Review Article

Applying Game-Based Approaches for Physical Rehabilitation of Poststroke Patients: A Systematic Review

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Objective. A large number of patients need critical physical rehabilitation after the stroke. This study aimed to review and report the result of published studies, in which newly emerged games were employed for physical rehabilitating in poststroke patients. Materials and Methods. This systematic review study was performed based on the PRISMA method. A comprehensive search of PubMed, Scopus, IEEE Xplore Digital Library, and ISI Web of Science was conducted from January 1, 2014, to November 9, 2020, to identify related articles. Studies have been entered in this review based on inclusion and exclusion criteria, in which new games have been used for physical rehabilitation. Results. Of the 1326 retrieved studies, 60 of them met our inclusion criteria. Virtual reality-oriented games were the most popular type of physical rehabilitation approach for poststroke patients. “The Nintendo Wii Fit” game was used more than other games. The reviewed games were mostly operated to balance training and limb mobilization. Based on the evaluation results of the utilized games, only in three studies, applied games were not effective. In other studies, games had effective outcomes for target body members. Conclusions. The results indicate that modern games are efficient in poststroke patients’ physical rehabilitation and can be used alongside conventional methods.

1. Introduction

Stroke is one of the diseases that can lead to disability and affect people’s daily activities and lead to reduced performance [1]. According to the Global Burden of Diseases (GBD 2010), stroke is the second most common cause of death worldwide [2]. In 2010, the number of people with the first stroke was 16.9 million, and people who died of stroke was 5.9 million [2]. Disability-adjusted life years (DALYs) lost also was 102 million, and the number of stroke survivors was 33 million [2]. Ninety percent of stroke survivors have a disability in one of their functions [3]. Most people with poststroke disability experience changes in emotional function, limb movement, balance, and muscle strength, and there is a risk of falling for these patients in performing ordinary activities, all of which affect the quality of life of survivors [4]. The main treatment solution to reduce functional defects after stroke is rehabilitation [5]. Poststroke physical rehabilitation in common is a gradual process that can take months or even years, and these patients require multiple sessions of treatment.

However, patients may not be able to attend these treatment sessions for rehabilitation fully. Several factors may lead to limited access to these treatment sessions, including the following: difficulty accessing a physiotherapist by the patient, high cost of attending the treatment session, patient’s age and disability, the long distance that the patient has to travel, or poor patient compliance [6]. One of the solutions that can be offered to overcome these problems is to do rehabilitation activities at home; for rehabilitation exercises to be effective at home, high-intensity methods focused on specific repetitions of the practice with the feedback of performance should be used [7]. Consequently, one of the innovative methods that can obviate the above...
problems is applying modern games; these games have been used in various fields, including education, public policy, and healthcare [8]. Furthermore, they can also be utilized as a support tool for rehabilitation activities and provide an enjoyable environment for patients and increase adherence to treatment sessions [9, 10].

As it turns out, various studies have been performed to determine the effectiveness of the mentioned games. A systematic review study by Primack et al. found that games improved 69% of psychological therapy outcomes, 46% of clinician skills outcomes, 42% of health education outcomes, and 37% of disease self-management outcomes [11]. Another study examined the games managed for rehabilitation in respiratory conditions and concluded these games were effective [12, 13]. The purpose of this study is reviewing, summarizing, and reporting studies in which modern games have been used for physical rehabilitation of poststroke patients and tries to answer the following questions:

1. Which type of games is the most used?
2. Which gamification approaches have been used to improve the performance of poststroke patients?
3. What was the most common type of physical rehabilitation in stroke survivors?
4. What are the evaluation results of games used in poststroke patients?

2. Research Methodology

This systematic review was conducted based on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist to ensure inclusion of relevant studies [14].

2.1. Design. In this review, a systematic search of scientific databases including ISI Web of Science, PubMed, IEEE Xplore Digital Library, and Scopus was performed from January 1, 2014, to November 9, 2020. The comprehensive search strategy comprised a set of main keywords from PubMed Mesh terms and Emtree related to “game,” “rehabilitation,” and “poststroke” patients. The specific detail of main applied keywords for each database is presented in Table 1.

2.2. Inclusion and Exclusion Criteria for Study Selection. The extracted studies were included if they fulfilled the following criteria: (1) original articles and proceedings, (2) the focus of this review was on only physical rehabilitation innovative game-based solutions for poststroke physical disabilities, (3) one of the gamification techniques was employed for physical rehabilitation or disability treatment, (4) in this study, the result of using different games and outcomes of video games or immersive-oriented approaches on physical rehabilitation were reviewed, and (5) studies were limited to those published in the English language. Besides, the studies were excluded if they met the following criteria: (1) the title, abstract, or full text of the article that did not relate to video games, virtual, or mixed reality-based games, (2) studies which were review or meta-analysis, book chapters, letter, reports, and technical reports, (3) articles in which the result of applying games was not reported quantitatively, (4) articles about cognitive rehabilitation, and (4) non-English published ones.

2.3. Literature Refinement. In comprehensive and scientific databases searching, 833 studies were retrieved after duplicate removal. Some inclusion and exclusion criteria were set for the study selecting phase. In the first phase, two independent reviewers (SS and SR) specified the primary classification of included studies; then, they synthesized selected citations’ critical features. MG validated the primarily determined classifications. All titles and abstracts of extracted studies were investigated and screened based on the research questions and unique aims to select relevant ones by two reviewers under MG’s supervision. In the last phase, citations that met inclusion and exclusion criteria were selected to enter the full-text review phase. The full-texts of relevant studies were screened by SS and SR thoroughly. Key characteristics were entered into a spreadsheet in Excel for each study. Two authors (SR and SS) independently extracted the study characteristics based on the predefined classifications. For reaching an agreement, the information was examined again by two authors. The next reviewer (MG) evaluated and validated all of the obtained results. EndNote X9 was used for resource management, and all qualitative analyses were performed in SPSS v20. The main classifications of screened citations are shown in Figure 1.

3. Results

The flow of screening articles based on the PRISMA method is shown in Figure 2. Prior scientific searches assigned 833 citations after the duplicate removal phase. Next, 41 studies were eliminated due to their irrelevancy in the full-text screening phase. In the last screening step, 60 studies were included based on our main study objectives as eligible studies. Based on the predefined classification elements, a summary of the key results is described in Table 2.

3.1. Study Characteristics. The reviewed studies in this study were published in 53 journals and 7 international conferences. All the names of journals and conferences are listed in Table 3 based on their frequency. As it is clear, the “Archives of Physical Medicine and Rehabilitation,” “Clinical Rehabilitation,” “Games for Health Journal: Research, Development, and Clinical Applications,” and “Journal of Stroke and Cerebrovascular Diseases” have the first rank with 5 or 4 published studies among journals. The distribution of studies by year and country of publication is presented in Table 4. As it is conducted, the majority of citations were published in 2019. Accordingly, in different countries, innovative physical rehabilitation solutions were employed and Korea with 13 citations had the highest number of studies.
3.2. The Distribution of Literature by Main Gamification Types and Approaches. Based on analysis, virtual reality-oriented games and video games are the most popular physical rehabilitation types for poststroke patients. The distribution of reviewed literature based on the type of games is shown in Figure 3. Besides, it turns out “Microsoft Xbox 360 Kinect” and “the Nintendo Wii Fit” approaches have been the widest utilized game-based tools that have been extracted in studies (Figure 4).

The deployment platform for most of the studies included in this review (n = 28, 46.66%) was Nintendo and Microsoft Xbox 360 Kinect.

There are many games in the field of rehabilitation that researchers and therapists can use for rehabilitating patients. However, in this systematic review, most studies have used existing games in rehabilitation and do not develop games for the purpose of research that we can refer to the Nintendo Wii Fit, Microsoft Xbox 360 Kinect games, Peggie, IREX, and HTC Vive games.

3.3. Distribution of Studies Based on Type of Physical Rehabilitation. The critical types of physical rehabilitation therapies applied for poststroke patients based on different games were divided into several main categories. The most important types of rehabilitation are “Balance training,” “Mobilization of the limbs,” and “Muscular strengthening” (Figure 5).

3.4. Distribution of Studies Based on Type of Studies, Sample Size, and Session Detail. In the investigated studies, three types of intervention studies and their effectiveness have been utilized (Table 5). The sample size from minimum to maximum number is 5 people in 2 studies and 209 people in one study. The highest frequency for the selected sample size was 10 people, which is in 4 studies. The lowest age of the recruited subjects in studies was 24 years on average, and the highest mean of age was 72 years old. In most studies, the number of males included in the intervention was higher than females; in 4 studies, the exact number of genders was not reported.
3.5. Distribution of Studies Based on Assessment Scores. According to the results of reviewed different studies, numerous indicators and tests have been applied to evaluate physical rehabilitation outcomes in poststroke patients. In other words, according to the type of rehabilitation treatment provided to patients, different indicators and metrics have been calculated to assess the condition of the rehabilitated organs of the body (before and after the intervention). For this reason, we were unable to compare the assessment scores calculated during the intervention. However, considering how many indicators and metrics in each study were affected by physical rehabilitation during the intervention treatment, we added a brief assessment from the authors’ perspective. At the end of the intervention, if all indicators of functional or physical appraisal of patients are affected by game-based rehabilitation and a significant difference is seen, then we have labeled this rehabilitation approach “Effective.” If only one or two of the several evaluation metrics are not affected by game-based rehabilitation, then we label them “Partly effective.” Finally, if there is no significant difference in all evaluation measures before and after the intervention, we label them “No effective.” In the following, the distribution of the reviewed studies based on effectiveness is shown in Figure 7.

4. Discussion
This survey’s main objective was to review the studies in which games were applied for improving the physical functions and rehabilitation of poststroke patients.
| No. | Authors | Year | Name of gamification approach | Type of gamification | Rehabilitation target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|---------|------|-------------------------------|----------------------|-------------------------------|-------------|------------|-------------------------------------|----------------|----------------|----------------|--------------|---------|
| 1   | Laffont I et al. [15] | 2019 | Not mentioned | Video game | Mobilization of the limbs | Shoulder, arm, and hand | RCT | 50 | AgeM = 58; male = 31 and female = 20 | 45 min, 5 sessions in a week for 6 weeks | Baseline and postintervention at the end of the program, between days 45 and 60 and follow-up at 6 months | In the subacute stroke stage, a difference of 9/10 points on the UL-FMS is considered, and BBT minimally detectable change is gained to be 5.5 blocks/min. Significant differences between the groups were found with the eyes closed, sharpened Romberg test (p = 0.05), and standing on the right leg (p = 0.035). MR game training provided significant reaction time improvements (p < 0.05) and vestibular performances (p < 0.05). FMA scores revealed a significant improvement in the motor function (p = 0.001). BBT scores increased from 12 pretherapy to 20.6 posttherapy, and the MAL-AOM scores increased from 1.09 pretherapy to 1.8 posttherapy. Elbow flexion score (joint range of motion) increased from 127 to 134, and shoulder flexion score increased from 114 to 134. | Effective | Post hoc analysis showed that scores in UL-FMS or BBT were significantly higher in the VG group than in the CR group. Video games enable independent balance training is feasible without strenuous physiotherapy. The results showed visuomotor reaction time, and balance metrics were significantly improved following MR game rehabilitation. |
| 2   | Cikajlo I et al. [16] | 2020 | Nintendo Wii Fit | Virtual reality game | Balance training | Legs | RCT | 20 | AgeM = 50.3; male = 15 and female = 2 | 15 min, 5 sessions for 1 week | Baseline and postintervention | Significant differences between the groups were found with the eyes closed, sharpened Romberg test (p = 0.05), and standing on the right leg (p = 0.035). MR game training provided significant reaction time improvements (p < 0.05) and vestibular performances (p < 0.05). | Effective | Video games enable independent balance training is feasible without strenuous physiotherapy. |
| 3   | Glueck AC and Han DY [17] | 2019 | Microsoft developed RoboRaid | Mixed reality game | Balance training | Legs | Before and after trial | 14 | AgeM = 25.21; male = 11 and female = 3 | 59.22 min, 35.71 days | Baseline and postintervention | FMA scores revealed a significant improvement in the motor function (p = 0.001). BBT scores increased from 12 pretherapy to 20.6 posttherapy, and the MAL-AOM scores increased from 1.09 pretherapy to 1.8 posttherapy. Elbow flexion score (joint range of motion) increased from 127 to 134, and shoulder flexion score increased from 114 to 134. | Effective | Significant improvement in all outcome measures was found after the intervention. |
| 4   | Ayoubi F et al. [18] | 2020 | Nintendo Wii Fit | Virtual reality game | Mobilization of the limbs | Shoulder, wrist, hand, and finger | Before and after trial | 10 | AgeM = 61.1; male = 5 and female = 5 | 30 min, 10 sessions, 2 days in 5 weeks | Baseline and postintervention | Metrics showed that there were statistically significant improvements for all trained measures. |
| 5   | de Gouvêa JX et al. [19] | 2015 | Nintendo Wii Fit | Virtual reality game | Mobilization of the limbs | Shoulder and elbow | Before and after trial | 22 | AgeM = 66.4; male = 15 and female = 7 | 60 min, 3 sessions in a week | Baseline and postintervention | Metrics showed that there were statistically significant improvements for all trained measures. | Effective | Video games enable independent balance training is feasible without strenuous physiotherapy. |
| No. | Authors | Year | Name of gamification approach | Type of gamification approach | Rehabilitated target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|---------|------|-------------------------------|--------------------------------|-------------------------------|-------------|------------|-------------------------------------|----------------|----------------|----------------|--------------|---------|
| 6   | Cano- Mañas MJ et al. [20]. | 2020 | Microsoft Xbox 360 Kinect | Video game with Kinect | Balance training Postural control Functionality | Not mentioned | RCT | 48 | AgeM = 63.13: male = 23 and female = 25 | 20 min, 24 sessions in 8 weeks. | Baseline and postintervention assessments: 8 weeks after the intervention | Significant differences resulted in the baropodometric ($p < 0.01$), the modified Rankin scores ($p < 0.01$), and the variable related to strength and the pain/discomfort dimension ($p < 0.01$) of the EQ-5D. | Effective | The findings show that applying a video game approach combined with conventional therapy may produce postural control, improvements in balance, functionality, and quality of life. These results indicated that the Nintendo Wii Fit training was as effective on daily living functions and quality of life in subacute stroke patients. The application of Kinect2Scratch-oriented games may indicate a complementary strategy to conventional therapy for decreasing the therapists' workload. The results indicated that the WiiTM was not superior to arm exercises in home-based rehabilitation for stroke survivors with arm weakness. |
| 7   | Simsik TT and Çekok [21] | 2015 | Nintendo Wii Fit | Virtual reality game | Balance training Mobilization of the limbs | Shoulder, wrist, and elbow | RCT | 42 | AgeM = 58.04: male = 29 and female = 13 | 45–60 min, 10 week, 3 days/week. | Baseline and postintervention assessment: after 10 weeks, after intervention, and treatment satisfaction after 10 sessions | A statistically significant difference was found between before and after treatment FIM (functional independence measure) scores ($p < 0.05$). | Partly effective | |
| 8   | Hung JW et al. [22] | 2019 | Kinect2Scratch | Video game with Kinect | Mobilization of the upper limbs | Shoulder, elbow, and forearm | RCT | 33 | AgeM = 58.98: male = 22 and female = 11 | 30 min, 24 sessions in 12 weeks | Baseline, postintervention, and at the 3-month follow-up. | The total activity scores of the training on upper extremity was significantly higher in the Kinect2Scratch group than in the therapist-based training group ($p < 0.001$). There was no significant difference in the primary outcome of affected arm function at six weeks follow-up ($p = 0.12$) and no significant difference in secondary outcomes. | Effective | |
| 9   | Adie K et al. [23] | 2016 | Nintendo Wii Fit | Virtual reality game | Mobilization of the arms | Arm | RCT | 209 | AgeM = 67.3: male = 105 and female = 104 | 45 min, 42 sessions in 6 weeks | Baseline and postintervention after 6 weeks and six months | | No effective | |
| No. | Authors            | Year | Name of gamification approach | Type of gamification approach | Rehabilitated target members | Study design | Sample size | Sample description (sex, age [year]) | Session details | Assessment time | Assessment score | Effectiveness | Results                                                                 |
|-----|--------------------|------|-------------------------------|-------------------------------|-----------------------------|--------------|-------------|--------------------------------------|----------------|----------------|-----------------|---------------|--------------------------------------------------------------------------|
| 10  | Ahmad MA et al.    | 2019 | Not mentioned                 | Virtual reality game          | Mobilization of the upper limbs | Not mentioned | Before and after trial | AgeM = 63; male = 31 and female = 5 | 30 min, 8 sessions in 8 weeks | Baseline and postintervention on completion of the 8 weeks | The results showed a significant time-group interaction effect for IMI ($p = 0.001$), Lawton IADL ($p = 0.001$), and SIS domain of communication ($p = 0.03$). A significant time was found in FMA-UE ($p = 0.001$), WMFT ($p < 0.001$), and Lawton IADL ($p = 0.01$). FMA-UE in experimental and control groups was calculated 34.67 and 53.75. Changes in the B-stage in exp and con groups were indicated 3.17–4.24 for the arm and 3.08–4.58 for the hand. | Effective | The integration of VR games as an adjunct to standard physiotherapy for upper limb stroke rehabilitation was considered to be equally beneficial compared to standard physiotherapy. | Effective |
| 11  | Choi YH et al.      | 2016 | MoU-Rehab                     | Virtual reality game          | Mobilization of the upper limbs | Shoulder, elbow, and wrist | RCT         | AgeM = 66.55; male = 17 and female = 14 | 30 min, 10 sessions in 2 weeks | Baseline and postintervention on end of treatment and at 1 month | Post hoc analysis revealed significant differences in AP-axis, and sway area; weightbearing symmetry of the game-based CIMT group is compared with the other groups ($p < 0.05$). The difference between the GR mirror therapy group versus the conventional mirror therapy and control groups was statistically significant ($p < 0.05$). | Effective | A larger improvement in the FMA-UE, B-stage, and MMT was found after treatment with the MoU-Rehab than with conventional therapy. | Effective |
| 12  | Choi HS et al.      | 2017 | Nintendo Wii Fit              | Virtual reality game          | Balance training Lower extremity | Not mentioned | RCT         | AgeM = 61.91; male = 21 and female = 15 | 30 min, 12 sessions in 4 weeks | Baseline and postintervention | The difference between the GR mirror therapy group versus the conventional mirror therapy and control groups was statistically significant ($p < 0.05$). | Effective | Game-based CIMT was more effective at improving static balance control (AP-axis and sway area) and weightbearing symmetry compared with the other groups. It indicated that GR device-based mirror therapy is an intervention that improves upper extremity function, neck discomfort, and quality of life. | Effective |
| 13  | Choi HS et al.      | 2019 | Not mentioned                 | Virtual reality game          | Mobilization of the upper limbs | Elbows, hands, wrists, and finger | RCT         | AgeM = 58.97; male = 23 and female = 13 | 30 min, 15 sessions in 5 weeks | Baseline and postintervention assessment on end of 5 weeks |Game-based CIMT was more effective at improving static balance control (AP-axis and sway area) and weightbearing symmetry compared with the other groups. It indicated that GR device-based mirror therapy is an intervention that improves upper extremity function, neck discomfort, and quality of life. | Effective | Game-based CIMT was more effective at improving static balance control (AP-axis and sway area) and weightbearing symmetry compared with the other groups. It indicated that GR device-based mirror therapy is an intervention that improves upper extremity function, neck discomfort, and quality of life. | Effective |
| No. | Authors Year | Name of gamification approach | Type of gamification approach | Rehabilitated target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|--------------|-------------------------------|-----------------------------|-----------------------------|-------------|-------------|-------------------------------------|----------------|---------------|----------------|--------------|---------|
| 14  | de Paula Oliveira T et al. [28] 2015 | Nintendo Wii Fit | Virtual reality game | Balance training | Not mentioned | RCT | AgeM = 50.21; male = 13 and female = 10 | 30 min, 14 sessions in 7 weeks | Baseline and postintervention assessment on 1-week AT and at a 2-month FU | The analyses of the FMA-LE score at FU for the control and experiment group are 21.39–24.58. The analyses of the BESTest score at FU for the control and experiment group are 75–83. Significant improvements were presented in both groups for gait speed ($F = 3.9, p = 0.02$), grip strength of the weaker ($F = 6.67, p = 0.002$), and stronger hands ($F = 7.5, p = 0.001$). Daily steps and functional ability of the weaker hand did not increase in either group. Range of motion improved for 18 out of 23 upper extremity movement variables ($p = 0.01$) between pretournament and posttournament assessments. The calculated metrics showed that the patients in the intervention group showed significantly better 10MWT ($p = 0.033$), the CoPAP sway ($p = 0.01$), and the sway area ($p = 0.006$) than in the control group. | Effective | Balance training performed in virtual reality by using NWF was more efficient than conventional balance training |
| 15  | Givon N et al. [29] 2015 | Nintendo Wii Fit | Virtual reality game | Balance training Mobilization of the upper limbs | Not mentioned | RCT | AgeM = 56.35; male = 28 and female = 19 | 60 min, 2 sessions in a week for 3 months | Baseline and postintervention, a 3-month intervention and at 3-month follow-up | Video and VR games can promote measures of physical activity of patients with chronic stroke. | Partly effective | |
| 16  | House G et al. [30] 2016 | The BrightArm™ | Virtual reality game | Mobilization of the upper limbs Arm, hand, shoulder, and wrist | Before and after trial | RCT | AgeM = 69.7; male = 5 and female = 2 | 45–50 min, 16 sessions in 8 weeks | Baseline and postintervention, on each booster period, each consisting of 4 sessions over 2 weeks in 8 weeks | The results indicate that BrightArm is effective in improving the range of motion of the upper extremity. | Effective | |
| 17  | Hsieh HC [31] 2018 | Not mentioned | Video game | Walking Balance training | Not mentioned | RCT | AgeM = 58.5; male = 33 and female = 23 | 30 min, 3.5 hours/week, 10 weeks | Baseline and postintervention | This game improves exercise compliance and promotes recovery of balance and mobility after stroke. | Effective | |
| No. | Authors | Year | Name of gamification approach | Type of gamification approach | Name of rehabilitated target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|---------|------|-------------------------------|-------------------------------|--------------------------------------|-------------|------------|-------------------------------------|----------------|----------------|----------------|--------------|---------|
| 18  | Hsieh HC [32] | 2018 | Not mentioned | Video game | Balance training | Leg | RCT | 54 | AgeM = 64.07 | 40 min, 3 sessions in 1 week for 12 weeks | Baseline and postintervention | Significant changes in CoP sway kinematics were observed in sway path ($p = 0.001$), sway area ($p = 0.002$), and sway velocity ($p = 0.007$). Balanced tests are the BBS test ($p = 0.001$ and TUG test $p = 0.001$), and there was no significant change in the FABS test. | This innovative gaming approach with adaptive PC games will be a useful therapy for stroke rehabilitation |
| 19  | Huang LL and Chen MH [33] | 2016 | Gardening digital game | Video game | Mobilization of the upper limbs | Not mentioned | Before and after trial | 10 | AgeM = 61.20: male = 5 and female = 5 | 24 sessions in three sessions per week | Baseline and postintervention | Fugl–Meyer Assessment of motor function (increases of 9.30); the Box and Block Test of manual dexterity (increases of 5.80); higher functional independence measure (increases of 6.50); and range of motion measurement of the upper extremity proxima (increases of 5.56) and distal (increases of 3.83) | The gardening digital game is benefit to improve upper extremity motor function. |
| 20  | Khan RU et al. [34] | 2019 | Not mentioned | Video game | Muscular strengthening | Fist, wrist, and forearm | Before and after trial | 5 | AgeM = 24: male = 3 and female = 2 | Not mentioned | Baseline and postintervention | The scores of 3 players were improved up to 150, 171, and 172, respectively, for 2 players, and there is not mainly improvement. For the experimental group, the change of BBT (pre-to-postdifference) scores showed a significant improvement when compared to the control group ($p = 0.007$), but the change of FMA-UE and the FIM scores for the experimental group were not significantly higher ($p = 0.057$, $p = 0.677$) | This result shows that an attractive environment and real-time feedback mechanism can improve the rehabilitation process. |
| 21  | Afsar SI et al. [35] | 2018 | Microsoft Xbox 360 Kinect | Virtual reality game | Mobilization of the upper limbs | Shoulder and elbow | RCT | 35 | AgeM = 66.43: male = 20 and female = 15 | 30 min per day for 4 weeks | Baseline and postintervention | Party effective | The Kinect-based game system in addition to conventional therapy has supplemental effectiveness for stroke patients. | Partly effective |
| No. | Authors Year | Name of gamification approach | Type of gamification approach | Type of rehabilitation | Rehabilitated target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|--------------|--------------------------------|------------------------------|------------------------|-------------------------------|--------------|-------------|-------------------------------------|----------------|----------------|----------------|-------------|---------|
| 22  | Lee MM et al. [36] 2016 | Canoe game | Virtual reality game | Trunk postural stability | Balance training | Trunk muscles and leg | RCT | 10 | AgeM = 65.7; male = 5 and female = 5 | 30 min a day, 3 sessions a week for 4 weeks | Baseline and postintervention | Improvements in trunk postural stability, balance, and upper limb motor function were observed in the EG and CG, but were greater in the EG. The mean SUS scores in the EG and TG were 71 ± 5.2 and 74.2 ± 6.8, respectively. The scores of TIs, Sib, TIs, and TIs, s for the intervention group improved up to 5.9, 6.18, and 3.0. The score of DGI is calculated up to 17.27. The score of TWT and TUGT decreased up to 42.27 and 39.32. In five participants, scores showed improvement both in ARAT and BBT. ARAT (pretraining 22.3 and postraining 31.1), BBT (pretraining 11.2 and postraining 19.6), and MB1 (pretraining 90.4 and postraining 93.0) | Effective | Canoe game-based virtual reality training is a beneficial intervention for improving trunk postural stability, balance training, and upper limb motor in stroke patients. |
| 23  | Lee D and Bae Y [37] 2019 | DBIVG | Video game | Trunk postural stability | Walking | Trunk and leg | RCT | 21 | AgeM = 55.1; male = 14 and female = 7 | 30 min, 12 sessions in 4 weeks | Baseline and postintervention | I/²he scores of TIs, sib, TIs, dsb, and TIs, co for the intervention group improved up to 5.9, 6.18, and 3.0. The score of DGI is calculated up to 17.27. The score of TWT and TUGT decreased up to 42.27 and 39.32. In five participants, scores showed improvement both in ARAT and BBT. ARAT (pretraining 22.3 and postraining 31.1), BBT (pretraining 11.2 and postraining 19.6), and MB1 (pretraining 90.4 and postraining 93.0) | Effective | The analysis demonstrated DBIVG can improve trunk control and gait ability in patients with chronic stroke. |
| 24  | Lee SH et al. [38] 2019 | HTC Vive | Virtual reality game | Mobilization of the upper limbs | | Hand, shoulder, fingers, and wrist | Before and after trial | 12 | AgeM = 40.2; male = 7 and female = 5 | 30 min, 10 sessions 2-3 times a week | Baseline and postintervention | In five participants, scores showed improvement both in ARAT and BBT. ARAT (pretraining 22.3 and postraining 31.1), BBT (pretraining 11.2 and postraining 19.6), and MB1 (pretraining 90.4 and postraining 93.0) | Partly effective | This study indicates a fully immersive VR rehabilitation program can be used for upper extremity rehabilitation in patients with chronic stroke. |
| 25  | McNulty PA et al. [39] 2015 | Nintendo Wii Fit | Virtual reality game | Mobilization of the upper limbs | | Shoulder, elbow, and wrist | RCT | 41 | AgeM = 58; male = 31 and female = 10 | 60 min, 10 consecutive weekdays | Prebaseline (14 days pretherapy), baseline, postintervention, and postrtention after six-month follow-up | The Wolf Motor Function Test (WMFT-tt) improved from 21 to 17 after Wii-based movement therapy, and Motor Activity Log Quality of Movement Scale scores improved from 67.7 to 102.4 after Wii-based movement therapy. | Effective | This result indicated Wii-based movement therapy is an effective upper limb rehabilitation post-stroke. |
| No. | Authors            | Year | Name of gamification approach | Type of gamification approach | Rehabilitated target members | Study design | Sample size (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|--------------------|------|-------------------------------|-------------------------------|-----------------------------|--------------|------------------------------|----------------|----------------|-----------------|--------------|---------|
| 26  | Nijenhuis SM et al. [40] | 2016 | MyoCI                        | Video game                    | Muscular strengthening Arm and hand | RCT          | AgeM = 60: male = 10, female = 9 | 30 min, 6 sessions in a week for six weeks | Prebaseline (one week before training), baseline, and 1 week after training (postintervention) and two months after the end of training follow-up | The control group reported a higher training duration (189 versus 118 minutes per week). No differences in clinical outcomes over training between groups were found ($p > 0.165$). Significant improvements were resulted with the JHFT, BBT, and NHPT from pretesting to posttesting ($p = 0.03, p = 0.03$, and $p = 0.01$, respectively). An increase in QOL from pretesting to posttesting is determined by the SIS ($p = 0.009$). The number of falls was statistically significant ($p = 0.049$) only in the treatment group. The differences in gait balance in the control group ($p = 0.047$) is resulted. ARAT extremely improved by 13.9% and 9.6% following the video games and traditional self-training programs. The scores for the Box and Block Test were 20.6 and 21.3 for pre and posttreatment in the experimental group. | No effective | An extra advantage of this arm and hand training over the conventional arm and hand exercises at home was not proven. |
| 27  | Paquin K et al. [41] | 2015 | Nintendo Wii Fit             | Virtual reality game          | Mobilization of the upper limbs | Before and after trial | AgeM = 72:1: male = 10 | 15 min, 16 sessions, 2 sessions per week, for 8 weeks | Baseline and postintervention | Effective | Findings demonstrated important improvements occurred between pretesting and posttesting on 4 metrics. |
| 28  | da Fonseca EP et al. [42] | 2016 | Nintendo Wii Fit             | Virtual reality game          | Balance training Legs, arms, trunk, and hip | RCT          | AgeM = 52:4: male = 9 and female = 18 | 45 min, 20 sessions in 3 months | Baseline and postintervention | Partly effective | The rehabilitation of gait balance in poststroke people applying virtual reality had the reduction of falls. |
| 29  | Rand D et al. [43] | 2016 | Microsoft Xbox 360 Kinect    | Virtual reality game          | Balance training Mobilization of the upper limbs | RCT          | AgeM = 62: male = 15 and female = 9 | 60 min a day, 6 times/week for 5 weeks | Baseline (an average of two assessments) and postintervention, and at the 4-week follow-up | Effective | Video games or self-training programs can be applied for practice repetitive upper extremity movements without the supervision of a clinician. |
| No. | Authors          | Year | Name of gamification approach | Type of gamification approach | Type of rehabilitation | Rehabilitated target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|------------------|------|-------------------------------|-------------------------------|------------------------|-------------------------------|--------------|-------------|-------------------------------------|----------------|----------------|----------------|--------------|---------|
| 30  | Shin JH et al.   | 2015 | RehabMaster™                 | Virtual reality game          | Mobilization of the upper limbs | Upper limb and trunk          | RCT          | 32          | AgeM = 53.95: male = 24 and female = 8  | 30 min for 5 days per week for 4 weeks | Baseline and postintervention | The scores of FMA-UE, physical functioning were improved for pre and post treatment (experimental group) 35.5 up to 38.5 and 15 up to 20. Both groups exhibited significantly improved upper extremity function ($p = 0.001$). The improvements in the game group were supported by significant FM-total: $F = 6.48, p = 0.006$; FM-prox: $F = 5.73, p = 0.007$; FM-dist: $F = 4.64, p = 0.024$). The improvements in the JTTtotal in the game group was supported by significant JTTtotal: $F = 4.073, p = 0.032$). There was a significantly greater change from baseline in the intervention group on midpoint wolf MFT strength (intervention group: 2.47; control group: 2.19), and two subscales of the final Motor Activity Log are improved (intervention group: 12.80; control group: 12.53). The scores of ARAT for the experimental game-based group improved from 30 up to 40, also the Box and Block Test improved for this group from 25 up to 30, and standing balance improved too from 16 p to 29. | Effective | Results indicate that game-based VR rehabilitation has specific effects on health-related quality of life and upper extremity function. |
| 31  | Shin JH et al.   | 2016 | I/¨he                          | Virtual reality game          | Mobilization of the upper limbs | Forearm, wrist, finger, shoulder, and elbow | RCT          | 46          | AgeM = 58.5: male = 36 and female = 10 | 30 min, 20 sessions for 4 weeks | Baseline and postintervention in the middle of the treatment immediately after the intervention and 1 month after the intervention | I/¨he improvements in the game group were supported by significant FM-total: $F = 6.48, p = 0.006$; FM-prox: $F = 5.73, p = 0.007$; FM-dist: $F = 4.64, p = 0.024$). The improvements in the JTTtotal in the game group was supported by significant JTTtotal: $F = 4.073, p = 0.032$). There was a significantly greater change from baseline in the intervention group on midpoint wolf MFT strength (intervention group: 2.47; control group: 2.19), and two subscales of the final Motor Activity Log are improved (intervention group: 12.80; control group: 12.53). The scores of ARAT for the experimental game-based group improved from 30 up to 40, also the Box and Block Test improved for this group from 25 up to 30, and standing balance improved too from 16 p to 29. | Effective | The game system used in VR-based rehabilitation might be an ideal rehabilitation tool for the distal upper extremity in stroke survivors. |
| 32  | Standen PJ et al.| 2016 | Nintendo Wii Fit              | Virtual reality game          | Mobilization of the upper limbs | Arm, hand, shoulder, and finger | RCT          | 27          | AgeM = 61: male = 16 and female = 11 | 20 min, 3 times a day, for 8 weeks | Baseline and postintervention four weeks (midpoint) and eight weeks (final) | I/¨he was a significantly greater change from baseline in the intervention group on midpoint wolf MFT strength (intervention group: 2.47; control group: 2.19), and two subscales of the final Motor Activity Log are improved (intervention group: 12.80; control group: 12.53). The scores of ARAT for the experimental game-based group improved from 30 up to 40, also the Box and Block Test improved for this group from 25 up to 30, and standing balance improved too from 16 p to 29. | Effective | There is a greater improvement from baseline in the intervention group, so it is effective to use and help clinicians. |
| 33  | Rand D et al.    | 2015 | Microsoft Xbox 360 Kinect     | Virtual reality game          | Balance training Mobilization of the upper limbs | Not mentioned           | RCT          | 12          | AgeM = 63: male = 7 and female = 5  | 60 min, 5 times a week for 5 weeks | Prebaseline, baseline, postintervention, and 4 weeks after the intervention. | I/¨he video games encouraged upper extremity movements and have potential to promote standing balance. | Effective | These video games encouraged upper extremity movements and have potential to promote standing balance. |
| No. | Authors | Year | Name of gamification approach | Type of gamification approach | Rehabilitated target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|---------|------|--------------------------------|-------------------------------|-------------------------------|-------------|------------|--------------------------------------|----------------|----------------|-----------------|--------------|---------|
| 34  | Kottink AIR et al. [48] | 2014 | Not mentioned | Virtual reality game | Mobilization of the limbs | Arm and hand | RCT | 18 | AgeM = 61.4; male = 13 and female = 5 | 30 min, 3 sessions in a week for 6 weeks | Baseline and postintervention | ARA and FM improvements were significant within both groups \(p \leq 0.009\) for the main effect for session, with effect sizes (partial eta squared) of 0.47 and 0.53 for the ARA test and FM assessment, respectively. | Effective | The present study showed that both the arm and hand function improved after training. |
| 35  | Rand D et al. [49] | 2014 | Microsoft Xbox 360 Kinect | Video game | Mobilization of the limbs | Upper extremity | RCT | 29 | AgeM = 59; male = 17 and female = 12 | 60 min, 2 sessions per week for 3 months | Postintervention during the last month of the intervention and 1–2 weeks following the sessions | Participants in the VGG performed a median (IQR) of 271 (157–490) active purposeful movements compared to 48 (3–125) active purposeful movements in the TG \(z = 3.0, p = 0.001\). No change in the FMA-UL scores between t1 and t2, indicating a stable baseline; a significant increase in the FMA-UL scores between t2 and t3; a significant increase in the FMA-UL scores between t2 and t4; and no change in the FMA-UL scores between t3 and t4 | Partly effective | Video games elicited more UE purposeful repetitions and higher acceleration of movement compared with traditional therapy. |
| 36  | Jordan K et al. [50] | 2014 | Not mentioned | Virtual reality game | Mobilization of the limbs | Upper limb | Before and after trial | 12 | AgeM = 68.6 | 45 min, 3 sessions per week for 4–6 weeks | Baseline (t1), 4 weeks later (t2), within 1 week of completing the intervention (t3), and a final assessment was given 4 weeks later (t4). | Dunn's pairwise comparison showed that TTP contractions in the Wii group improved significantly more than that of the no-treatment group \(p < 0.005\). | Effective | The intervention improved the arm function in survivors of chronic stroke. |
| 37  | Fan SC et al. [52] | 2014 | Nintendo Wii Fit | Virtual reality game | Mobilization of the limbs | Upper arm | RCT | 20 | AgeM = 64.4; male = 14 and female = 6 | 60 min, 3 sessions per week for 3 weeks | Baseline and postintervention (week 0), immediately after treatment (week 4) and four weeks after treatment (week 8). | Dunn's pairwise comparison showed that TTP contractions in the Wii group improved significantly more than that of the no-treatment group \(p < 0.005\). | Effective | In this pilot study, OTSVR gaming had immediate effects on motor recovery and provided motivation for treatment compliance in stroke patients. |
| No. | Authors | Year | Name of gamification approach | Type of gamification approach | Type of rehabilitation | Rehabilitated target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|---------|------|-----------------------------|-----------------------------|------------------------|-----------------------------|--------------|-------------|----------------------------------|----------------|----------------|----------------|--------------|---------|
| 38  | McEwen D et al. [52] | 2014 | IREX Virtual reality game | Mobilization of the limbs | Lower extremity | RCT | 59 | AgeM = 64.1; male = 32 and female = 27 | 30 min, daily sessions for 3 weeks | Before, immediately after, and 1 month after training | More individuals in the treatment group than in the control group showed reduced impairment in the lower extremity as measured by the Chedoke McMaster Leg Domain (p = 0.04) immediately after training. At 3-month follow-up, the improvement in TUG and FR tests was maintained (time effect in TUG, p = 0.03, partial η² = 0.17; FR, p = 0.01, and partial η² = 0.22), but there was an increased fear of falling in both groups MAL-QOM and both mobility and physical domains of the SIS with mean difference of 1.0%, 5.5%, and 6.7% between the intervention and control groups, respectively at postintervention. Differences from baseline of FMA, MI, and AROM (except adduction of the shoulder and extension of the elbow) were greater in group A (p < 0.05). | Effective | VR exercise intervention for inpatient stroke rehabilitation improved mobility-related outcomes. |
| 39  | Hung JW et al. [53] | 2014 | Nintendo Wii Fit Video game | Balance training | Leg | RCT | 28 | AgeM = 54.4; male = 18 and female = 10 | 30 min, 2 sessions per week for 4 weeks | Baseline, postintervention, and 4-week follow-up | The analyses showed only a significant effect for the side (ANOVA: F = 27.80, p < 0.001, ES = 0.99). | Partly effective | Exergaming is enjoyable and effective for patients with chronic stroke. |
| 40  | Norouzi-Gheidari N et al. [54] | 2019 | Jintronix system Virtual reality game with Kinect | Mobilization of the limbs | Upper extremity | RCT | 18 | AgeM = 49.9; male = 10 and female = 8 | 44 min, 2-3 sessions per week for 4 weeks | Baseline, postintervention, and 4-week follow-up | Partly effective | Using virtual reality exergaming technology may be beneficial to upper extremity functional recovery. | Kinect-based VR training may contribute to the improvement of the UE motor function and AROM in chronic stroke patients. People showed performance improvement after training with VR, but there was no transfer of the gains obtained to an untrained task with similar balance demands. |
| 41  | Aslıın A et al. [55] | 2018 | KineLabs Virtual reality game with Kinect | Mobilization of the limbs | Upper extremity | RCT | 38 | AgeM = 55.0; male = 27 and female = 11 | 60 min, 5 sessions per week for 4 weeks | Baseline and postintervention | Partly effective | People showed performance improvement after training with VR, but there was no transfer of the gains obtained to an untrained task with similar balance demands. |
| 42  | Miranda CS et al. [56] | 2019 | Nintendo Wii Fit Virtual reality game | Balance training | Lower limbs | RCT | 29 | AgeM = 50.96; male = 15 and female = 14 | 3 sessions for 1 week: Session 1: 60 min; sessions 2 and 3: 30 min | Baseline and postintervention, 15 (first session), 2S (2 days after the 1 session), and 3S (7 days after the 1 session) of training. | Partly effective | People showed performance improvement after training with VR, but there was no transfer of the gains obtained to an untrained task with similar balance demands. |
| No. | Authors Year | Name of gamification approach | Type of gamification approach | Rehabilitated target members | Study design | Sample size | Sample description (sex, age [year]) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|--------------|-------------------------------|-------------------------------|-----------------------------|--------------|------------|--------------------------------------|----------------|----------------|----------------|--------------|---------|
| 43  | Fernandes  AB et al. [57] 2014 | "Paddle Panic Mini Game" | Virtual reality game with Kinect | Mobilization of the limbs | Upper extremity | Nonrandomized clinical trials | 40 | AgeM = 50.75: male = 20 and female = 20 | Not mentioned | Baseline and postintervention | Comparing the participants' performance by ANOVA, there was a significant difference in the number of hits between the patients and healthy individuals' groups, according to the trials ($p = 0.008$). Wii fit training was more effective than usual balance therapy in improving balance (BBS: 53 versus 48, $p = 0.004$) and independency in activity of daily living (BI: 98 versus 93, $p = 0.021$). Significant effect sizes ($d$) were found for QFG strength ($d = 0.5$; $p = 0.021$), QFG control ($d = 1.1$; $p < 0.001$), HSG strength ($d = 1.1$; $p = 0.001$), HSG control ($d = 1.5$; $p = 0.003$), functional mobility ($d = 0.3$; $p < 0.001$), gait speed ($d = 0.6$; $p = 0.007$), and motor recovery ($d = 1.0$; $p < 0.001$). An improvement in the mean scores was observed after treatment independent of the allocation group with significant intragroup changes: 14.5, 10.5, and 10.4 for PNF, VR, and PNF/VR, respectively. | Patients with right brain injury responded better to the virtual reality game. | Partly effective |
| 44  | Morone G et al. [58] 2014 | Nintendo Wii Fit | Video game | Balance training, Standing | Transferring Facilitation of movements | Paretic side, upper limb, and leg | RCT | 50 | AgeM = 60.16 | 20 min, 3 sessions per week for 4 weeks | Baseline and postintervention | Wii fit training was more effective than usual balance therapy in improving balance (BBS: 53 versus 48, $p = 0.004$) and independency in activity of daily living (BI: 98 versus 93, $p = 0.021$). Results indicate that the intervention of a SC with both the proper apparatus and evaluation system may effectively promote lower limb motor rehabilitation of hemiparetic stroke patients. | Balance training with game was found to be more effective than conventional therapy alone in improving balance and reducing disability in patients with subacute stroke. | Effective |
| 45  | Noveletto F et al. [59] 2020 | MimPong | Video game | Muscular strengthening | Lower limb | Before and after trial | 11 | AgeM = 59.0: male = 6 and female = 5 | 12 min, 2 sessions per week for 10 weeks | Baseline and postintervention (third evaluation occurred one month after the end of rehabilitation) | Significant effect sizes ($d$) were found for QFG strength ($d = 0.5$; $p = 0.021$), QFG control ($d = 1.1$, $p < 0.001$), HSG strength ($d = 1.1$; $p = 0.001$), HSG control ($d = 1.5$; $p = 0.003$), functional mobility ($d = 0.3$; $p < 0.001$), gait speed ($d = 0.6$; $p = 0.007$), and motor recovery ($d = 1.0$; $p < 0.001$). An improvement in the mean scores was observed after treatment independent of the allocation group with significant intragroup changes: 14.5, 10.5, and 10.4 for PNF, VR, and PNF/VR, respectively. | Effective |
| 46  | Junior VA dos S et al. [60] 2019 | Nintendo Wii Fit | Virtual reality game | Mobilization of the limbs, Balance training | Sensory function improvement | Upper limb and lower limb | RCT | 40 | AgeM = 55.6: male = 23 and female = 17 | 50 min, 2 sessions per 2 months | Baseline and postintervention (second assessment after 2 months of treatment) | The use of a program combining virtual rehabilitation and PNF presented results that were comparable with those obtained with the isolated techniques. | Partly effective |
### Table 2: Continued.

| No. | Authors | Year | Name of gamification approach | Type of gamification approach | Type of rehabilitation | Rehabilitated target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|---------|------|--------------------------------|-------------------------------|------------------------|----------------------------|--------------|-------------|---------------------------------------|----------------|----------------|----------------|-------------|---------|
| 47  | Choi D et al. [61] | 2018 | Nintendo Wii Fit | Virtual reality game | Balance training Walking | Lower limb | RCT | 28 | AgeM = 50.25: male = 17 and female = 11 | 30 min, 3 sessions per week for 6 weeks | Prebaseline, baseline, and postintervention (1 week before and after training) | WVRT group showed significant improvements of +3.00 (5.25) in the BBS score and −1.92 (6.33) s in the TUG test, with all results being significantly better than those of the GBT group (p < 0.05). The mean, median, and interquartile range for within-subjects change on the WMFT (rate/60 seconds) and MAL-QOM (0–5 scale) were 5.8 (3.7), 5.8, 2.7–9.4 and 0.74 (0.66), 0.46, 0.28–1.11, respectively. Evaluated outcomes were better for all EG participants. The BBS test showed a balance improvement of 12.1 ± 7.8% with a large ES (0.9). The functional mobility assessed by the TUG test showed an improvement of 15.1 ± 7.4%, but ES was small (0.4). Descriptive data showed an improvement of the motor function of the upper limb items (26 ± 19.5) and total score (35.6 ± 20.2) of the scale. | Effective | The WVRT was a useful program for improving visual perception and postural balance in individuals with chronic stroke. |
| 48  | Borstad AL et al. [62] | 2018 | Recovery rapids | Virtual reality game with Kinect | Mobilization of the limbs | Upper limb | Before and after trial | 16 | AgeM = 49: male = 10 and female = 6 | 3 hours per day for 10 days over 2 weeks | Baseline and postintervention | I/¨he mean, median, and interquartile range for within-subjects change on the WMFT (rate/60 seconds) and MAL-QOM (0–5 scale) were 5.8 (3.7), 5.8, 2.7–9.4 and 0.74 (0.66), 0.46, 0.28–1.11, respectively. Evaluated outcomes were better for all EG participants. The BBS test showed a balance improvement of 12.1 ± 7.8% with a large ES (0.9). The functional mobility assessed by the TUG test showed an improvement of 15.1 ± 7.4%, but ES was small (0.4). Descriptive data showed an improvement of the motor function of the upper limb items (26 ± 19.5) and total score (35.6 ± 20.2) of the scale. | Partly effective | Favorable changes in performance speed and quality of arm use were found in this study. |
| 49  | Noveletto F et al. [63] | 2018 | MyBalance | Video game | Balance training | Not mentioned | Before and after trial | 18 | AgeM = 55.3: male = 8 and female = 10 | 12 minutes per day in the first ten sessions and 20 minutes per day in the remaining sessions: 2 sessions per week for 10 weeks | Baseline and postintervention | Evaluated outcomes were better for all EG participants. The BBS test showed a balance improvement of 12.1 ± 7.8% with a large ES (0.9). The functional mobility assessed by the TUG test showed an improvement of 15.1 ± 7.4%, but ES was small (0.4). Descriptive data showed an improvement of the motor function of the upper limb items (26 ± 19.5) and total score (35.6 ± 20.2) of the scale. | Effective | The results of this study support the clinical potential of a biomedical SG for balance rehabilitation of hemiparetic stroke patients. |
| 50  | Carregosa AA et al. [64] | 2018 | Nintendo Wii Fit | Virtual reality game | Mobilization of the limbs | Upper limb and lower limb | Before and after trial | 5 | AgeM = 54.8: male = 3 and female = 2 | 50 min, 2 sessions per week for 2 months | Baseline, postintervention, and 8 weeks after the treatment | Evaluated outcomes were better for all EG participants. The BBS test showed a balance improvement of 12.1 ± 7.8% with a large ES (0.9). The functional mobility assessed by the TUG test showed an improvement of 15.1 ± 7.4%, but ES was small (0.4). Descriptive data showed an improvement of the motor function of the upper limb items (26 ± 19.5) and total score (35.6 ± 20.2) of the scale. | Effective | The results suggest that patients had motor learning retention, achieving a sustained benefit through the technique. |
| No. | Authors | Year | Name of gamification approach | Type of gamification approach | Type of rehabilitation | Rehabilitated target members | Study design | Sample size | Sample description (sex, age (year)) | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|---------|------|--------------------------------|--------------------------------|------------------------|-----------------------------|-------------|------------|-------------------------------------|----------------|----------------|----------------|-------------|---------|
| 51  | Park JH and Park JH [65] | 2016 | Nintendo Wii Fit | Virtual reality game | Mobilization of the limbs | Upper extremity | RCT | 30 | Male = 16 and female = 14 | 30 min, 5 sessions per week for 4 weeks | Baseline and postintervention (after 4 weeks) | There were significant differences in the changes between the two groups in the FM (p < 0.05), BBT (p < 0.05), and MAL-QOM (p < 0.05). FM pre: 89.3 and FM post 54.4 (Fugl–Meyer Assessment) | Effective | Game-based virtual reality movement therapy alone may be helpful to improve functional recovery of the upper extremity, but the addition of MP produces a larger improvement. The results of the experiment show that dynamic adaptation technique increases movement amplitude during a therapeutic session. |
| 52  | Hocine N et al. [8] | 2015 | PRehab | Video game | Mobilization of the limbs | Upper limb | RCT | 6 | AgeM = 60.66: male = 4 and female = 2 | 20 min, for 2 weeks (3 sessions) | Baseline and postintervention | It revealed a significant effect of the difficulty strategy on patient performance (Wilks’ Lambda = 0.10; F = 2.38; p < 0.02). | Partly effective | Improvements were observed in the majority of secondary outcomes over time in both groups. The balance group participants demonstrated greater improvements in Wii balance board-derived measures with small to large effect sizes (d = 0.30–1.00) at four weeks (p = 0.007 – 0.048). No differences were found across time on any of the WMFT subscales or the CAHAI-9 WMFT functional activity score: A1: 1.79 ± 0.71; A2: 1.77 ± 0.68; A3: 1.79 ± 0.66 | |
| 53  | Bower KJ et al. [66] | 2014 | Nintendo Wii Fit | Not mentioned | Balance training Mobilization of the limbs | Upper limb and lower limb | RCT | 30 | AgeM = 63.6: male = 17 and female = 13 | 45 min, 3 sessions per week over 2–4 weeks | Baseline, two weeks, and four weeks | Improvements were observed in the majority of secondary outcomes over time in both groups. The balance group participants demonstrated greater improvements in Wii balance board-derived measures with small to large effect sizes (d = 0.30–1.00) at four weeks (p = 0.007 – 0.048). No differences were found across time on any of the WMFT subscales or the CAHAI-9 WMFT functional activity score: A1: 1.79 ± 0.71; A2: 1.77 ± 0.68; A3: 1.79 ± 0.66 | Partly effective | Specific activities targeted at balance training are potentially effective for improving standing balance. |
| 54  | Brown EVD et al. [67] | 2014 | Peggle | Video game | Balancing training | Upper extremity | RCT | 9 | AgeM = 60: male = 5 and female = 4 | 45 min, 5 sessions per week for 4 weeks | Baseline and postintervention assessments, approximately 4 weeks apart, before system use | No differences were found across time on any of the WMFT subscales or the CAHAI-9 WMFT functional activity score: A1: 1.79 ± 0.71; A2: 1.77 ± 0.68; A3: 1.79 ± 0.66 | No effective | This study had limited changes in kinematic and activity level outcomes | |
| No. | Authors | Year | Name of gamification approach | Type of gamification approach | Rehabilitated target members | Study design | Sample description (sex, age (year)) | Sample size | Sample size | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|---------|------|-------------------------------|-------------------------------|-------------------------------|--------------|-----------------------------------|-------------|-------------|----------------|----------------|----------------|--------------|---------|
| 55  | Slijper A et al. [68] | 2014 | Not mentioned | Video game | Mobilization of the limbs | Upper extremity | Before and after trial | Age M = 58; male = 5 and female = 6 | 11 | 5 weeks, mean time: 1070 min | Baseline, during, postintervention, and follow-up 6-18 weeks after the treatment phase | FMA-UE A-D (motor function) showed significant improvements in the upper extremity function between baseline (A1) and posttest (A2) (0.005) as well as a follow-up (<0.0001). Fugl-Meyer A-D: preintervention: 44; intervention: 49; postintervention: 51 | Effective | The results indicate that computer game-based training could be a promising approach to improve upper extremity function. |
| 56  | Chen CC et al. [69] | 2017 | Not mentioned | Virtual reality game | Mobilization of the limbs | Upper limb | Before and after trial | Age M = 55.7; male = 14 and female = 7 | 21 | 60 min, 3 sessions per week for 8 weeks | Baseline and postintervention | The statistical results confirmed a significant effect of treatment. FMA: baseline: 30.35 ± 13.8. After intervention: 38.80 ± 14.61 | Effective | Finding suggests that VR-based rehabilitation can induce significantly kinetic changes than facilitate recovery. |
| 57  | Lee MM et al. [70] | 2018 | Nintendo Wii Fit | Virtual reality game | Mobilization of the limbs | Upper extremity | RCT | Age M = 48.56; male = 18 and female = 12 | 30 | 30 min, 3 sessions per week for 5 weeks | Baseline and postintervention one day after the five-week intervention period | MFT was significantly improved in both groups compared with baseline values (p < 0.05). Pre: 8.93 ± 1.53; post: 11.40 ± 2.47 | Effective | Evidence supports the use of additional VR training with the Xbox Kinect gaming system as an effective therapeutic approach for improving motor function. |
| 58  | Park DS et al. [71] | 2017 | Microsoft Xbox 360 Kinect | Virtual reality game with Kinect | Mobilization of the limbs | Lower extremity | RCT | Age M = 63.65; male = 10 and female = 10 | 20 | 30 min, daily sessions for a 6-week period | Baseline and postintervention | The pre-to-post difference scores on BBS, TUG, and 10 mWT for the intervention group were significantly more improved than those for the control group (p < 0.05). After training, hand strength, MFT, and BBT were improved in the experimental group compared to the control group (P < 0.001, both); MFT: pre: 12.91 ± 5.73; post: 16.23 ± 5.95 | Effective | Game-based VR canoe paddling training is an effective rehabilitation therapy that enhances postural balance and upper extremity function. |
| 59  | Park JS et al. [72] | 2019 | Not mentioned | Video game | Mobilization of the limbs | Hand | RCT | Age M = 59.43; male = 26 and female = 17 | 43 | 30 min, 5 sessions per week, for 6 weeks | Baseline and postintervention | Effective | Game-based exercise is more effective than manual exercise in improving muscle strength, motor function, and compliance in stroke patients. |
Table 2: Continued.

| No. | Authors   | Year | Name of gamification approach | Type of gamification approach | Rehabilitated target members | Study design | Sample description (sex, age (year)) | Sample size | Session details | Assessment time | Assessment score | Effectiveness | Results |
|-----|-----------|------|--------------------------------|-------------------------------|------------------------------|--------------|-------------------------------------|-------------|----------------|-----------------|-----------------|--------------|---------|
| 60  | Ahmadi HS et al. [73] | 2019 | Virtual reality game | Mobilization of the limbs | Upper limb | Nonrandomized clinical trials | AgeM =55.24: male = 20 and female = 10 | 30          | 40 min, 3 sessions per week, for 4 weeks | Baseline and postintervention | The finding shows the improvement of upper limb motor function, tone, and range of motion in this group. Mean differences: FMA (total score); intervention: 6.53; control: 3.86 | Effective | Computer games can improve upper limb motor function, muscle tone, and the range of motion in stroke patients. |

FMA-UE, Fugl–Meyer Assessment for Upper Extremity; WMFT, Wolf Motor Function Test; IMI, Intrinsic Motivation Inventory; IADL, Lawton of instrumental activities of daily living; SIS, Stroke Impact Scale; B-stage, brainstorm stage; MMT, manual muscle testing; AP-axis, anterior-posterior axis; CIMT, constraint-induced movement therapy; GR, gesture recognition; NWF, Nintendo Wii Fit™ game; FU, follow-up; FMA-LE, Fugl–Meyer Assessment; BESTest, Balance Evaluation Systems Test; AT, after training; 10MWT, 10-meter test of walking score; CoP, center of pressure; AP sway, sway kinematics in the anterior-posterior; BBS, the Berg Balance Scale; FABS, Fullerton Advanced Balance Scale; TUG, Timed Up and Go; FM, Fugl–Meyer; ARA, Action Research Arm; UE, upper extremity; VGG, video game group; TG, traditional group; IQR, interquartile range; FMA-UL, Fugl–Meyer upper limit assessment; OTSVR, off-the-shelf virtual reality; TTP, time-to-peak; VR, virtual reality; FR, forward reach; MAL-QOM, Motor Activity Log Quality of Movement; FMA, Fugl–Meyer Assessment; MI, Motricity Index; AROM, active range of motion; BI, Barthe Index; SG, serious games; QFG, quadriceps femoris; HSG, hamstrings; PNF, proprioceptive neuromuscular facilitation; WVRT, Wii Fit virtual reality training; GBT, general balance training; EG, experimental group; ES, effect sizes; BBT, Box and Block Test; MP, mental practice; CAHAI-9, Chedoke Arm and Hand Activity Inventory-9; MFT, manual function test; RCT, randomized controlled trial or randomized control trial.
According to results, emerging games possess the capacity and potential to rehabilitate physical aspects in poststroke patients; furthermore, these games can help patients improve their independence. According to surveys, virtual reality-based approaches and “the Nintendo Wii Fit” games were used more than other games. The most common use of games in poststroke survivors’ rehabilitation was related to limb movement and balance training.

Due to the included studies’ results, different indicators and scales have been calculated and statistically analyzed to evaluate and test game-based physical rehabilitation therapies for poststroke patients. These statistical analyses demonstrated the positive effect of innovative rehabilitation is provided in the form of games for these patients. Even in many studies, applied games in different environments (virtual reality, and video-based games) have led to a great improvement in patients’ physical problems such as balance disorder, upper extremity spasticity, and limbs’ immobility and muscular weakness [3, 5, 11, 74–77]. Researchers in these studies have concluded that they can incorporate these games into the treatment plan and physiotherapy of poststroke patients and use them as alternative therapies to traditional methods because, in these experimental studies, significant improvements in all outcome measures were found after the intervention [76, 78]. However, in infrequent articles, no significant differences can be observed in all assessment scales (baseline and post-intervention assessments in the experimental and control groups) to evaluate game-oriented physiotherapies’ effectiveness. For this reason, in these studies, the researcher has concluded that the

| Journal/conference name                                               | Conference | Journal |
|---------------------------------------------------------------------|------------|---------|
| Clinical Rehabilitation                                             |            |         |
| Journal of Stroke and Cerebrovascular Diseases                      |            |         |
| Archives of Physical Medicine and Rehabilitation                   |            |         |
| Games for Health Journal: Research, development, and clinical applications |            |         |
| Disability and Rehabilitation                                       |            |         |
| Journal of NeuroEngineering and Rehabilitation                      |            |         |
| NeuroRehabilitation                                                  |            |         |
| IEEE Transactions on Neural Systems and Rehabilitation Engineering   |            |         |
| International Journal of Environmental Research and Public Health    |            |         |
| Journal of Medical and Biological Engineering                       |            |         |
| International Medical Journal of Experimental and Clinical Research  |            |         |
| American Journal of Physical Medicine and Rehabilitation            |            |         |
| Computers in Biology and Medicine                                   |            |         |
| Journal of Central Nervous System Disease                           |            |         |
| BioMed Research International                                       |            |         |
| Brain Impairment                                                    |            |         |
| European Journal of Physical and Rehabilitation Medicine             |            |         |
| User Modeling and User-Adapted Interaction                          |            |         |
| Frontiers in Psychology                                             |            |         |
| Iranian Rehabilitation Journal                                      |            |         |
| Journal of Physical Therapy Science                                 |            |         |
| Journal of Healthcare Engineering                                    |            |         |
| Annals of Physical and Rehabilitation Medicine                      |            |         |
| Journal of Motor Behavior                                            |            |         |
| American Academy of Physical Medicine and Rehabilitation            |            |         |
| Journal of Patient-Centered Research and Reviews                    |            |         |
| Restorative Neurology and Neuroscience                              |            |         |
| Stroke                                                              |            |         |
| Medical Science Monitor                                             |            |         |
| Neurorehabilitation and Neural Repair                                |            |         |
| Somatosensory and Motor Research                                    |            |         |
| The Journal of Physical Therapy Science                             |            |         |
| International Journal of Stroke                                     |            |         |
| Virtual Reality                                                     |            |         |
| International Journal of Neuroscience                               |            |         |
| In Proceedings of the 3rd 2015 Workshop on ICTs for improving Patients Rehabilitation Research Techniques | 2          |         |
| Proceedings of the IEEE International Conference on Advanced Materials for Science and Engineering | 1          |         |
| In 2019 International Conference on Robotics and Automation in Industry | 1          |         |
| 2019 Fifth International Conference on Advances in Biomedical Engineering (ICABME) | 1          |         |
| International Conference on Virtual Rehabilitation                 | 1          |         |
| 2017 International Conference on Applied System Innovation (ICASI)  | 1          |         |
| Total                                                               | 7          | 53      |
A game chosen to rehabilitate poststroke patients cannot be a useful tool to alternate with the traditional physical rehabilitation methods, and applying them can destroy the patient’s time and motivation.

The reason for the ineffectiveness of newly emerged games for motor rehabilitation of stroke patients can have different reasons as follows: insufficient session times and training duration to generate consistent improvements in all patients, the insufficient number of participants in the experimental studies (randomized trails would require at least 25 participants in each group) [38, 76], the high mean age of patients in both intervention and control groups (underlying disability of people due to their age), and excessive movement limitations of the patients recruited in the study [79, 80].

According to this study’s results, the most popular type of game for physical rehabilitation of poststroke patients was virtual reality games. Virtual reality-based games allow patients to interact with a virtual environment while performing rehabilitation exercises and simulating real

Table 4: Distributions of studies of publication years and country.

| Row labels          | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | Total |
|---------------------|------|------|------|------|------|------|------|------|-------|
| Australia           | 1    | 1    |      |      |      |      |      |      | 2     |
| Brazil*             | 1    | 2    | 1    |      | 2    | 2    | 1    | 9    |
| Canada              | 1    | 1    |      |      |      |      |      | 3    |
| China               |      | 1    |      |      |      |      |      | 1    |
| France              |      |      | 1    |      | 1    |      |      | 2    |
| Iran                |      |      |      |      |      |      | 1    | 1    |
| Israel              | 1    | 2    | 1    |      |      |      |      | 4    |
| Italy               |      | 1    |      |      |      |      |      | 2    |
| Lebanon             |      |      |      |      |      |      | 1    | 1    |
| Malaysia            |      |      |      |      |      |      |      | 1    |
| Netherlands         | 1    | 1    |      |      |      |      |      | 2    |
| New Zealand         |      |      |      |      |      |      |      | 1    |
| Pakistan            |      |      |      |      |      |      |      | 1    |
| Republic of Korea*  |      | 1    | 4    | 2    | 2    | 4    |      | 13   |
| Spain               |      |      |      |      |      |      |      | 1    |
| Sweden              |      |      |      |      |      |      |      | 1    |
| Taiwan*             | 1    | 1    |      |      | 1    | 2    | 1    | 6    |
| Turkey              |      |      |      |      |      |      |      | 1    |
| UK                  |      |      |      |      | 2    |      |      | 2    |
| USA                 |      |      |      |      |      | 1    | 1    | 1    |
| Grand total         | 1    | 10   | 9    | 11   | 3    | 9    | 13   | 4    |

*3 countries with the highest number of study prints.

Figure 3: The distribution of studies based on gamification types.
The Nintendo Wii Fit
The Xbox 360°
E-Link
RehabMaster™
Gardening digital game
PRehab
DRBG
IREX
MyoCI
Paddle Panic Mini Game
Jintronix system
Peggle
Kinect2Scratch
Recovery Rapids
Kinelabs
The BrightArm™
Micros®-developed RoboRaid
The RAPAEL Smart Glove™
MimPong
Canoe game
MoU-Rehab
Virtual reality game
Video game
Virtual reality game with kinect
Video game with kinect
Mixed reality game
Not mentioned

Figure 4: The distribution of studies based on type and name of games.

Mobilization of the limbs, 24
Balance training, 23
Walking, 4
Muscular strengthening, 8
Motor function, 5
Trunk postural stability, 2
Postural control, 2
Coordination, 1
Lower extremity, 1
Standing, 1

Figure 5: Physical rehabilitation therapies in reviewed studies.
functions. These games increase patients’ motivation to perform rehabilitation exercises and provide a pleasant environment for patients, which can lead to more repetition of rehabilitation exercises in these patients [77]. People get feedback while playing virtual reality games, and this factor encourages patients with disabilities to attend therapy sessions and use their remaining functional capacity to succeed in the game [81].

Results have shown that “the Nintendo Wii Fit” games are used more than other games to rehabilitate poststroke patients. Several factors can lead to the most use of this game. Among these factors, we can mention the price of these games, which are relatively inexpensive. These games are widely available to people, and studies have shown that providing an attractive environment increases patients’ enjoyment and more repetition of rehabilitation exercises [82–84]. Features of the Wii Fit game system lead to the stimulation of people’s interest in continuing to play and can be useful for improving motor function and balance control [61].

Studies showed that the most common use of games in the rehabilitation of stroke survivors was related to limb movement and balance training. In other words, the results of studies that were run to examine the effect of games on people after a stroke had shown these games were effective in improving the balance of people and strengthening the muscles of the limbs [85]. In a systematic review conducted by Corbetta, the effectiveness of virtual reality games has

| Row labels                          | Effectiveness |
|-------------------------------------|---------------|
| Effective                           | 41            |
| Before and after trial              | 13            |
| Nonrandomized clinical trials       | 2             |
| RCT                                 | 26            |
| Not effective                       | 3             |
| RCT                                 | 3             |
| Partly effective                    | 16            |
| Before and after trial              | 3             |
| RCT                                 | 13            |
| Total                               | 60            |

**Table 5:** Distribution of studies based on the type of study and effectiveness.

**Figure 6:** The distribution of studies based on the total time of rehabilitation duration.

**Figure 7:** The distribution of the reviewed studies based on effectiveness.
been investigated and concluded that managed games have the most significant impact on patient mobility [75]. According to the results of this survey and other studies that show the effect of the game on maintaining balance and movement, it is recommended to use these games in poststroke survivors.

This systematic review had several strengths and limitations. One of the strengths was the use of broad keywords to search in 4 crucial databases. Another strength of this survey was the inclusion of studies presented at conferences. The limitations were the exclusion of articles in non-English language and the time limit imposed on searching databases (from 2014 onwards). Another limitation of this review was the different scales used to measure people’s performance, and this factor made it difficult to compare the results of different surveys.

5. Conclusion

Game-based approaches lead to patients being able to smoothly perform their rehabilitation movement techniques without going to the treatment centers. These games can immerse the person in the environment by providing virtual or augmented reality capabilities and multiplying the effectiveness of the treatment. Therefore, the use of appropriate technology-based gaming solutions can improve patients’ treatment and minimize the waste of time and cost of providing traditional motor rehabilitation. Consequently, these game-based treatments are considered complementary to traditional ones and can reduce the workload of therapists and accelerate the rehabilitation process. Future research should focus on how task-specific game-oriented systems can improve function after stroke, and statistical studies can show this effect more.

Data Availability

All data generated or analyzed during this study are included within this article.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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