Telerehabilitation in upper limb recovery after stroke: a systematic review

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Delivery date: Jun 2016
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Abbreviations index

- VR: Virtual Reality.
- THRB: Teletehabilitation
- CPT: Conventional physical therapy
- UL: Upper limb
- LL: Lower Limb
- NW: Nintendo Wii™
- RCT: Randomised Controlled Trial
- IG: Intervention Group
- CG: Control Group
- AG: Active Group
- DLA: Daily life activities
- FM: Fugl-Meyer UE.
- WMT: Wolf Motor Test.
- MAS: Modified Asworth Scale.
- VAS: Visual analogue Pain Scale.
- MAL-AS: Motor Activity Log Quality of Movement.
- MT: Mirror therapy
- ROM: Range of Movement
1. Abstract

**Background:** The use of telerehabilitation (TRHB) and virtual reality (VR) devices like Nintendo Wii™ (NW), is becoming a more viable treatment for stroke recovery as communication technologies improves, however, is currently unclear how effective is this model compared to conventional physical therapy (CPT) with face to face rehabilitation.

**Goals:** Reviewing the scientific literature and results about the feasibility of using a telerehabilitation (TRHB) device, virtual reality (VR) and Nintendo Wii™ (NW) as an adjunct to conventional stroke rehabilitation in order to determine if is preferable to apply telerehabilitation at clinical practice.

**Methodology and materials:** Pubmed, The Cochrane Library and PEDro were the databases of choice for the search of randomized controlled trials until 7th April of 2016 using “Telerehabilitation”, “Virtual reality”, “Wii”, “Upper Limb” and “Stroke” as key words. 7 scientific articles have been included in this systematic review.

**Results:** In general, patients have improved after treatment but non-significant differences were found after de intervention. All participants had better Fulg-Meyer scale outcomes in upper limb motor functionality.

**Discussion** We behold promising clinical application but it is necessary to continue with further studies in this field.

**Keywords:** “Telerehabilitation”, ”Virtual reality”, “Wii”, “stroke” and “upper limb”
2. Background

The meSH definition of stroke involves a group of pathological conditions characterized by sudden, non-convulsive loss of neurological function due to brain ischemia or intracranial hemorrhages. It is classified by the type of tissue necrosis, such as the anatomic location, vasculature involved, etiology, age of the affected individual, and hemorrhagic vs. non-hemorrhagic nature [1].

Stroke illness is one of the most serious neurological disorders rated as the third cause of death worldwide [2] the mainly cause of incapability in adults with 65% of supervivence [3]. Early rehabilitation after stroke is really important to overcome the disabilities caused by the brain injury and provide the best quality life to the patient.

The stroke symptoms depends on extension, function and severity of the injured brains area. Among the survivors to a first stroke onset, 73% to 88% result in acute hemiparesis [4]. Paresis of the arm post stroke remains an important clinical problem with fewer than 50% of patients recovering some degree of movement or function [5]. Patients with hemiplegia after stroke generally show abnormal motor patterns in terms of muscle tone, primitive reflexes, flexor synergy, extensor synergy, co-ordination, associated reactions and movements, which greatly reduce motor function of the affected limb because of musculoskeletal disorders and sensory disturbances [6]. As result, physical activities related to the daily life activities are adversely affected [7].

The traditional rehabilitation approaches based on “one to one” physiotherapist-patient interaction are the most widespread for the treatment of the upper extremity in clinical settings and its effectiveness was demonstrated by several studies [8,10].
However, most of these interventions are labor intensive, requiring a “hands on” approach by therapists for several weeks [11], and concentrate on facilitating the functional abilities of affected side. Also, if severe activity restrictions occur on affected side, patients are reluctant to provide physical access, and therapeutic effects are diminished [12]. Furthermore, these interventions make patients use affected limbs less during the daily life activities and could adversely affect motor function recovery in the long term [13]. Luckily, recent evidence is enlightening the possibility that innovative approaches, based on the augmentation of specific kinematic feedbacks, could enrich the rehabilitation environment, possibly leading to a significant improvement of the motor function [14,18].

In the last decade, physiotherapy treatment of stroke has included the use of technological devices develop to rise the effectiveness of recovery [19], such as telerehabilitation which is considered an emerging technique currently applied in stroke rehabilitation program, primarily for upper limb recovery [20], as well as in other pathologies such as multiple sclerosis, cerebral palsy and traumatic brain injuries [21] which let us to think in the major potentiality this new technique can have in the future for physical therapy development.

According to the 2016 Mesh term, Telerehabilitation is defined as “the delivery of therapeutic rehabilitation at a distance or offsite using telecommunication technologies” [22].

There were no meSH terms related to telerehabilitation nor virtual reality (VR) until 2008, due to its recent application as a subfield of telemedicine. The first article about the topic is dated in 1998 [20].

Telerehabilitation includes several instruments constantly changing through evolution of technologies. This therapy can be used at home, with non-expensive tools such as:
Ergonomic sensors, adapted to the body part we want to recover, capable of measure and sent information about the realized exercises. A console (computer, a laptop, tablet etc...) with software to guide the exercises (there is a visual biofeedback in the screen which emulates the movements the patient have to recreate). A central platform that records measurements and allows the therapist to monitor the patient’s improvement, adjust exercises and reassess the recovery. The system must have suitable exercises for each pathology and a physiotherapist who coordinate it [22].

Since ten years ago, virtual reality (VR) technologies first began to be studied and developed as potential tools for assessment and treatment in rehabilitation. The Nintendo Wii (NW) is a simple and affordable VR alternative therapy that is being used in stroke and rehabilitation units worldwide [23]. This device became the focus of much attention due to its low cost, ability to be used independently by the patient, for individual training and suitability for use in the home [24].

As an emerging technique, there is not enough evidence to support the use of telerehabilitation on clinical practice yet. Nowadays, scientific literature is more focused on technological development than on clinical trials to evaluate the effectiveness [21].

The goal of this review is to analyze whether it is really effective and efficient the use of telerehabilitation to the detriment of more conventional therapies in patients with stroke, and mainly focus in upper limb recovery.

We aim to provide more evidence to the topic with the only purpose that to be able to apply telerehabilitation, in form of virtual reality or Wii console, confidently and judiciously in clinical practice for stroke patients.
3. Methods and materials

A scientific literature research of randomised controlled trials (RCT) published until April of 2016 was made. Focusing on telerehabilitation, virtual reality or Nintendo Wii on upper limb recovery after stroke, the following criteria were established.

I. Inclusion criteria

All scientific articles included in this systematic review should be governed by:

**Design**

- All scientific articles are from Pubmed, PEDro and Cochrane databases.
- All selected scientific papers contain information about telerehabilitation, virtual reality and/or Wii consoles, and its effectiveness in upper limb recovery after stroke disease.
- To narrow the search options, we have included only titles that appear in more than one databases, only the most relevant ones.
- We only included randomized controlled clinical trial, with positive answer to the CASPe evaluation “elimination questions” with at least 5/11 punctuation in CASPe clinical trial template. [FIG. 3 CASPe Evaluation]
- Scientific articles were chosen with an equal or superior punctuation of 5/10 PEDro score.

**Intervention**

- Scientific papers related to stroke recovery, concretely in upper arm rehabilitation using technological devices.
• Studies comparing Telerehabilitation, Virtual Reality or Nintendo Wii with conventional physical therapy.
• Programmes must have lasted longer than one session.

Participants

• All patients had received a stroke diagnosis and we included all types of stroke, at all levels of severity and in all stages post-stroke (acute, subacute and chronic).
• They all suffer malfunction of the upper limb in daily life activities and have been evaluated with Fugl-Meyer Assessment upper-limb (FM).
• All patients understood the exercises and performed what the physiotherapists asked for.
• A minimum of 10 participants per clinical trial, all adults with no age limit.
• During the study they did not participate in any other rehabilitation programme.

Measures

They must follow an assessment with standard tests (Wolf Motor Function Test, Motor Activity Log, Action Research Arm Test, The Stroke Impact Scale, Fugl-Meyer Assessment of Motor Recovery…) in all the phases of the treatment, at the beginning, intermediate and final phases in so as to evaluate the effectiveness of the therapy.

Search dates

Due to its recent therapy application we made the date criteria as wide as possible without limit until 7th April of 2016.

Language

English and Spanish languages were chosen.
II. Exclusion criteria

- We did not include systematic reviews neither clinical guides or similar in order to have the original information and not get any influences in our search process.
- Randomised controlled trials related to different neurological pathologies, with different treatment goals than upper arm functional recovery.
- Studies where there was no clear methodology of evaluation or the participant’s selection process.

III. Search Strategy

An electronic research was made between December 2015 and 7th April of 2016 in the PEDro, Pubmed and The Cochrane Library databases. We also contacted the authors for those unachievable publications.

After a previous research of several systematic reviews about telerehabilitation to establish some parameters, the line of work was limited and defined to begin with the actual research process.

A) Pubmed

In the initial research, to get an idea of the amount of publishing, we found 392 results with the key word “Telerehabilitation” in Pubmed. 90 results when we added “stroke” and 12 when also added “upper limb”. We select only randomized clinical trials with a final amount of 1 title about the topic.
As we described in the introduction, virtual reality and Wii are the most used techniques from stroke telerehabilitation so we thought it was necessary to repeat the same process with those new keywords, to emphasis in those techniques.

In Pubmed we found 5824 results when writing “Virtual Reality”, a total of 385 results when we add “stroke”, and 85 results adding also “upper limb” and finally 11 randomised controlled trials, one of them is in the previous search.

Following the same process for “Wii” we started with 582 results, they decreased to 60 results by adding “stroke”, and till 19 results when adding “upper limb” and with 3 remaining randomised controlled clinical trials, which 2 of them also present in the previous research.

To sum up, in Pubmed we finished with a total amount of **12 randomised controlled clinical trials**. [FIG.1. Search strategy in pubmed database].

**B) PEDro**

In PEDro database, using the same search strategy as in Pubmed: “telerehabilitation and stroke and upper limb” we found 2 results with **only 1 clinical trial**.

With “Virtual reality and stroke and upper limb” we ended with 18 results and **only 5** of them where clinical trials with more than 5/10 in PEDro score.

By writing “Wii and stroke and upper limb” we got 8 results with **only 3 clinical trials** within PEDro score.

Several PEDro results were also included in the Pubmed selected literature. [FIG.2. Search strategy in PEDro database.]
C) Cochrane

In the Cochrane Library, in the clinical trials section, after tipping “telerehabilitation and stroke and upper limb” we got 3 clinical trials. 26 clinical trials using “Virtual reality” instead of “telerehabilitation” and 11 clinical trials for “Wii” term. The most relevant studies were also present in the previous databases.

D) Other options

There were also vainly performed researches in others databases such as Embase-Elsevier and Clinical trials, with unclear outcomes, thus no paper were included.

In the manual research, from other studies bibliography, we included 2 more scientific papers about the topic.

Finally, we selected those articles more cited in all databases. After reading the majority of the abstracts, and apply our inclusion criteria we ended with a total amount of 7 publications suitable to complete our systematic review.

4. Results

I. Methodology evaluation

To assess the methodology quality of the selected papers we used CASPe clinical trial template [25] to assign internal and external critical reading validity. This Spanish scale
uses 11 criteria/questions [FIG.3. CASPe Evaluation]. We only included those articles with positive answer to the first three CASPe “elimination questions”.

All the chosen articles are randomized controlled clinical trials (RCTs) with defined clinical study question, they all explain the purpose and goals of the study with well-explained intervention and methodology and adequate results.

Participants were considered using a computer randomization system, or similar aleatory strategies. Crobie et al [28] used computer randomisation, as well as Ribeiro et al [26] that used a webpage called Random.org to divide the patients in groups, Bower et al [29] used STREAM score to do the group differentiation, meanwhile the rest of the studies used sequentially numbered Piron et al [31], or simple randomization strategies Kiper et al [32] (CASPe question 1 and 2).

All patients in the studies had a follow-up. In case of patients drop off - Ribeiro et al [26] 3 patients dropped-off, Lee et al [27] 6 patients abandoned and JH Crobie et al [28] 1 subject withdrew - is contemplate in the results and the remaining groups were still balanced (CASPe question 3 and 5).

The majority of the papers were single blind, with only blind examiner/assessor - Crobie et al [28], Ribeiro et al [26], J Bower et al [29], Kiper et al [30], Piron et al [31] - only Subramanian et al [32] was double blinded for both assessor and authors (CASPe question 4).

Regarding to question 6, 7 and 8 of the CASPe evaluation we cannot determine if the groups were treated equally, because there is no record about it in the articles. Neither we can determine the treatment effectiveness and precision due to reduced sample of patients in every study and the non-significant results of the majority of the literature. We cannot make any valid conclusion.
In all the selected literature the results can be extrapolable to the population or environment to some degree thus strict criteria is used and the methodology is easily explained. (CASPe question 9).

In our opinion, all the studies justify the cost and risk of the intervention, no patient got negative outcomes, in the opposite, all patients improved, and the intervention is affordable in all cases. (CASPe 11).

II. Studies characteristics

In all the literature the objective of the study is to compare telerehabilitation, Nintendo Wii or Virtual Reality with Conventional Physical Therapy. They all are randomised controlled clinical trials single-blind to the assessor except for Subramian et al [32] which is double-blinded.

The intervention methodology is varied Piron et al [31] and Kiper et al [30] compare a control group of CPT with TRHB in the intervention group. In the same way, Ribeiro et al [26] compare CPT with NW, Subramian et al [32], Crosbie et al [28] and Lee et al [27] compare CPT with VR. Only Bower et al [29], compare two NW approaches and also mirror therapy (MT).

The intervention period is similar, a 4 weeks/1month treatment in 5 of the selected scientific papers: Ribeiro et al [26], Lee et al [27], Kiper et al [30], Subramanian et al [32], Piron et al [31]. J Bower et al [29] had a 2 to 4 week period and Crosbie et al [28] elonged it to 6 weeks period of time.
The participants sample is around 30 patients in all the studies, being *Crosbie et al* [28] and *Subramian et al* [32] the smallest group with 18 and 20 participants respectively and *Kiper et al* [30] the bigger study group with 44 participants.

They all did two groups differentiation, a control group and a intervention group, except *Bower et al* [29] which has an active group and the intervention group, always with similar patient characteristics (age, gender, condition…) in both groups.

All patients had a stroke condition, ischemic or hemorrhagic in different phases, acute (*Piron et al* [31]) to chronic (*Subramian et al* [32]).

They were always UL affected and evaluated with FM scale in all of them and some other specific scale, for each study [FIG.4. Studies Characteristics].

Participants age variates from 18 to 85 years old.

Cognitive impairment, neglect and comprehension difficulties are excluding criteria common in all the studies. [FIG.4. Studies Characteristics]. They follow the same line criteria: Both *Ribeiro et al* [26] and *Lee et at* [27] excluded patients with hemineglect, pusher syndrome, have intellectual disability and orthopedic diseases that promoted dysfunction. Medically unstable, severe dysphasia, dyspraxia or cognitive impairment are the exclusion criteria of *Bower et al* [29]. Meanwhile *Kiper et al* [30] included a scale criteria; Clinical evidence of severe cognitive impairment (-24 Mini-Mental score), clinical history of neglect, complete hemiplegia (FM = 0pts.), sensory disorders and history of traumatic injuries. As well as *Crosbie et al* [28] low Mental score and upper limb motricity index, - 6/10 VAS scale, and *Piron et al* [31], excluded patients with cognitive impairment; apraxia (- 62 Den Renzi score), neglect and language disturbances interfering with verbal comprehension (+ 40 Token Test errors). *Subramanian et al* [32] excluded comprehension difficulties, marked apraxia, attention or visual field deficits.
III. Synthesis of results

7 scientific articles were included in this systematic review: Ribeiro et al [26], Lee et al [27], Crosbie et al [28], J Bower et al [29], Kiper et al [30], Piron et al [31], and Subramanian et al [32].

They are all recent publications, developed in a variety of countries: Piron et al [31] was published in 2009 in Italy. Also an Italian study is Kiper et al [30] conducted in 2014. From 2014 we also found the Canadian study of J Bower et al [29]. There are two scientific papers from 2012 Crosbie et al [28] developed in United Kingdom, Subramanian et al [32] conducted in USA. Lee et al [27] published the scientific article in Korea in 2013 and Ribeiro et al [26], the most recent publication in Brazil (2015).

On the whole, they gather 214 stroke patients (24 patients from Lee et al [27], 36 in Piron et al [31], 18 subjects in Crosbie et al [28], 32 in Subramanian et al [32], 44 in Kiper et al [30] and 30 patients from Ribeiro et al [26] as well as from J Bower et al [29]) with a total amount of 10 patients drop-out.

In all selected scientific papers, the subjects were treated with different forms of telerehabilitation, more specifically with virtual reality technologies and devices like Nintendo Wii™.

All literature appreciate significant improvement over time in both groups after intervention, but non-significant improvement between-groups are found in any of the selected papers, so further studies are needed.

Bower et al [29] results are that Wii use by the Balance Group was associated with trends for improved balance, with significantly greater improvement in outcomes including the Step Test p=0.004 and Wii Balance Board-derived centre of pressure scores. The Upper
Limb Group had larger, non-significant changes in arm function $P = 0.652$. In conclusion, a Wii-based approach appears feasible and promising for post-stroke balance rehabilitation.

Piron et al [31] claim that both groups maintained the benefits achieved and that the TRHB group improved only in FM scale (motor upper arm function) $T_0 = 48.3$ (7, 2) – $T_90 = 53.1$ (7,3).

Ribeiro et al [26] found a significant difference between groups before and after the treatment in FM assessment of passive movement and pain $P = 0.048$, motor function of the upper limbs (ULs) $P = 0.002$, and balance $P = 0.001$. The CPT group also showed a significant difference with regard to their UL $P = 0.891$ and lower limb (LL) coordination $P = 0.120$.

The SF-36 scale analysis revealed a significant difference within both groups regarding physical functioning $P = 0.000$, role limitation due to physical aspects $P = 0.003$, vitality $P = 0.018$, and role limitation due to emotional aspects $P = 0.026$. The NW group also exhibited a significant difference in the mental health domain $P = 0.002$.

The results indicate that both approaches improved the patients’ performance in a similar manner.

When comparing the efficacy of TRHB in different stroke etiology, Kiper et al [30] found significant better improvement in hemorrhagic stroke patients than ischemic. And TRHB showed to be more effective than CPT. the FM ($P = 0.030$), FIM ($P = 0.140$). The patients affected by hemorrhagic stroke significantly improved FIM ($P = 0.031$), time ($P = 0.011$), and peak ($P = 0.020$) after treatment, whereas the patients affected by ischemic stroke improved significantly only speed ($P = 0.005$) when treated by TRHB.
Subramian et al [32] got better outcomes in VR group, and claim to need at least 72 exercises repetitions per session to appreciate any significant difference. Only participants in the VE group improved shoulder horizontal adduction at POST (9.5°) and flexion at both POST (6.3°) and RET (13°). After VE training, the mild group increased elbow extension (RET, 25.5°). The moderate-to-severe group in VR increased arm use at POST (0.5 points) and reaching ability at RET (2.2 points). The moderate-to-severe group training in PE increased reaching ability earlier (POST, 1.7 points) and both elbow extension (10.7°) and arm use (0.4 points) at RET, but these changes were accompanied by increased compensatory trunk displacement (RET, 30.2 mm). VE training led to more changes in the mild group and a motor recovery pattern in the moderate-to-severe group indicative of less compensation, possibly because of a better use of feedback.

In the article of Donglin Lee et al [27], both groups showed significant increases in upper limb function, excepting spasticity, after intervention (P> 0.05, 1-way repeated-measures analysis of variance [ANOVA]). A significant group–time interaction was demonstrated only for shoulder/elbow/wrist items of FMA, BBT, grip strength, and ROM of wrist flexion, extension, and ulnar deviation (P> 0.05, 2-way repeated-measures ANOVA). Thus, asymmetric training program using virtual reality reflection equipment and a metronome effectively improves upper limb function in stroke patients.

In Crosbie et al [28] study Both groups demonstrated small (7–8 points on upper limb Motricity Index and 4 points on the Action Research Arm Test), but non-significant, changes to their arm impairment and activity levels. It is feasible to continue this pilot study with a larger group of patients RCT.
5. Discussion

This review aimed to investigate the effectiveness of telerehabilitation using virtual reality devices and Nintendo Wii™ in upper limb recovery of stroke patients. As a 10 years existance treatment, promised to substitute the conventional physical therapy in the clinical practise.

Virtual reality is a new tool for stroke rehabilitation with involvement in the upper limb but evidence on their effectiveness is still considered weak to moderate [33].

We should point out some limitations we found through the process of this systematic review.

Firstly, the sample size is not significant, the numbers are not enough to reach any general conclusion, for example the bigger group with 44 participants is Kiper et al [30] and the minimum group with only 18 subjects is Crosbie et al [28].

Regarding the treatment time, it is observed that there is also quite reduced. We found little variation between studies, the majority lasted 4 weeks - Lee et al [27], Kiper et al [30], Subramanian et al [32], Piron et al [31] - J Bower et al [29] they had 2 to 4 week period and Crosbie et al [28] elonged it to 6 weeks period of time and Ribeiro et al [26] until 8 weeks. None of the studies presented an appropriate period of treatment to assess the effectiveness of long-term interventions.

Generally the follow-up period matched the treatment period. Ribeiro et al [26], Bower et al [29], Kiper et al [30], Piron et al [31], Subramanian et al [32], and Lee et al [27], did a 1 month follow-up after the treatment. Crosbie et al [28] did a 6 weeks follow-up, doubling treatment period. They all perform a scarce and insufficient follow-up period to reach any conclusions.
Rehabilitation should be intensively for long periods of time and it requires dedicated staff, resources and logistics. The duration of the effects of rehabilitation after completion of treatment with VR systems is crucial and it must be determined with follow-up studies. This discrepancy contrasts with the increasing availability of advanced technologies and need for reliable criteria to help define the cost-benefit relationships and priorities in local public and private health [34].

A variety of scales was observed in the upper limb measuring. This is a limitation to make proper conclusions when comparing several scientific studies. At least, they all have in common the use of Fugl-Meyer Motor Assessment (FM). This fact also highlights the lack of agreed criteria to assess the movement in neurology and the limitations they assess are only partly offset by scales in use of neuro - rehabilitation [33].

In our opinion, telerehabilitation is another alternative to stroke rehabilitation, it may be advisable to use it in some patients and not really recommendable in other cases. The patient who should benefit from this technique must be able to understand how to follow the exercises and the rehabilitation program, they also have to manage technological devices so, minimum ability is required. There is a group of patients with stroke comorbidity illness, as well as mental disorders or intelligence limitations that remain excluded from the intervention.

In addition, telerehabilitation users must have remaining certain body control, motor functionality, expecific ROM and independence. Afresh, we have to exclude spasticity and reduced mobility patients.
Evidently, a qualified physiotherapist could adapt those exercises to any patient but it would require more dedication to one single patient and that would lose, the one of the great advantage of this therapy, cost—time. TRHB should increase the number of patients catered for a same therapist and by so generate significant savings and wider approach of health system on individuals, even in remote access housing [35].

As well as we can find limitation we found some aspects that support the use of this approach:

The main advantages of using telerehabilitation in comparison with conventional physical therapy are: consistency, precision, no fatigability, programmability and the ability to measure and record data from therapy. This therapeutic modality, improved significantly motor function in the upper extremity of subjects with stroke and motor deficits. Significant gains are achieved with TRHB, VR and NW in comparison with the conventional physical therapy, that lead us to think that telerehabilitation is a reasonable choice therapy.

We would also like to positively remark those studies which don’t forget to measure the grip, and hand ability making a complete assessment of the upper limb. For example, Piron et al [31] use Abilhand and Lee et al [27] measured it with “Box and block” and “Grip Strength” test.

Several other authors Ribeiro et al [26] SF-36, Bower et al [29] with “Likert scales” and “Functional Reach Test”, have reported a significant improvement in daily life activities as treatment outcome which also indicate that functional exercises is a better choice.

The advantages of home-rehabilitation starts by improving life quality, rehabilitation is less traumatic in a familiar environment. It is more comfortable and accessible for the
patient, even more evident in reduced-mobility patients. If transfers to clinical centers are avoided, we are offering a schedule and therapy placement flexibility for both patient and family, thus absenteeism decreases [36].

As reduces the spent time in transfers and the cost of transport for patients, Improves self-care of patients, they are much more motivated for the therapy which can be proposed as a game with achievable goals so there is more satisfaction for patients. And it could prevent depression in this type of patients [35].

A convenient next step, according to Lucca et al [37] would be to encourage research to achieve broad application reduced costs, possibly making rehabilitation at home under remote control and extending the use of VR to people who are unfamiliar with the use of technological systems [38,39].

Telerehabilitation appers as a really promising intervention due to its many advantages, mentioned throughout this work, but we would like to point out that, physical therapist should simply consider TRHB as another approach to stroke recovery. Remarking that no approach will be better than a functional treatment with daily life activities adapted individually to the patient. As we support the idea of the duty of the qualified physiotherapist is to make any treatment interesting, dynamic and biologically adapted.

To highlight some new investigating lines, none of the revised paper conducted studies to estimate the validity of this new technologies as an assessment method, not only as treatment possibility. It would be also interesting to investigate the potentiality in other pathologies, such as Alzheimer’s and Cerebral Palsy. Also with another sample criteria, for example, with gender or age categories to advice if there is any significant difference that we should have in consideration.
The use of telerehabilitation could also facilitate the intradisciplinary model. If every therapist involved in a patient’s recovery were allowed to follow the patient’s performance online, they could instantly make the assessments and contributions necessary for an early recovery of the patient.

To conclude, we also would like to remark that, in spite of the results in the selected literature are not very persuasive, we still foresee the promising potentiality of telerehabilitation and we cheer to follow further research in this field.

6. Conclusion

Based in the studies we analysed in this review we cannot confirm any of the hypothesis of the cited authors due to its minimum patients sample, and scarce follow-up. We agree that further studies are necessary due to its promising outcomes in all this revised literature and we can foresee the potential benefits of telerehabilitation for stroke rehabilitation.
7. Acknowledgment

In this project, the last step of this stage of my life, I would like to mention to all those people thanks to which it has been possible for me to accomplish it successfully.

To my family and friends, for the unconditional support.

To all the teachers and other workers E.U. Gimbernat - Cantabria, for sharing their knowledge and the hard work with the only purpose of training quality professionals.

To my tutor Natalia Requejo Juez, for the help, guidance and availability even from the distance.

Thank you.
8. References


9. Anexes

[FIG. 1 Search strategy in Pubmed database]
PEDro SEARCH STRATEGY (December 2015 - 7th April 2016)

**Telerehabilitation AND stroke AND upper limb**
- 2 results
- Clinical trial
- Pedro score ≥ 5/10
- 1 result
- Also in Pubmed selection

**Virtual reality AND stroke AND upper limb**
- 18 results
- Clinical trial
- Pedro score ≥ 5/10
- 8 results

**Wii AND stroke AND upper limb**
- 8 results
- Clinical trial
- Pedro score ≥ 5/10
- 4 results
- Same as Pubmed selection

[FIG. 2 PEDro search strategy]
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<th>Study Description</th>
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<td>1. Virtual rehabilitation via Nintendo Wii™ and conventional physical therapy effectively treat post-stroke hemiparetic patients</td>
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<td>2. Asymmetric training using virtual reality reflection equipment and the enhancement of upper limb function in stroke patients: a randomized controlled trial</td>
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<td>3. Virtual reality in the rehabilitation of the arm after hemiplegic stroke: a randomized controlled pilot study</td>
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<tr>
<td>JH Crosbie et al [28], (2012)</td>
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<tr>
<td>4. Clinical feasibility of the Nintendo Wii™ for balance training post-stroke: a phase II randomized controlled trial in an inpatient setting</td>
<td>✓</td>
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<td>J Bower et al [29], (2014)</td>
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<tr>
<td>5. Reinforced Feedback in Virtual Environment for Rehabilitation of Upper Extremity Dysfunction after Stroke: Preliminary Data from a Randomized Controlled Trial</td>
<td>✓</td>
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<td>Kiper et al [30], (2014)</td>
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<tr>
<td>6. Exercises for paretic upper limb after stroke: a combined Virtual-reality and telemedicine approach</td>
<td>✓</td>
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<td>Piron et al [31], (2009)</td>
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<tr>
<td>7. Arm Motor Recovery Using a Virtual Reality Intervention in Chronic Stroke: Randomized Control Trial</td>
<td>✓</td>
<td>✓</td>
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<td>Subramanian et al [32], (2012)</td>
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</table>

**[FIG. 3 CASPe Evaluation]**. La pregunta del ensayo debe definirse en términos de la población, la intervención realizada y los resultados considerados. 2. ¿Fue aleatoria y se mantuvo oculta la asignación de los pacientes al tratamiento?. 3. ¿Fueron adecuadamente considerados hasta el final del estudio todos los pacientes que entraron en él? 4. ¿Se mantuvieron ciegos al tratamiento los pacientes, los clínicos y el personal de estudio?. 5. ¿Fueron similares los grupos al comienzo del ensayo?. 6. ¿Fueron tratados de igual modo los grupos?. 7. ¿Es muy grande el efecto del tratamiento?. 8. ¿Cuál es la precisión de este efecto?. 9. ¿Pueden aplicarse estos resultados en tu medio o población local?. 10. ¿Se tuvieron en cuenta todos los resultados de importancia clínica?. 11. ¿Los beneficios a obtener justifican los riesgos y los costes?
### 1. Virtual rehabilitation via Nintendo Wii™ and conventional physical therapy effectively treat post-stroke hemiparetic patients  
*Ribeiro et al [26], (2015) Brazil*

<table>
<thead>
<tr>
<th>Objective</th>
<th>Compare the effect of a rehabilitation treatment using NW with CPT to improve sensoriomotor function and life quality on hemiparetic patients</th>
</tr>
</thead>
</table>
| Method and Duration | Single-blind RCT  
8 weeks treatment |
| Sample | N= 30 patients  
Equally divided similar in age, gender and stroke type |
| Characteristics | Patients with post-stroke hemiparesis diagnosis (at least 6 months prior) between 18-60 years old, able to ambulate and hold the game controller without assistive devices  
Excluded: Hemineglect, pusher syndrome, intellectual disability and orthopedic diseases that promoted dysfunction. |
| Evaluation scales | SF-36, FM |
| Statistics | SPSS, Kolmogorov-Smirnov test, Mann-Whitney, Wilcoxon, Chi-square, Fisher’s exact test |
| Intervention/ Nº of sesions | 60 min twice a week for 2 months  
IG: NW  
CG: CPT |
| Outcomes | Significant difference between pre- and post-treatment were found  
No significant differences between-group were found for any of the variables except SF-36 domain physical functioning in the CPT group. |
<table>
<thead>
<tr>
<th>Objective</th>
<th>Effects of an asymmetric training programme using VR reflection equipment on upper limb function in stroke patients.</th>
</tr>
</thead>
</table>
| Method Duration | RCT  
4 weeks duration |
| Sample | N=24 patients  
Equally divided, similar in age, gender and stroke type |
| Characteristics | Patients with stroke diagnosis, at least 21 score in Mini-Mental Test  
Excluded: Hemineglect, pusher syndrome, intelectual disability and orthopedic diseases that promoted dysfunction. |
| Evaluation | Scales  
FM, Box and block, Grip Strenght, MAS  
Statistics  
ANOVA |
| Intervention/ N° of sesions | 2x30 min/day 5 day/week for 4 weeks  
- IG: CPT + (VR) Asymmetric training reflection  
- CG: (CPT) Mirror therapy symmetric |
| Outcomes | No significant differences, both therapies shows improvement.  
No spasticity improvement |
Virtual reality in the rehabilitation of the arm after hemiplegic stroke: a randomized controlled pilot study

Crosbie et al [28], (2012) United Kingdom

| Objective | Investigate the feasibility and potential efficacy of NW for balance after stroke
| Efficacy of this approach for improving balance, mobility and UL function |

<table>
<thead>
<tr>
<th>Method and Duration</th>
<th>RCT</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 Weeks treatment</td>
<td></td>
</tr>
<tr>
<td>6 weeks follow-up</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sample</th>
<th>N=18 patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>IG (VR)</td>
<td>Age: 60.3 years old</td>
</tr>
<tr>
<td>CG (CPT)</td>
<td>Gender: 8 men and 10 women</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>10.8 months stroke patients 18-85 aged and medically stable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excluded: low Mental score and upper limb motricity index, - 6/10 VAS scale</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Evaluation</th>
<th>Scales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Limb Motricity Index, Action Research Arm Test</td>
<td></td>
</tr>
</tbody>
</table>

| Statistics | SPSS, Mann-Whitney |

<table>
<thead>
<tr>
<th>Intervention/ Nº of sessions</th>
<th>9 sessions over 3 weeks</th>
</tr>
</thead>
<tbody>
<tr>
<td>VR vs CPT</td>
<td></td>
</tr>
</tbody>
</table>

| Outcomes | Both groups demonstrated small, non-significant changes. |
| **Objective** | Investigate the feasibility and potential efficacy of NW for balance after stroke  
                              Efficacy of this approach for improving balance, mobility and UL function |
| **Method and Duration** | Single-blind RCT Phase II  
                              2 to 4 weeks |
| **Sample** | N=30 patients  
                              - IG (balance group): 17  
                              - AG (Upper Limb Group): 13  
                              Age: 63.6 ± 14.7 years old  
                              No gender differentiation |
| **Characteristics** | Adults with non-cerebellar stroke diagnosis less than 3 months prior with functional use of at least one upper limb  
                              Excluded: Medically unstable, severe dysphasia, dyspraxia or cognitive impairment |
| **Evaluation** | Scales  
                              Likert scales (enjoyment), VAS, BORG Scale (perceived exertion), Step-test, Functional Reach Test, Timed Up and Go, Wii Balance Board, Short Falls Efficacy Scale, FM, STREAM  
                              Statistics  
                              Shapiro-Wilk test, Mann-Whitney U, Chi-square, ANOVA, SPSS for Windows |
| **Intervention/ Nº of sessions** | 1h a day, 5 days a week for 1 month.  
                              IG: TRHB system at home (VRRS.net)  
                              CG: CPT |
| **Outcomes** | Both groups improved significantly over time  
                              Larger, non-significant improvements in the upper limb subcale of the STREAM and FM compared to the Balance group were found. |
5. Reinforced Feedback in Virtual Environment for Rehabilitation of Upper Extremity Dysfunction after Stroke: Preliminary Data from a Randomized Controlled Trial

*Kiper et al [30], (2014) Italy*

| Objective | Evaluate if TRHB is more effective than CPT in UL post-stroke recovery  
|           | Efficacy of TRHB in different stroke etiology |
| Method and Duration | Single-blind RCT  
|                     | 4 weeks duration |
| Sample | N=44 patients  
|       | - IG (TRHB):21  
|       | - CG (CPT): 23  
|       | Age: 64.3 ± 12.6 years old  
|       | Gender: 29 men and 15 women  
|       | Etiology: 24 ischemic stroke and 20 hemorrhagic stroke |
| Characteristics | At last 1 year stroke patients never treated with TRHB  
|                 | Excluded: Clinical evidence of severe cognitive impairment (-24 Mini-Mental score), clinical history of neglect, complete hemiplegia (FM = 0pts.), sensory disorders and history of traumatic injuries |
| Evaluation | Scales  
|             | FM, FIM  
| Statistics | Kolmogorov-Smirnov test |
| Intervention/ Nº of sessions | 5 days weekly for 4 weeks  
|                             | - IG (TRHB): 1h/day TRHB (Virtual Reality Rehabilitation System) + 1h/day CPT  
|                             | - CG (CPT): 2h/day CPT |
| Outcomes | The TRHB treatment showed to be significant more effective than CPT  
|          | Hemorrhagic stroke patients improved significantly with TRHB better results |
6. Exercises for paretic upper limb after stroke: a combined Virtual-reality and telemedicine approach
*Piron et al [31], (2009) Italy*

<table>
<thead>
<tr>
<th>Objective</th>
<th>Compare the effects of TRHB with CPT</th>
</tr>
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<tbody>
<tr>
<td><strong>Method and Duration</strong></td>
<td>Single-blind RCT</td>
</tr>
<tr>
<td></td>
<td>Duration: 3 months (1 month prior / 1 month treatment/ 1 month follow up)</td>
</tr>
<tr>
<td><strong>Sample</strong></td>
<td>N=36 patients</td>
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<tr>
<td></td>
<td>- IG:18</td>
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<td></td>
<td>- CG: 18</td>
</tr>
<tr>
<td></td>
<td>Age : 65.2 ± 7.8 years old</td>
</tr>
<tr>
<td></td>
<td>Gender: 21 men and 15 women</td>
</tr>
<tr>
<td><strong>Characteristics</strong></td>
<td>Ischaemic stroke in the region of the left (16 subjects) and right (20 subjects) middle cerebral artery</td>
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<td>Mild to intermediate arm motor impairment (FM score 30-35)</td>
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<td></td>
<td>Excluded: Cognitive impairment ; apraxia (- 62 Den Renzi score), neglect and language disturbances interfering with verbal comprehension (+ 40 Token Test errors)</td>
</tr>
<tr>
<td><strong>Evaluation</strong></td>
<td>Scales</td>
</tr>
<tr>
<td></td>
<td>ABILHAND, FM, MAS</td>
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<tr>
<td></td>
<td>Statistics t-test</td>
</tr>
<tr>
<td></td>
<td>Wilcoxon test, Mann-Whitney U, WINSTEPS Rasch software</td>
</tr>
<tr>
<td><strong>Intervention/ Nº of sessions</strong></td>
<td>45 minutes, 3 times per week, from 2 to 4 weeks</td>
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<td></td>
<td>IG (Balance group): NW (Wii Fit Plus) + CPT</td>
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<td></td>
<td>AG (UL Group): NW (Wii Sports) in seated position + CPT</td>
</tr>
<tr>
<td><strong>Outcomes</strong></td>
<td>No significant differences in t-test</td>
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<td>Both groups improved in all fields after therapy</td>
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<td></td>
<td>Significant improvement in the Fulg- Meyer UE in TRHB group</td>
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<td>In the follow-up both groups maintained the benefits achieved.</td>
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</tbody>
</table>
### Objective
Effectiveness of VR on chronic stroke UL recovery
VR training vs physical environment training

### Method and Duration
Double blind RCT
4 weeks duration

### Sample
N=32 patients similar in age, sex, side affected, type of stroke
- IG: VR
- CG: CPT

### Characteristics
40 to 80 years old single ischemic or hemorrhagic stroke patients, 6 to 60 months prior.
Excluded: comprehension difficulties, marked apraxia, attention or visual field deficits

### Evaluation
**Scales**
FM, RPSS, WMT, MAL-AS, Intrinsic Motivation Task Evaluation Questionnaire

**Statistics**
ShHor, IREDs, ANOVAs, CONSORT

### Intervention/ Nº of sessions
Sessions of 45 min. 3 times/week over 4 weeks
Patients in sitting position did same exercises and amount of repetitions CG in physical environment and IG in VR.

### Outcomes
Both groups improved, they need 72 repetitions per session to spot significant differences.
Better outcomes in VR group.

---

[FIG.4 Studies Characteristics]