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Physiotherapy English Stream

The effect of gaming as an additional therapy for physical functioning of the arm in chronic stroke patients

A systematic review

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Preface

This paper is part of my graduation at Fontys University of Applied Sciences, department of Physiotherapy English Stream, Eindhoven. To be able to complete my Bachelor of Science, this systematic review was written. The subject, game-based rehabilitation in stroke, caught my eye and immediately interested me. I was very lucky to have been given one of the subjects that I was most interested in. I think it is very important to keep improving the rehabilitation for stroke patients and looking for new possibilities to do so. With techniques improving and becoming available to the public, why not integrate this into rehabilitation?

I would very much like to thank my supervisors Tjarco Koppenaal, who helped me starting up, and Chris Burtin, who took over his responsibilities when Tjarco had to step down as supervisor. Both helped me a lot with feedback on my thesis and with the questions I asked concerning my thesis.

Writing this thesis would not have been possible without the support and understanding of my family and friends, which was very much needed in this final period of my study. A thank you to them is in order, not only for this part of my study, but for the rest of these last four years as well.

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Abstract

Background: Stroke is the second leading cause of severe disability worldwide. Six months after stroke, 30-66% of patients still have no function in the paretic upper extremity, which decreases their functional independence. Physical therapy is focused on the wishes of the patient, thus usual care is very diverse and the arm might not always be trained. Movement therapy improves upper extremity function and game-based rehabilitation could be supportive to this therapy.

Method: The design of this research is a systematic review, conducted on the PubMed and PEDro databases. Studies had to consist of chronic stroke patients, tested and trained on upper extremity function with use of a home-based gaming console.

Results: Three articles were included in this systematic review. Two studies (a randomised controlled trial and a case series) investigated the effects of game-based therapy on stroke patients, and one (a cross-sectional cohort study) investigated the difference in overall movement between two consoles. All three articles show significant ($p < 0.05$) improvements or differences.

Conclusion: The results of this systematic review show the benefit of using game-based rehabilitation in chronic stroke patients. These results cannot be generalised, as not enough high quality studies were found. Nevertheless, it shows the promising results game-based therapy can achieve in stroke patients.

Keywords: Chronic stroke, gaming, upper extremity, function

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1. Introduction

Stroke has been defined by the World Health Organisation (WHO) as “rapidly developing signs of focal (or global) disturbance of cerebral function lasting more than 24 hours (unless interrupted by surgery or death), with no apparent nonvascular cause.”¹ It is among the major causes of death around the world. Above the age of 60, it is even the second leading cause of death. 15 million people suffer from a stroke each year worldwide, of which nearly six million die and about 5 million are permanently disabled. After dementia, stroke is the second leading cause of severe disability worldwide.²

Of stroke patients, 30 to 66% have no function in the paretic arm six months measured after stroke.³ Upper extremity function is needed in many activities of daily life, such as dressing and self-care. The functional independence of a patient decreases if someone is not able to use their arm according to its function.⁴ Kwakkel et al.⁵ have shown that in stroke, the recovery process of the upper extremity is slower than the recovery process in the lower extremity in stroke. Therefore it is very important to improve the upper extremity function of stroke patients, especially in chronic stroke patients.

Disability caused by stroke can be partially treated by the scope of physical therapy. Following the patterns of natural recovery, different phases can be defined to be used in therapy. Several guidelines (Royal College of Physicians, UK⁶; Royal Dutch Society for Physical Therapy (KNGF)⁷) acknowledge and use these phases, but named them differently. This review will be using the appellation of the KNGF. It has defined the following three consecutive phases⁷:

1. the *acute and sub-acute* phase:
 - a. the *acute phase*: the first week after the onset of a stroke;
 - b. the *sub-acute phase*: from the second to the fourth week after the onset of stroke;
2. the *post-acute phase*: from the first to the sixth month after the onset of stroke; and
3. the *chronic phase*: from six months after the onset of stroke.

Many rehabilitation programmes for stroke patients are terminated if the patient is not responding positively to treatment or is in the chronic phase. However, even after six months improvements can be made, if treatment is suited to the patient's needs.⁸ Often physical therapy is focussed on improving the daily activities of the patient, without training the actual function of the arm.⁹ The focus of physical therapy in stroke is tailored to the wishes of the patient and his/her family, not to curing the underlying cause, as it might be with other pathologies. Their wishes are adjusted into specific goals for a physical therapy treatment plan. As the goals can be different from patient to patient, the physical therapy interventions, and thus the 'usual care' for stroke, are very diverse. This may include exercise therapy or applications such as electrotherapy, or a combination of both.⁷ Since the treatment is focused on the wishes of the patient, it might happen that some functions are not trained. If the arm is not used because its functions are not trained, this will lead to even more limitations.⁹

It has been shown that stroke rehabilitation based on movement therapy improves upper extremity motor function.¹⁰ Technology can help providing this movement therapy. Technology-assisted rehabilitation supporting stroke patients with upper extremity dysfunction is shown to be effective on small-scale studies.¹¹ However, as the duration of patient's treatment in hospitalisation is shortening¹¹, it becomes more important to find home-based solution. If technology will be supporting treatment at home, it should also be affordable to patients. Nintendo Wii™, Sony EyeToy™ and Xbox Kinect™ are examples of consoles which are easily accessible and affordable. Those are options for supporting upper extremity rehabilitation, but nonetheless there is relatively little research done. More research and reviews are needed to investigate if home-based gaming-therapy with these consoles is effective.

The aim of this systematic review is to find the significance of using technology-assistance in rehabilitation of the physical functioning of the upper extremity in chronic stroke patients. It will also address the question what console would be best to use. This review could be used to decide on whether to use technology as part of the rehabilitation programme. What the effect is of gaming-therapy in addition to usual care in chronic stroke patients in terms of physical function of the upper extremity, will be discussed in this review.

2. Method

Search strategy

This literature review was based on articles found in the online databases of PubMed and PEDro. Articles had to consist of a randomized controlled trial (RCT), clinical controlled trial (CCT), cross-sectional or case study to be involved in this review. The keywords that were used to find relevant articles were: "Stroke", "Upper extremity" and "gaming", combined with Medical Subject Headings (Mesh) and Booleans (and, or, not). These were made into the following search string: ("Stroke"[Mesh]) AND ("Upper Extremity"[Mesh] OR "arm") AND ("gaming" OR "wii" OR "eyetoy" OR "kinect"). The language filter was set to English and Dutch. A simplified version was used for the PEDro database: "stroke" AND "upper extremity" AND "gaming".

Inclusion and exclusion criteria

Included were studies that performed research on chronic stroke patients, studies that performed research with available home-based gaming consoles, studies that performed research with outcome on functionality of the upper extremity, randomized control trials, clinical controlled trials, cohort studies and case studies, studies (translated) in Dutch or English and studies that are available in full-text (via database or elsewhere). All of these aspects had to be present in the study.

Excluded were studies that performed research with virtual reality, harness gaming or other unavailable consoles and systematic reviews.

Selection procedure

When the final search string was completed and put into PubMed, studies were selected on their relevance to this study. Those with a title or abstract that did not meet the in- and exclusion criteria were excluded. The articles that were left were fully read and checked if they met all the in- and exclusion criteria. Those articles were included in this review.

Data extraction

The data of included articles was extracted to give an overview of the studies involved in this review. Data extraction of the included articles is based on the following study details: author and year of publishing, type of study, number of patients, mean age of patients, gender, affected side, type and intensity of training, type of console, outcome measurement, results and statistics. To keep an overview, these details have been separated in four tables, one about study details, one about the study design and two about the outcome results. These can be found in the result section.

Quality assessment

The PEDro scale¹² was used to assess the methodological quality by scoring the method and result section of the found randomized controlled trials on the described items on the scale. The PEDro scale can be found in Appendix I. The classification of the methodological quality¹³ can be observed in table 1.

Table 1, classification of methodological quality

Pedro-score	Classification
9-10 points	Very good
6-8 points	Good
4-5 points	Reasonably good
0-3 points	Poor

Level of evidence

To assess the level of evidence of this review, the EBRO-platform classification¹⁴ is used, as stated in table 2.

Table 2, EBRO classifications

A1	Meta-analyses (systematic review) which includes at least two independent studies of quality level of A2 that show consistent results.
A2	Randomized double-blind controlled trials of good quality with sufficient consistency.
B	Randomized controlled trial of moderate quality, nonrandomized cohorts, patient-control group studies that involve intergroup comparison.
C	Non-comparable studies
D	Expert opinions

3. Results

21 articles have been found when the search was conducted, as stated in figure 1. Of these 21 articles, seven articles were excluded based on the title. Of the 14 articles left, 11 articles had to be excluded on the in- and exclusion criteria according to the abstracts. The final three articles were fully read and checked if those met all the in- and exclusion criteria. All three were included in this review. No extra articles were found in the PEDro database.

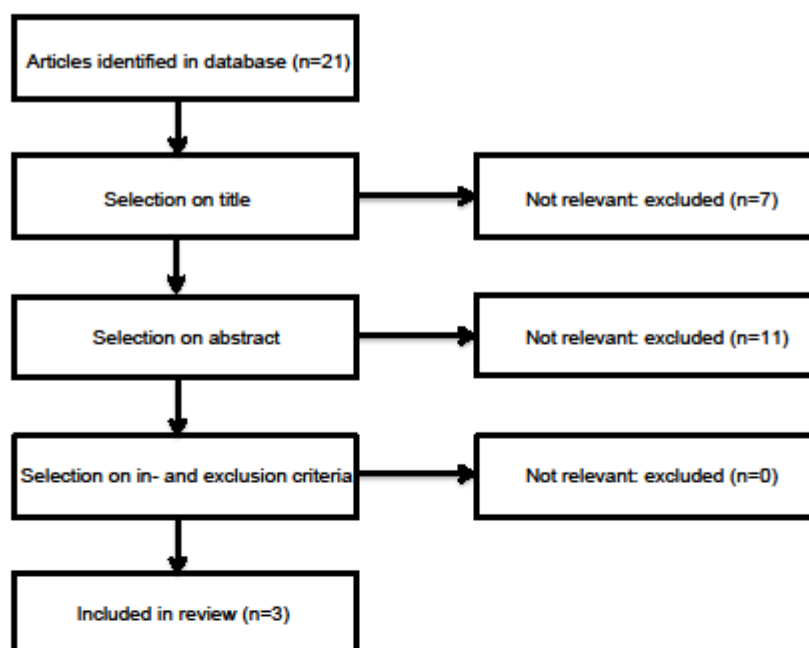


Figure 1, selection procedure

Sin et al.¹⁵ conducted a randomized controlled trial in 2013 on 40 participants. The purpose was to study the effects of using Xbox Kinect™ as additional therapy for stroke rehabilitation. A control group and intervention group were formed, each consisting of 20 patients. Of the control group, three patients did not take part in this study for unknown reasons. In the experimental group, two patients did not take part. This RCT scored six out of 10 points on the PEDro scale¹², making it of 'good' methodological quality (table 1).

Mouawad et al.¹⁶ performed a case series to investigate the efficacy of using the Nintendo Wii™ as rehabilitation for post-stroke patients. Seven patients were included in the trial, but only six patients were included in this systematic review. One patient was excluded from this review as she was in the post-acute phase after a stroke. The rest of the patients could be used in this study, as the results were shared per patient. The trial also included 5 healthy subjects, to make sure none of the improvements were due to skill acquisition. Those subjects had no other meaning in the trial. It is stated that these healthy subjects performed the same training and assessments, but none of these results are shared in the article.

Neil et al.¹⁷ conducted a cross-sectional cohort study on 20 patients in 2013, researching the difference between the Nintendo Wii™ and Sony PS2 EyeToy™. The study also compared the difference between healthy and stroke participants, having 10 participants per group. Table 3 shows the details per study.

Table 3, data extraction regarding study details

Author/ Year of publishing	Type of study	No. of patients	Mean age of patients, intervention / control [SD]	Gender, intervention / control	Affected side, intervention / control
Sin et al. ¹⁵ , 2013	Randomized Controlled Trial	40	71.78 [9.42] / 75.59 [5.55]	8 female, 10 male / 7 female, 10 male	11R, 7L / 12R, 5L
Mouawad et al. ¹⁶ , 2011	Case series	7	65.3 [14.6]	1 female, 5 male	4R, 2L / n/a*
Neil et al. ¹⁷ , 2013	Cross- sectional cohort study	20	61.0 [7.3] / 54.4 [12.6]	6 female, 4 male / 4 female, 6 male	2 R, 8L / n/a*
Legenda: - R: right side affected - L: left side affected - *: affected side is not applicable, as control group existed of healthy subjects or no control group was used					

In the study by Sin et al.¹⁵, the experimental group received 30 minutes of occupational therapy, followed by 30 minutes of additional therapy involving Xbox Kinect™. The control group only received occupational therapy. Treatment sessions took place three times a week, for a total of six weeks. For the interventional training sessions, the screen was set up in an independent environment, so no external factors were present. The participants were distanced from the screen approximately 1.5-2 meters, either sitting or standing. The occupational therapy sessions included active and passive ROM exercises, muscle strengthening and therapeutic stretching of the shoulder, elbow, wrist and fingers. Training of activities of daily living were chosen by the therapist, depending on the needs and wishes of the participant. All participants were tested on the Fugl-Meyer Assessment (FMA)¹⁸ and the Box and Block Test (BBT)¹⁹.

The participants in the study by Mouawad et al.¹⁶ played the Wii-games on 10 consecutive weekdays for one hour with a supervising therapist. This was extended by 30 minutes a day of home-based Wii-playing. A console was installed at the patient's home on day 2. This was progressively increased to 180 minutes a day. The different games that could be played on the Nintendo Wii™ were tennis, golf, boxing and baseball. Patients played the games according to the rules. The amount of practice was

measured by time playing the games, not the amount of games played. The patients were tested on the Fugl-Meyer Assessment (FMA)¹⁸ and the Wolf Motor Function Test (WMFT)²⁰ before and after the trial.

Neil et al.¹⁷ tested the participants on the overall upper extremity movement and intensity of the Nintendo Wii™ and Sony PS2 EyeToy™. This was measured by the use of accelerometers, which the participants wore on a watchband on both wrists during all games. The participants played two games on each console, with a duration of 10 minutes per game, including a warm-up of three minutes. This makes the total duration of the study intervention 40 minutes. To ensure safety for the stroke subjects and keep the consistency between the two groups, all subjects performed the games seated in a chair without armrests. The projection screen was six feet away from the chair at all times.

A systematic overview of the study designs can be observed in table 4.

Table 4, data extraction regarding study design

Author	Type of training	Intensity and duration of training	Type of console	Outcome measurement
Sin et al. ¹⁵	Experimental group: 30 min usual care, 30 min intervention Control group: occupational therapy alone, 30 min	3 times a week, for a total of 6 weeks	Xbox Kinect™	Fugl-Meyer Assessment (FMA) ¹⁸ , Box and Block Test (BBT) ¹⁹
Mouawad et al. ¹⁶	Nintendo Wii™ games, no usual care	60 minutes of supervised training on 10 weekdays, home-based practice 30-180 minutes a day. Total of 14 days.	Nintendo Wii™	Fugl-Meyer Assessment (FMA) ¹⁸ , Wolf Motor Function Test (WMFT) ²⁰
Neil et al. ¹⁷	2 games on each console, no usual care	10 minutes per game, total of 40 minutes	Nintendo Wii™ and Sony PS2 EyeToy™	Upper extremity movement with accelerometers

Sin et al.¹⁵ showed a mean increase on the FMA of 10.89 points for the experimental group and 6.53 for the control group. This means a 41.79% improvement for the game-based therapy, which is a statistically significant improvement ($p=0.041$) compared to a 20.22% improvement for the control group. The BBT for the experimental group showed a mean 9.56 increase, in contrast to a 2.71 increase for the control group. This comes to an 86.05% improvement for the experimental group, which is statistically significant ($p=0.043$) compared to the control group, which improved with 19.94%.

Mouawad et al.¹⁶ showed a mean increase of 5.5 points on the FMA and a mean 77.89 second decrease of seconds on the WMFT. This means an improvement of 13% for the FMA and an improvement of 15% for the WMFT. These numbers are calculated by the author of this review, as the original study included the post-acute patient, which is excluded in this review. Therefore, the p-value given in the study (FMA $p=0.013$, WMFT mean time $p<0.001$, WMFT mean summed time $p=0.027$, WMFT weight-lifting $p=0.006$), cannot be applied to these numbers. The BBT results were not given per patient, thus could not be included in this review.

An overview of these results is shown in table 5.

Table 5, data extraction on outcome results

Author	FMA (mean change in score [SD or range])	WMFT (mean change in seconds[range])	BBT (mean change in number [SD])	P-value (intervention versus control)
Sin et al. ¹⁵	Experimental: 10.89 [6.31] Control: 6.53 [2.60]	n/a	Experimental: 9.56 [4.61] Control: 2.71 [3.12]	FMA: $p<0.05$ BBT: $p<0.05$
Mouawad et al. ¹⁶	5.5 [1 ; 9]	77.98 [-8.5 ; 266.8]	n/a	n/a

The overall upper extremity movement in the study by Neil et al.¹⁷ was defined as ‘the sum of the total activity counts of the right and the left hands for both of the two games (7 minutes each)’. This was then measured for both consoles. The overall upper extremity intensity was calculated as a mean score of the intensity of movement of both hands while playing both games, divided by 2. The outcomes of this can be viewed in table 6. It shows that the Sony PS2 EyeToy™ elicits more movement compared to the Nintendo Wii™ and has more intensity. These outcomes were for both the stroke and the healthy group. All outcomes were statistically significant.

Table 6, data extraction from Neil et al.¹⁷

Game console	Overall upper extremity movement (mean [SD])	Intensity (mean [SD])
Sony PS2 EyeToy™	Stroke: 13 916 [8 045] Healthy: 23 743 [11 446]	Stroke: 2.64 [0.49] Healthy: 3.11 [0.24]
Nintendo Wii™	Stroke: 8 924 [6916] Healthy: 15 745 [7 442]	Stroke: 2.18 [0.42] Healthy: 2.81 [0.3]
P-value between consoles	0.004	0.001
P-value between groups	0.02	0.002
Legenda: - SD: standard deviation		

4. Discussion

The aim of this study was to investigate whether gaming as an additional therapy to usual care would be beneficial for patients in the chronic phase after a stroke. The results of the articles used in this review all show a significant improvement and suggest that gaming is beneficial for stroke patients. One of the articles was a good quality RCT (Sin et al.¹⁵), which indicates that the level of evidence of this conclusion is A2, according to the levels of evidence of EBRO¹⁴ (mentioned in the method section, table 2). However, this systematic review cannot confirm nor deny this hypothesis, as not enough high quality studies were found. This means that the results found in this review cannot be generalised and suggest further research.

Only the RCT by Sin et al.¹⁵ answered the main question of this review, as the game-based therapy was added to usual care. The experimental and control group received the same usual care, but in addition the experimental group received gaming therapy. The experimental group improved significantly in both tests compared to the control group (FMA¹⁸ and BBT¹⁹, $p=0.041$ and $p=0.043$ respectively). However, the experimental group received the gaming therapy additionally to usual care. The control group only received the usual care. The observed improvements might be due to the increase in therapy time. By adding gaming therapy at the facility and at home to usual care, the experimental group had more therapy time compared to the control group. It would be beneficial to investigate whether this increase is indeed due to the positive effect of the game-based therapy or solely due to the increased therapy time.

The study by Mouawad et al.¹⁶ could not be fully used in this review, as previously stated. As the baseline characteristics and outcome results were shared per patient, this study could still be used, excluding the patient who was in the post-acute phase. The study did not have a control group and the participants did not receive usual care besides the Wii-based training. Therefore, this does not fully answer the question of this review, but shows the effects of Wii-based rehabilitation in stroke patients nonetheless.

The patients did improve on both tests (FMA¹⁸ and WMFT²⁰), but a p-value could not be given in this review due to the post-acute patient that was taken out. However, the p-value including the post-acute patient was for the FMA $p=0.013$, and on all aspects of the WMFT statistically significant (mean time $p<0.001$, mean summed time $p=0.027$, weight-lifting $p=0.006$), except for the hand grip aspect, which did not improve. Even though this includes the post-acute patient, these numbers conclude that Wii-based therapy is effective.

It is interesting to see the difference in improvements between the two studies. If the intervention group of Mouawad et al.¹⁶ is compared to the control group of Sin et al.¹⁵, it can be observed that the control group improved more than the intervention of the other study. It is known that the study by Sin et al.¹⁵ has a higher methodological quality, which makes the results by Mouawad et al.¹⁶ questionable.

A difference between the studies by Sin et al.¹⁵ and Mouawad et al.¹⁶ was the console that was used. Sin et al.¹⁵ used the Xbox Kinect™, whereas Mouawad et al.¹⁶ used the Nintendo Wii™. The small differences in games aside, an important difference between the consoles is the set-up. With the Xbox Kinect™, a calibrated camera follows the movement of the participant and records it, where the Nintendo Wii™ has a handheld remote, which is recorded by a synchronised system. Mouawad et al.¹⁶ mentioned to have bandaged the handheld remote if patients had a weak handgrip, but it can still make a difference whether to hold a remote or to move freely without holding anything. The problem that might occur during therapy sessions with the camera-based consoles, is that the therapist standing beside the patient might be recognised as well. Therefore the camera needs to be calibrated again, which would interrupt the training session. However, home-based therapy would not face this problem.

The study by Neil et al.¹⁷ tried to shed some light on that problem. The study investigated the difference between the Sony Eyetoy™ and the Nintendo Wii™ in a cross-sectional study. The Sony Eyetoy™ is similar to the Xbox Kinect™, as it has no handheld remote and uses a calibrated camera to observe the participant's movement. Even though the trial did not use the same outcome results as Sin et al.¹⁵ and Mouawad et al.¹⁶, it observed the upper extremity movement using wrist accelerometers during the games. It showed that Sony Eyetoy™ provokes more movement than the Nintendo Wii™ in both the stroke and the healthy group. It can be observed that the healthy subjects elicited more movement than the stroke subjects. This is not unexpected, as it is known that stroke patients have a diminished upper extremity function.³

Compared to the results by Rand et al.²¹, the participants of Neil et al.¹⁷ moved the upper extremity in 40 minutes approximately half of the amount a regular stroke patient moves the upper extremity in a whole day. Research has shown that chronic stroke patients do not exercise enough which can lead to secondary conditions.²² This elaborates the importance of home-based gaming therapy, especially once discharged from the rehabilitation centre. The game consoles used in this study are commercially available and can be used by the individual without supervision. The games are not specified for stroke patients, but even the basic games for these consoles show increasing effects on the upper extremity function.

One of the issues that might arise is the question whether the games translate to reality. The main reason for rehabilitation is to gain functionality in the upper extremity, and this should translate in the chosen form of therapy. The games can be chosen according to the patient in question, but in this study the relation between games and reality is made by functional test measures. It is difficult to find a way to measure the functionality of the upper extremity and whether it improves over time. The Fugl-Meyer Assessment (FMA)¹⁸, the Box Block Test (BBT)¹⁹ and the Wolf Motor Function Test (WMFT)²⁰ are the three measures used in the studies included in this review to assess the function of the arm. These ask for specific movements of the upper extremity, which is as close as we can get to re-enact the function of it.

The Fugl-Meyer Assessment¹⁸ used by Sin et al.¹⁵ and Mouawad et al.¹⁶ is a modified version of the full scale, which also assesses the lower extremity and the sensory function, and tests purely the upper extremity motor function. The upper extremity function is scored, with a maximum of 66 points in total, on different movements. How many points a participant scores per aspect, is stated in the test with a fixed amount of points. The Box and Block test¹⁹ is performed by moving 2.5 cm blocks from one box to another, as many as possible in 60 seconds, one at a time. It is scored by the number of blocks moved. The Wolf Motor Function Test²⁰ is a list of 15 tasks to be performed in 120 seconds. These tasks are based on their functionality in everyday life, such as picking up a paperclip or turning a key. All tests showed to be of good quality and reliability for stroke patients.²³⁻²⁵

The problem with the FMA is mostly the ceiling-effect. As the FMA tests the participant on different movements and is scored with points, there is a maximum of points to be reached. It can be expected that a stroke patient will not reach the maximum points, otherwise there might not even be a functional problem, but it still limits the test. The WMFT and the BBT are in that way better tests, as they test the time that it takes a participant to perform a certain task. There is no ceiling-effect in these tests and it is purely the time aspect that can improve.

Research has shown the positive effects of virtual reality training on chronic stroke patients with different consoles that are not publically available.^{26, 27} The study by Cameirão et al.²⁷ tested three different aspects of virtual reality training, vision-based tracking, haptics, and a passive exoskeleton, and found that subjects improved significantly on all three. An important conclusion from this study is that even vision-based tracking, which is used in most commercially available gaming system, is also effective to use in the rehabilitation of stroke patients.

Others have investigated the effects of virtual reality on earlier stroke phases with the same consoles used in this review.^{28, 29} The patients in the sub- to post-acute phase all showed significant improvements, however sometimes these improvements were small. One of these studies found that the participants experienced the Wii-therapy as enjoyable and comparable to usual care, if not more.²⁸ Another study conducted research on acute patients as well, but used a non-commercially available console.³⁰ The between-group comparison showed that the intervention group significantly improved. Saposnik et al.³¹ investigated not only the effectiveness, but also the safety of using the Nintendo Wii™ on patients after a stroke. The study compared the use of Wii-based therapy and recreational therapy on acute to post-acute stroke survivors. There was no significant difference regarding the safety of the two interventions, meaning game-based therapy is just as safe as 'regular' recreational therapy. These results suggest that using a game-based therapy is more effective than using recreational therapy, and is just as safe. Therefore, it could be beneficial to use gaming-bases therapy.

Even though these studies²⁶⁻³¹ included patients in different stroke phases or different gaming consoles, they show significant results. It remains questionable whether these results are because of the game-factor or the time-factor. As Saposnik et al.³¹ showed, their experimental group improved more than their control group, while they experienced the same length of therapy. This would exclude the time-factor as an improvement and shows that the game-factor is what has improved. It is

important more high quality research is done to investigate what aspect improves the functionality of the arm in stroke patients.

The positive factor of using a game-based therapy is the possibility to use it at home. With the current trend of shortening the hospitalised rehabilitation period¹¹, it becomes more and more important what patients can do for their own rehabilitation at home. The commercially available gaming consoles can provide a solution for this. Saposnik et al.³¹ showed that a gaming console is just as effective as recreational therapy, and is easier to use as it only requires the participant and can be done without a supervising therapist.

These findings all implicate that game-based rehabilitation is beneficial for stroke patients. The consoles are at relatively low cost, easy to use without supervision and available to the public. This also may suggest it is helpful for those who live in rural areas and do not live close to a rehabilitation centre.¹⁶

There are limitations to this research, which need to be addressed. The amount of articles found that corresponded with the in- and exclusion criteria of this research was very limited. Not only was the amount limited, the quality was also relatively low. Because of the small group of studies and patients, the result of this review should not be generalised. More high quality RCTs should be conducted to get a solid answer to the research question.

This review was carried out by one author. This has implications for the in- and exclusion criteria, the data extraction and assessment of methodological quality of the articles. It is common to have more than one author writing a systematic review, to exclude any form of possible bias.

Notwithstanding these limitations, this systematic review suggests that a game-based rehabilitation has sufficient evidence to be effective for stroke survivors and shows the clinical relevance. It can easily be added as home exercise and that way won't decrease the face-to-face time with a therapist during sessions. It is a safe and easy way to increase movement at home for a stroke patient.

5. Conclusion

This systematic review has investigated the use of game-based rehabilitation for chronic stroke patients. The results of this review show significant improvements and the benefit to use game-based rehabilitation for chronic stroke patients. However, this systematic review cannot confirm nor deny the research hypothesis, as not enough high quality studies were found. Therefore, the results found in this research should not be generalised.

More information is known on the effects of non-commercially available consoles or patients in an earlier stage of the effects following a stroke. Those studies show promising results for the rehabilitation of stroke survivors using game-based therapy and suggest it is worth using. More specific research needs to be done on the effect of commercially available consoles on chronic stroke patients.

6. Literature

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Appendix – PEDro scale

PEDro scale

1. eligibility criteria were specified	no ☐ yes ☐ where:
2. subjects were randomly allocated to groups (in a crossover study, subjects were randomly allocated an order in which treatments were received)	no ☐ yes ☐ where:
3. allocation was concealed	no ☐ yes ☐ where:
4. the groups were similar at baseline regarding the most important prognostic indicators	no ☐ yes ☐ where:
5. there was blinding of all subjects	no ☐ yes ☐ where:
6. there was blinding of all therapists who administered the therapy	no ☐ yes ☐ where:
7. there was blinding of all assessors who measured at least one key outcome	no ☐ yes ☐ where:
8. measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups	no ☐ yes ☐ where:
9. all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome was analysed by “intention to treat”	no ☐ yes ☐ where:
10. the results of between-group statistical comparisons are reported for at least one key outcome	no ☐ yes ☐ where:
11. the study provides both point measures and measures of variability for at least one key outcome	no ☐ yes ☐ where:

The PEDro scale is based on the Delphi list developed by Verhagen and colleagues at the Department of Epidemiology, University of Maastricht (*Verhagen AP et al (1998). The Delphi list: a criteria list for quality assessment of randomised clinical trials for conducting systematic reviews developed by Delphi consensus. Journal of Clinical Epidemiology, 51(12):1235-41*). The list is based on "expert consensus" not, for the most part, on empirical data. Two additional items not on the Delphi list (PEDro scale items 8 and 10) have been included in the PEDro scale. As more empirical data comes to hand it may become possible to "weight" scale items so that the PEDro score reflects the importance of individual scale items.

The purpose of the PEDro scale is to help the users of the PEDro database rapidly identify which of the known or suspected randomised clinical trials (ie RCTs or CCTs) archived on the PEDro database are likely to be internally valid (criteria 2-9), and could have sufficient statistical information to make their results interpretable (criteria 10-11). An additional criterion (criterion 1) that relates to the external validity (or “generalisability” or “applicability” of the trial) has been retained so that the Delphi list is complete, but this criterion will not be used to calculate the PEDro score reported on the PEDro web site.

The PEDro scale should not be used as a measure of the “validity” of a study’s conclusions. In particular, we caution users of the PEDro scale that studies which show significant treatment effects and which score highly on the PEDro scale do not necessarily provide evidence that the treatment is clinically useful. Additional considerations include whether the treatment effect was big enough to be clinically worthwhile, whether the positive effects of the treatment outweigh its negative effects, and the cost-effectiveness of the treatment. The scale should not be used to compare the "quality" of trials performed in different areas of therapy, primarily because it is not possible to satisfy all scale items in some areas of physiotherapy practice.

Last amended June 21st, 1999

Notes on administration of the PEDro scale:

All criteria	Points are only awarded when a criterion is clearly satisfied. If on a literal reading of the trial report it is possible that a criterion was not satisfied, a point should not be awarded for that criterion.
Criterion 1	This criterion is satisfied if the report describes the source of subjects and a list of criteria used to determine who was eligible to participate in the study.
Criterion 2	A study is considered to have used random allocation if the report states that allocation was random. The precise method of randomisation need not be specified. Procedures such as coin-tossing and dice-rolling should be considered random. Quasi-randomisation allocation procedures such as allocation by hospital record number or birth date, or alternation, do not satisfy this criterion.
Criterion 3	<i>Concealed allocation</i> means that the person who determined if a subject was eligible for inclusion in the trial was unaware, when this decision was made, of which group the subject would be allocated to. A point is awarded for this criteria, even if it is not stated that allocation was concealed, when the report states that allocation was by sealed opaque envelopes or that allocation involved contacting the holder of the allocation schedule who was “off-site”.
Criterion 4	At a minimum, in studies of therapeutic interventions, the report must describe at least one measure of the severity of the condition being treated and at least one (different) key outcome measure at baseline. The rater must be satisfied that the groups’ outcomes would not be expected to differ, on the basis of baseline differences in prognostic variables alone, by a clinically significant amount. This criterion is satisfied even if only baseline data of study completers are presented.
Criteria 4, 7-11	<i>Key outcomes</i> are those outcomes which provide the primary measure of the effectiveness (or lack of effectiveness) of the therapy. In most studies, more than one variable is used as an outcome measure.
Criterion 5-7	<i>Blinding</i> means the person in question (subject, therapist or assessor) did not know which group the subject had been allocated to. In addition, subjects and therapists are only considered to be “blind” if it could be expected that they would have been unable to distinguish between the treatments applied to different groups. In trials in which key outcomes are self-reported (eg, visual analogue scale, pain diary), the assessor is considered to be blind if the subject was blind.
Criterion 8	This criterion is only satisfied if the report explicitly states <i>both</i> the number of subjects initially allocated to groups <i>and</i> the number of subjects from whom key outcome measures were obtained. In trials in which outcomes are measured at several points in time, a key outcome must have been measured in more than 85% of subjects at one of those points in time.
Criterion 9	An <i>intention to treat</i> analysis means that, where subjects did not receive treatment (or the control condition) as allocated, and where measures of outcomes were available, the analysis was performed as if subjects received the treatment (or control condition) they were allocated to. This criterion is satisfied, even if there is no mention of analysis by intention to treat, if the report explicitly states that all subjects received treatment or control conditions as allocated.
Criterion 10	A <i>between-group</i> statistical comparison involves statistical comparison of one group with another. Depending on the design of the study, this may involve comparison of two or more treatments, or comparison of treatment with a control condition. The analysis may be a simple comparison of outcomes measured after the treatment was administered, or a comparison of the change in one group with the change in another (when a factorial analysis of variance has been used to analyse the data, the latter is often reported as a group × time interaction). The comparison may be in the form hypothesis testing (which provides a “p” value, describing the probability that the groups differed only by chance) or in the form of an estimate (for example, the mean or median difference, or a difference in proportions, or number needed to treat, or a relative risk or hazard ratio) and its confidence interval.
Criterion 11	A <i>point measure</i> is a measure of the size of the treatment effect. The treatment effect may be described as a difference in group outcomes, or as the outcome in (each of) all groups. <i>Measures of variability</i> include standard deviations, standard errors, confidence intervals, interquartile ranges (or other quantile ranges), and ranges. Point measures and/or measures of variability may be provided graphically (for example, SDs may be given as error bars in a Figure) as long as it is clear what is being graphed (for example, as long as it is clear whether error bars represent SDs or SEs). Where outcomes are categorical, this criterion is considered to have been met if the number of subjects in each category is given for each group.