.45	25-100	<0.0001
Caregives QoL	67.3	0-100	78.1	0-100	<0.0001

9HPT: The Nine-Hole Peg test; ARAT: Action research arm test; FMA-UE: Fugl-Meyer Assessment of Upper Extremity Scale; Patients/Caregives QoL: The Pediatric quality of life inventory; * Wilcoxon signed-rank test.

TABLE 3
Pre- and post-telerehabilitation measurements of patients with stroke

	Before telerehabilitation		After telerehabilitation		
	Median	Min-Max	Median	Min-Max	*p**
9HPT	35.69	0-240	26.00	0-178	<0.0001
ARAT	40.00	1-57	50.50	3-57	<0.0001
FMA-UE	45.00	7-70	54.50	15-70	<0.0001
AOU	1.71	0.00-4.93	2.91	0.00-5.00	<0.0001
QUM	2.00	0.00-5.00	2.98	0.00-5.00	<0.0001

9HPT: The Nine-Hole Peg test; ARAT: Action Research Arm test; FMA-UE: Fugl-Meyer Assessment of Upper Extremity Scale; MAL-28 : Motor Activity Log-28; AOU: Amount of use; QUM: Quality of movement; * Wilcoxon signed-rank test.

DISCUSSION

In the present study, we investigated the efficacy of a newly developed telerehabilitation software program with motion capture camera-supported gamification on upper extremity functions and evaluated the QoL of stroke and CP patients. Our study results showed that the use of motion capture camera-supported telerehabilitation gamification significantly improved upper extremity functions and QoL of patients with stroke and CP. The results not only correspond, but also support the evidence indicating the application of telerehabilitation for upper extremity disabilities.

In a systematic review, the main outcomes of telerehabilitation for upper extremity disabilities were found to be improved musculoskeletal functions, increased patients' interest and motivation to perform rehabilitation exercises, and increased adherence to rehabilitation exercises and greater participation in treatment processes.[31] In our study, CP patients, as evaluated by the 9HPT, ARAT and the FMA-UE, showed a statistically significant improvement in upper extremity functions which aligns with existing literature, highlighting the effectiveness of telerehabilitation in improving motor skills in children with CP.[32] Research conducted on children with CP using computer game-assisted rehabilitation has shown that therapy is well delivered to CP patients, particularly in dexterity and coordination, that are key factors for daily living activity skills and independence of a person overall. In this study, parents reported an increase in the independence level of children in their daily living activities at home, school and leisure activities. This study provides further evidence that rehabilitation with gamification elements with the computer does not only progress the child's health, but also affects to entire family through the patients increased independence in daily living activities.[33] Besides, the telerehabilitation programs improve function of motor skills, and as the PedsQL scores for children and their parents significantly increases, they improve the psychosocial mood of patients and caregivers. A systematic review regarding gamification in rehabilitation concluded that the use of gamification in rehabilitation was helpful in the conventional treatment of neuromotor disorders in children and adolescents, with increased motivation and therapeutic adherence, strength, balance and functional status.[34] These results are also consistent with our study; none of the patients discontinued the treatment protocol, and there was a very good motivation and therapeutic adherence to telerehabilitation sessions which ended up with upper extremity motor improvements and better QoL.

Two studies were conducted in the literature to assess the effectiveness of telerehabilitation models, one with robotic assistance and the other one without, on the upper extremity functions of stroke patients. Both groups had significant changes in various areas; i.e., motor functions, cognitive abilities, and QoL; however, the non-robotic group outperformed in motor and cognitive skills.[35] These results imply that traditional telerehabilitation methods can be also useful in functional recovery of stroke patients without the use of highly priced robotic devices. It is of utmost importance to acknowledge that the availability of robotic devices trailing behind cost and the lack of robotic devices in healthcare providers is a major hurdle. More exploration of the advantages of robotic-assisted telerehabilitation may be needed to define the right targeted patients and the specific impairments.

The installation of robotic devices can be most useful in more serious motor dysfunction or more precise tasks that throughout a course of time require many repeats. Remote telerehabilitation can provide treatment to patients not only in rural or underserved areas, but also shorten the travel time and costs and create flexibility, since therapy can be scheduled according to the patient's convenience. Besides, telerehabilitation can be an effective tool for patient autonomy by giving patients the opportunity to engage in therapy at their homes possibly, which would lead them to stick to the treatment plan well. Moreover, a systematic review and meta-analysis which assessed the QoL of stroke patients, also showed significant improvements following telerehabilitation. In this review, the authors concluded that telerehabilitation has a positive impact on the QoL of patients with neurological diseases, particularly in stroke patients and that, in patients groups who had Parkinson's disease and multiple sclerosis, telerehabilitation seemed to yield comparable results to in-person treatment.[36] All these studies in the literature highlight that telerehabilitation can effectively address the multifaceted needs of stroke survivors, enhancing their overall well-being and functional capacity.[35,36,31] This aligns with our study findings, demonstrating that telerehabilitation can lead to significant improvements in the QoL for hemiplegic stroke patients.

Real-time feedback through motion capture technology, which was implemented in our study, is believed to be a major factor in promoting motor functions in stroke recovery. This idea was advocated by Lorenz et al.[37] who analyzed 908 articles and highlighted the significance of motion capture technology and functional neuroimaging in the process of rehabilitation. The authors concluded that motion capture technology could be beneficial for the future of motor rehabilitation. Our results are also consistent with this viewpoint, supporting that the technology of motion capture can actively make use of the patients in doing therapeutic exercises and consequently increase the rehabilitation outcomes. The improvement in functional outcomes and QoL found in our study, as well as the fact that no patients opted out from taking part in the exercise of telerehabilitation protocols showed that enjoying oneself and applying the video game concept were both highlights of the rehabilitation program.

The inclusion of more patients than the required number based on the power analysis would normally be the case in clinical trials to accommodate possible dropouts and thus ensure that the desired sample size is achieved. In our study, we, therefore, started the telerehabilitation sessions with a larger number of patients, which was calculated with power analysis. However, unlike most clinical studies, each participant was present in every session in our study and stayed in telerehabilitation program without missing any session. This was a compelling and clear case over the gamified program which actively engaged patients and made them attend telerehabilitation sessions. This is also the fact supported by some other researches, which imply that gamification can lead to patients being more motivated and committed to their treatment.[10,11]

Braga et al.[38] reported high levels of patient satisfaction in telerehabilitation after pandemics. The significant improvements in QoL in our study also suggest that patients perceive telerehabilitation as a valuable and effective mode of treatment. This is crucial for patient adherence and long-term success, as satisfaction and perceived quality of care are strongly linked to continued engagement in rehabilitation programs.

The patients' feedback was actively evaluated during our meetings, and the gamification software was continuously updated based on this feedback. According to our study, a user-friendly design and interactive exercises tailored to the patient with gamification increased the patient's adherence. They improved the results which made it possible for telerehabilitation to be a substitute for the traditional in-person therapy. This finding also gained support from a current pyramid review which reported that gamification was a robust instrument that, when applied to real-time, home-based telerehabilitation, could tremendously boost both patient involvement and rehabilitation outcomes, which, in turn, would make mastering the skills of recovery more efficient and add more pleasure to rehabilitation sessions for the stroke patients during the recovery period.[10,39]

The novel coronavirus disease 2019 (COVID-19) pandemic hastened the use of telehealth solutions.[40] Our study is an essential addition to the already existing body of evidence, suggesting that telerehabilitation should still be continued even during post-pandemic times. Our study with improved upper extremity function and QoL bears testimony to the potential for telerehabilitation to be integrated into rehabilitation services, thereby providing effective care, and no patient dropout among the sessions shows that gamification increases patient motivation and participation to the rehabilitation.

Nonetheless, there are some limitations to this study. The promising results observed in this study are focused on clinical outcomes, it underscores the need to address barriers to telehealth services particularly for underserved communities. Although telehealth can be a game changer in the treatment of patients in regions that are nowhere near health facilities, barriers such as the absence of technological awareness among the community and the existence of healthcare inequities still prevail.[39,40] Our research supports the viewpoint that the discussion of these obstacles in future ongoing studies is of high significance to keeping up with the sustaining of telerehabilitation to all patients equally. Along with the further development of telerehabilitation, there is a pronounced need to widen the access and simplify the use of such technology, particularly for the individuals who have such illnesses as stroke and CP and who would receive the most positive effects from the constant rehabilitation program. Another limitation to the present study is that, since it is a gamification telerehabilitation software developmental study, clinical outcome results are limited to the telerehabilitation group alone, and there is no group of home rehabilitation or control group. Therefore, further studies are warranted to compare different treatment groups.

In conclusion, the motion capture camera-supported telerehabilitation gamification proves to be a valuable means of improving both the upper extremity functions and the QoL of stroke and CP patients. These results underline the significance of technology integration, interdisciplinary methods and patient-centric design in telerehabilitation programs. Follow-up studies should center on raising the throughput of telehealth services, handling technological loopholes and diving deeper into the positives of gamification in re-establishment.

Data Sharing Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions: Idea/concept, writing the article, critical review, references and fundings: B.B.K., P.G.K., Ö.Ö., K.M.; Design, data collection and/or processing, literature review, analysis and/or interpretation, materials: B.B.K., P.G.K., Ö.Ö.; Control/supervision: B.B.K., K.M.

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