



Neurorehabilitation And Technology– A Systematic Review And Meta-Analysis

Deepa S^{*1}, Priya Kumari²

¹Saveetha College of Physiotherapy, SIMATS, Thandalam, Chennai- 602105, Tamil Nadu, India

²Department of Physiotherapy, VISTAS, Thazhambur, Chennai – 600130, Tamil Nadu, India



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ABSTRACT

With evolving innovations, physical therapy has adapted advancements of technology to impact a patient's recovery with interactive rehabilitation and improve the quality of life. Physical therapy has enriched the patient's experience and seeking new ways to improvise the treatment strategies for patients either in clinical setup or home-based rehabilitation. Evidence suggests that the amount of time spent by the therapist in rehabilitation has led to an increase in the progression of the patients physically and mentally. Still, with the increase in the grey population, it has put a strain on the skills of therapist attending such patients and has been chosen as an adjunct to traditional therapies. To understand the emerging interactive technology in improving the thorough rehabilitation this review of literature was done. This study was conducted according to PRISMA guidelines, and PEDro scale was applied to find out the methodological quantity. Relevant Original articles based on randomised control trials (RCT) interpreting the influence of the use of technology in the prognosis of the patient's rehabilitation from CINHAL, Scopus, Cochrane, Elsevier, Science Direct, research Gate and Pubmed were included. This study summarises that technology is an assistive tool for both physiotherapist and patients in showing prognosis in rehabilitation and improving the quality of life at home and community-based set up. Technology is promising rehabilitative intervention, although the evidence for this approach for rehabilitation purposes is still only moderate to weak. And that their effectiveness over traditional treatment which has yet to be established.

*Corresponding Author

Name: Deepa S

Phone: 9952038621

Email: deepasranganathan@gmail.com

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INTRODUCTION

The global prevalence of neurological disorders, in 2016 was the leading cause of DALYs (276 [95% UI 247–308] million) also a second leading cause of 9 million deaths, in India, the prevalence is about 1.27 billion, approximately 30 million people suffer from neurological disorders (Gourie-Devi, 2014). Ten million British population have been suffering from long term neurological condition, which requires an expenditure on health services like inpatient and outpatients, which is estimated to be £2.9 billion in 2009–2010. Apart from these direct expenses the everyday expenses as the unpaid care is on substantial increase patients rely on their family for support and care, which in turn gives stress, fatigue, anxi-

ety to their family this endorses the importance of developing feasible, portable, cost-effective technology in the therapy protocol (Jackson *et al.*, 2013).

Among the neurological disorders, stroke is the leading cause of disability. The amount of hospitalisation has been alarmingly increased globally and in India and looking at the different intensities of physical therapy treatment, a significant prognosis in Activities of Daily living is seen, as a result of higher intensity of treatment (Jones *et al.*, 1999). The average amount of time spent by the therapist in the rehabilitation centre is about 59% of their time (Steenkamp *et al.*, 2003). Further studies have shown that the amount of time spent by a stroke patient in their 9-hour active period is just 0.5 hours, which has put a burden on the therapist to show the prognosis in preferred time and duration (Kaur *et al.*, 2012).

Globally smartphones are used by 3.5 billion (2016 to 2021; Statista) and in India alone, there were around 51 million smartphone users in 2013. Recent statistics show 83% of the smartphones are turned on and always with users (Rodríguez *et al.*, 2018). Ninety-seven thousand health-related apps are useful and reliable when used as a complementary treatment alongside rehabilitation, especially those that are designed to promote a healthy lifestyle, retrain balance, assess disorders, improve therapist-patient interaction (Micera *et al.*, 2005).

The use of robotics has increased the therapist-patient interaction to a more considerable extent, thus influencing the patient in getting independent functionally. The factors as global population greying are 137 million (Gassert and Dietz, 2018), a worldwide shortfall of rehabilitation professionals, increasing evidence, advancements and proliferation in technology fuels the advanced rehabilitation of ecosystems (Béjot and Yaffe, 2019).

Moss talk word is a multinodular software developed for aphasia patients with help in phonology and word retrieval. This innovation showed significant improvement in patient satisfaction and minimal clinician guidance, but for the older generation the moss talk word was still unfamiliar and challenging (Jokel *et al.*, 2009).

Constraint-induced movement therapy has focused on the learned nonuse, showing results in improved motor performance and functional abilities on the hemiparetic side with improved quality of life. Extensive studies have done using CIMT with robotics and body weight support showing more significant cortical and subcortical stimulation. Amongst these body weight support with harnesses have shown a disadvantage, on the effort of

the therapist to align the paretic limb and control the weight shift. With the addition of treadmill later provided efficient gait training resulting in returning to walking faster (Mehrholz *et al.*, 2017).

Functional electrical stimulation which used a coordinated burst of electricity on the peripheral nerves of the paretic limb proved to improved muscle activation during the motor performance, clearance of foot while walking leading to reduced falls and improved gait symmetry. However, depending on the therapist's decision to introduce them during therapy protocol had kept them as an adjunct tool (Embrey *et al.*, 2010).

Mechanical devices like MIT-MANUS, MIME, The Lokomat have shown significant improvement in reaching movements, guiding the paretic arm, gains with independent ambulation.

Limb apraxia can cause disabling effects on the paretic side because of trajectory timing and purpose of movements are dysfunctional. Adding a robotic technology can limit the feedback on movement accuracy; thus, further research is directed towards assessing the strength and skilful, accurate movement acquisition.

There are limited evidence showing any particular design over other and future studies are to be held on providing a standard design, perfect actuator design and feedback to maximise patient safety which can be generalised in the usage of soft robots (Westlake and Patten, 2009).

In the inpatient phase at this phase, the traditional therapies and intensity drops drastically, to bridge the gaps portable, less complicated, cost-effective robots, telerehabilitation systems at home, have been on the rise and popular among patients for faster recovery (Gupta and Raja, 2011).

One of the significant limitations of these conventional therapies is they often provide insufficient treatment in terms of intensity and repetitions. Hence rehabilitation technology has been identified to the priority area in the research field also it cannot be used as a standalone therapy. Even though such innovations pose a threat to the therapist jobs, it has been analysed that these technologies need set up, programming and monitoring, which is impossible without a therapist.

Rehabilitation has been revolutionised with the use of robots, mobile apps, telerehabilitation, virtual reality, wearable motion tracking system and many other technologies along with which much research has been carried out. But, In India, only three robotic devices were installed by 2009. The need and objective of this study aim to find out the amount of

technology persuading the replacement of Physical Therapist in-person sessions, or it can only be of adjunctive use to rehabilitative protocols that are being devised by the physiotherapist, thus reducing the physical workload and strain.

The purpose of this study is to review through the literature, the effectiveness of the technology used as a protocol in the rehabilitation process, whether they have established set goals that can be applied independently as a treatment or is it validated only as an adjunct therapy which adds value to the conventional therapy monitored by a skilled therapist.

MATERIALS AND METHODS

A literature search was conducted from Jan 2020 on the influence of technology in the progression of neurorehabilitation using critical words as neurorehabilitation, mobile apps, robotic assistive devices, computer-human interface, soft robots, augmented robots, telerehabilitation, motion tracking system, the virtual reality according to the PRISMA guidelines [PRISMA-P (Preferred Reporting Items for Systematic Review and Meta-Analysis Protocols) 2015 checklist]. The literature articles were obtained from CINAHL, Scopus, Cochrane, Elsevier, Science Direct and PubMed. Use of technology has increased drastically and is a novel field; we have limited ourselves to the articles published in the last six years to be updated on recent studies. The methodological quality was assessed by the Physiotherapy Evidence Database (PEDro) tool; data were extracted on the bases of selection criteria provided.

While using the PEDro tool, each article was rated over an 11-item scale. Each item required a yes or no response. The first item on the PEDro tool was a measure of external validity and thus was excluded while scoring finally and which totals to a final score of 10. This tool has provided acceptable validity and reliability in quantifying the quality of each study.

Inclusion criteria

Studies were included if all the articles were published in English and studies which involved technology using apps, robotic devices for neurorehabilitation from the year 2014, Randomised control trials, studies included samples which were neurological conditions, articles having interventional group provided with a technological protocol and control group having conventional protocol there was no restriction on the sample size.

Exclusion criteria

The study excluded articles from other languages, conditions other than neurological ailments, Review articles, meta-analyses, systematic analysis, study

protocols and editorials were excluded.

Methodology

Articles were searched using keywords as neurorehabilitation, mobile apps, robotic assistive devices, computer-human interface, soft robots, augmented robots, telerehabilitation, motion tracking system, virtual reality, from the databases the articles were filtered and selected based on inclusion and exclusion criteria. The flow chart below shows the search results (Figure 1). A few review articles from n= 21 systematically analysed articles are mention below in (Table 1), which gives an idea about the tabulation done and the information which was extracted from each article.

Statistical Analysis

The total number of RCTs were tallied in the scores obtained by the PEDro scale, and the continuous data were summarised as analysis of percentage and with proportion Z- test. The mean, median and standard deviation were analysed over the PEDro scores and items in the scale. The statistical analysis was conducted on online software.

RESULTS AND DISCUSSION

The overall mean scores on the PEDro were 6.57. The median was 6, with a standard deviation of 1.3299. The methodological quality of the studies conducted showed 19% being low on the score 4-5, 57% being good quality on the scores 6-7 and 23.8% having excellent quality on the scores 8- 10 (Graph 1).

On examining the PEDro items, some of the items showed significance concerning the articles which satisfied each item on the scale. They showed higher adherence in the protocol of RCT in items as random allocation, groups being similar at baseline and at least one key outcome showed point measures in these studies accounting for 100%. The items where the results of at least one key outcome showed between-group comparison was 95%, sample size of 85% were reported to be 81%, and assessor blinding was 71% which showed the amount of bias is reduced in the studies. Items such as concealed allocation reported to be 47%, intention to treat and subject blinding reported being 29 %. Therapist blinding accounted for only 5%. These low results might be due to the intervention provided and sample population used.

Neurorehabilitation can be explained as a process to optimise patient's participation in the society and to provide a sense of wellbeing. It also emphasises on rehabilitation not being an intervention instead focusing on patient's goals as social functioning and

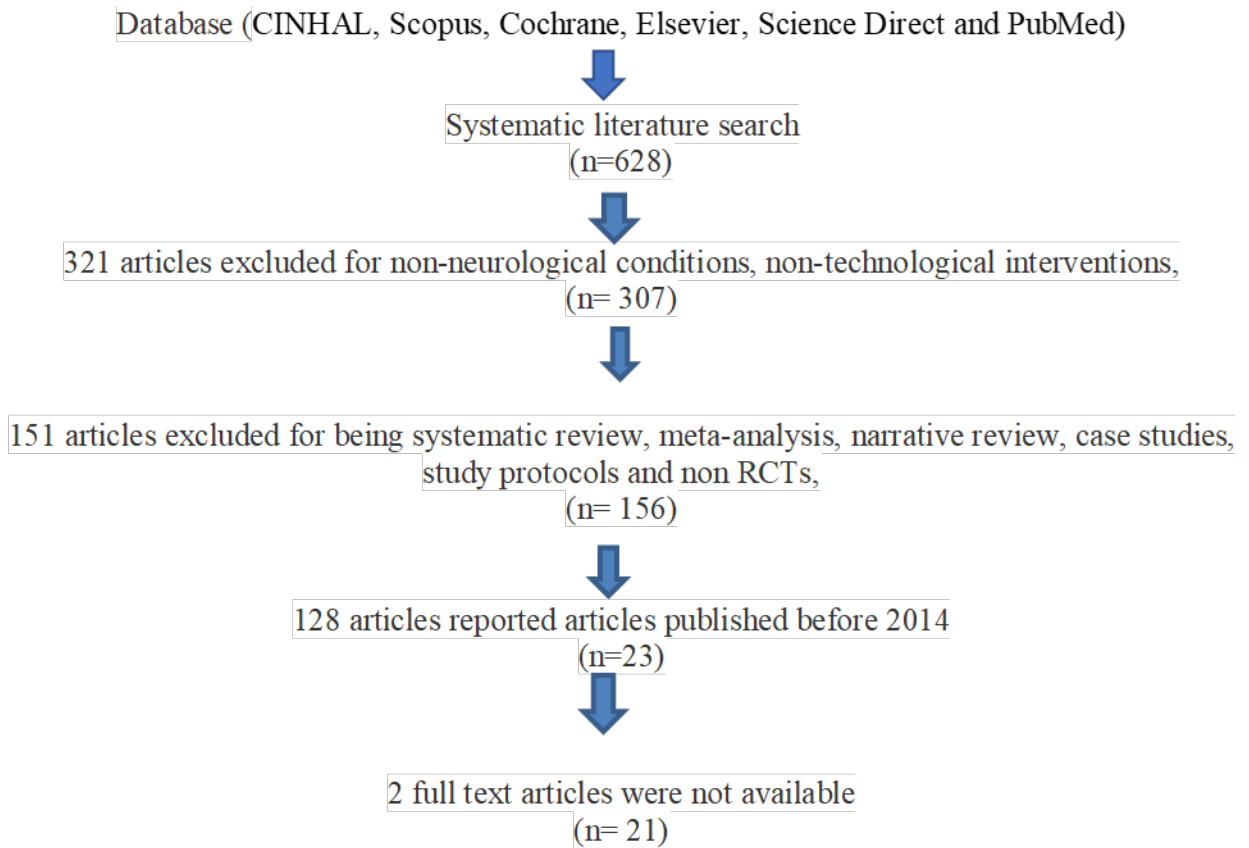
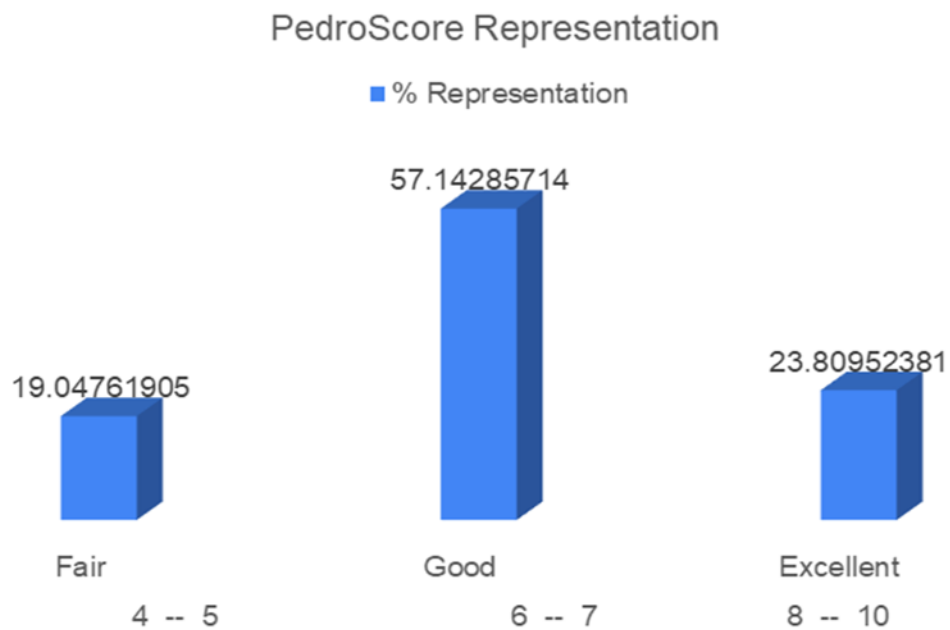


Figure 1: Flowchart representing the process of database search



Graph 1: Showing results of studies scored on the PEDro scale.

Table 1: Showing Review of the literature of the RCTs conducted on technology in neurorehabilitation

Study	n	Population	Technology used	Protocol	Results
(Ang <i>et al.</i> , 2014)	21	Chronic stroke	Electroencephalography (EEG)-based Motor Imagery (MI) Brain-Computer Interface (BCI) with a Haptic Knob (HK) robot.	Eighteen sessions of intervention over six weeks, three sessions per week, 90 min per session.	no intergroup differences were found
(McNulty <i>et al.</i> , 2015)	41	Stroke	Wii-based Movement Therapy	14-day program	No significant difference was found between the group
(Yang <i>et al.</i> , 2016)	23	Idiopathic Parkinson's	custom-made virtual reality balance training system	50-minute sessions twice per week for six weeks	no significant differences on any outcome measure
(Lee <i>et al.</i> , 2017)	50	Stroke	Robot-assisted game training with a rehabilitation robot Neuro-X	IV group = 30 + 30 min of robot assisted+ convention therapy, five days/week for two weeks The CG group =30 mins of conventional therapy	both groups showed significant improvements in motor and daily functions
(Sherrington <i>et al.</i> , 2018)	300	inpatient aged and neurological ill	video and computer games/exercises, tablet applications and activity monitors.	IV = video and computer games CG=no extra intervention	Physical activity was similar in both groups. Mobility was better in the IV group.
(Cramer <i>et al.</i> , 2019)	124	Stroke	home-based telerehabilitation (TR) system via an internet-connected computer	underwent 36 treatment sessions during a 6- to 8-week period	Both the groups showed significant improvement in motor abilities
(Hassett <i>et al.</i> , 2020)	300	Mobility limitations in neurological patients and elderly patients	virtual reality, wearables, and tablet and smartphone applications	IV and CG = conventional physiotherapy, IV group, was added with 30 to 60 5 days /week	There was a significant improvement in mobility in the IV group

*IV=interventional group, CG = control group, n= number of samples, VR= virtualreality, RAGT= robot assisted gait training, EEG= Electroencephalography, MI= Motor Imagery,BCI=Brain-Computer Interface, HK= Haptic Knob robot, TR= telerehabilitation,rTMS= transcranial magnetic stimulation, ILAT=Intensive Language-ActionTherapy

deals with patient's long-term problems (Oña *et al.*, 2018).

Studies have been conducted in India on the prevalence of neurological disorder which are a burden on the available present health care system, as the ratio of neurological patient's to health care is not enough to improve the quality of life and also to provide a long-term follow-up for the residual disabilities which are prevailing and delaying the recovery process. With the analysis of the trends in Asia majorly India has shown the occurrence of stroke among not only senior but also in the young population. (Gourie-Devi, 2014), which supports this study on the use of technology in rehabilitation protocol.

Functional electrical stimulation, transcranial stimulation, robotic assistive devices, body weight treadmill training have all shown improvement in the functional performance of the patient, they have also shown independence to train among the stroke subjects, but when these were compared with traditional techniques, there was no significant improvement among the subjects undergoing the treatment in each groups (Ifejika-Jones and Barrett, 2011), which explains the concept that even though these technologies provide uplift to the recovery process, they have to be provided as an adjunctive therapy, which supports this study on the use of technology as assistive therapy and arising the need of more future studies for its effectiveness.

Technologies as robotic devices, artificial intelligence, gait and balance gym, Nintendo, Wii, virtual training, bionic devices, soft robots, biofeedback, gait and balance sensors, mobile medical app, robotic aided pneumatic pump compressions, telerehabilitation have been on greater use recently and under intense study for their efficacy and their contribution towards the health promotion. With the increase in geriatric population leading to increasing in neurological cases every year and thus putting a strain on the therapist-patient ratio for treatment, these technological innovations have proved to be assistive in rehabilitation and causing a change in the social wellbeing, under the guidance and supervision of the therapist. Still, they haven't been effective enough to replace the work of the therapist.

A study done by (Micera *et al.*, 2005) on MEMOS system, a simple mechatronic device for neurorehabilitation has shown to be an effect on improving the level of impairment, movement accuracy and efficacy, the limitations were cost-effectiveness and workspace. (Dicianno *et al.*, 2015) described the emergence of mHealth technologies and to improve patient satisfaction, deliver care, and pro-

mote health and wellness, as the use of android and smartphones have been on the increase. These mobile apps can connect neurologically ill patients. Studies on children with these technologies also gave a futuristic goal where (Gonsalves *et al.*, 2015) conducted a study with active virtual reality gaming in children with a joint developmental disorder. Results showed that children used slower hand path speed. No data regarding movement outcome were assessed, and when appropriate active virtual reality gaming had to be selected.

Children with cerebral palsy of 3 to 8 years who were given virtual reality environment called REHAB FUN which was a motivating tool for the children to rehabilitate. Improving the quality of health care delivery, patient satisfaction, participation in self-care regimens, and behaviour modification with the evolution of mHealth technologies was explained in the study done by (Dicianno *et al.*, 2015). Their study showed limitations as long-term effects of these apps, acceptability, costs, and risks of such interventions, which warranted more research. Also, such digital therapeutic pose a threat to privacy and security (Choi *et al.*, 2019).

To overcome challenges in the treatment of the neurological ill subjects who pose a burden on the health care sector, on the family and caregivers and the rehabilitation team, there is a dire need for the innovations of cost-effectiveness and feasible of these technologies. These assistive technologies provide drastically improved in the long run, and they are integral to provide adequate training sessions required by the neurological patients. Still, they can be done by the supervision of the therapists; these technologies have not done better when compared with conventional therapy and are supportive of this study.

Assistive technology and specialist come in relevance when function, independence and participation are compromised in subject with muscular dystrophy. Use of small proportional joystick, robotics, Bluetooth capabilities, fall detection systems with built-in Global Positioning System detection, voice activation and texting systems on smartphones and tablets, and "smart home systems have helped in optimising function and improving the quality of life, but still have not provided cost-effective measures, funding and insurance for these devices have been in a critical situation. This supports our study in explaining the need for improvising economically efficient technology-based devices which supports the needed frequent therapy sessions and extended the influence of rehabilitation process even in the inactive hours of the patient. Despite these findings,

a thorough examination is the need of the hour in emerging technology with RCTs, where RCTs form the gold standard in research.

CONCLUSIONS

This study provides an insight for the emerging studies to conduct more multicentric studies or randomised control trial on larger sample size for the use of technology, as availability of these technologies in rural areas where more majority of the disabled population are residing and have the least access to the proper health care system, the feasibility of devices, access, cost-effectiveness, space, needed for the workstation, knowledgeable and skilled therapist on handling these equipment's, efficacy of applying these adjunct technologies at the right time of the rehabilitation process.

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Conflict of Interest

The authors declare that they have no conflict of interest for this study.

REFERENCES

- Ang, K. K., Guan, C., Phua, K. S., Wang, C., Zhou, L., Tang, K. Y., Joseph, G. J. E., Kuah, C. W. K., Chua, K. S. G. 2014. Brain-computer interface-based robotic end effector system for wrist and hand rehabilitation: results of a three-armed randomized controlled trial for chronic stroke. *Frontiers in Neuroengineering*, 7.
- Béjot, Y., Yaffe, K. 2019. Ageing Population: A Neurological Challenge. *Neuroepidemiology*, 52(1-2):76-77.
- Choi, M. J., Kim, H., Nah, H. W., Kang, D. W. 2019. Digital Therapeutics: Emerging New Therapy for Neurologic Deficits after Stroke. *Journal of Stroke*, 21(3):242-258.
- Cramer, S. C., Dodakian, L., Le, V., See, J., Augsburger, R., McKenzie, A., et al. 2019. Efficacy of Home-Based Telerehabilitation vs In-Clinic Therapy for Adults After Stroke. *JAMA Neurology*, 76(9):1079-1079.
- Dicianno, B. E., Parmanto, B., Fairman, A. D., Crytzer, T. M., Yu, D. X., Pramana, G., Coughenour, D., Petrazzi, A. A. 2015. Perspectives on the Evolution of Mobile (mHealth) Technologies and Application to Rehabilitation. *Physical Therapy*, 95(3):397-405.
- Embrey, D. G., Holtz, S. L., Alon, G., Brandsma, B. A., McCoy, S. W. 2010. Functional Electrical Stimulation to Dorsiflexors and Plantar Flexors During Gait to Improve Walking in Adults With Chronic Hemiplegia. *Archives of Physical Medicine and Rehabilitation*, 91(5):687-696.
- Gassert, R., Dietz, V. 2018. Rehabilitation robots for the treatment of sensorimotor deficits: a neurophysiological perspective. *Journal of NeuroEngineering and Rehabilitation*, 15(1):1-15.
- Gonsalves, L., Campbell, A., Jensen, L., Straker, L. 2015. Children With Developmental Coordination Disorder Play Active Virtual Reality Games Differently Than Children With Typical Development. *Physical Therapy*, 95(3):360-368.
- Gourie-Devi, M. 2014. Epidemiology of neurological disorders in India: Review of background, prevalence and incidence of epilepsy, stroke, Parkinson's disease and tremors. *Neurology India*, 62(6):588-588.
- Gupta, N., Raja, K. 2011. Rehabilitation robotics in India. *Journal of Neurosciences in Rural Practice*, 02(02):207-209.
- Hassett, L., van den Berg, M., Lindley, R. I., Crotty, M., McCluskey, A., van der Ploeg, H. P., et al. 2020. Digitally enabled aged care and neurological rehabilitation to enhance outcomes with Activity and Mobility Using Technology (AMOUNT) in Australia: A randomised controlled trial. *PLOS Medicine*, 17(2):e1003029-e1003029.
- Ifejika-Jones, N. L., Barrett, A. M. 2011. Rehabilitation—Emerging Technologies, Innovative Therapies, and Future Objectives. *Neurotherapeutics*, 8(3):452-462.
- Jackson, D., McCrone, P., Turner-Stokes, L. 2013. Costs of caring for adults with long-term neurological conditions. *Journal of Rehabilitation Medicine*, 45(7):653-661.
- Jokel, R., Cupit, J., Rochon, E., Leonard, C. 2009. Relearning lost vocabulary in nonfluent progressive aphasia with MossTalk Words®. *Aphasiology*, 23(2):175-191.
- Jones, T. A., Chu, C. J., Grande, L. A., Gregory, A. D. 1999. Motor Skills Training Enhances Lesion-Induced Structural Plasticity in the Motor Cortex of Adult Rats. *The Journal of Neuroscience*, 19(22):10153-10163.
- Kaur, G., English, C., Hillier, S. 2012. How Physically Active Are People with Stroke in Physiotherapy Sessions Aimed at Improving Motor Function? A Systematic Review. *Stroke Research and Treatment*, 2012(4):1-9.
- Lee, K. W., Kim, S. B., Lee, J. H., Lee, S. J., Kim, J. W. 2017. Effect of Robot-Assisted Game Training

- on Upper Extremity Function in Stroke Patients. *Annals of Rehabilitation Medicine*, 41(4):539–539.
- McNulty, P. A., Thompson-Butel, A. G., Faux, S. G., Lin, G., Katrak, P. H., Harris, L. R., Shiner, C. T. 2015. The Efficacy of Wii-Based Movement Therapy for Upper Limb Rehabilitation in the Chronic Poststroke Period: A Randomized Controlled Trial. *International Journal of Stroke*, 10:1253–1260.
- Mehrholz, J., Thomas, S., Elsner, B. 2017. Treadmill training and body weight support for walking after stroke. *Cochrane Database of Systematic Reviews*, (8).
- Micera, S., Carrozza, M. C., Guglielmelli, E., Cappiello, G., Zaccone, F., Freschi, C., Colombo, R., Mazzone, A., Delconte, C., Pisano, F., Minuco, G., Dario, P. 2005. A Simple Robotic System for Neurorehabilitation. *Autonomous Robots*, 19(3):271–284.
- Oña, E. D., de la Cuerda, R. C., Sánchez-Herrera, P., Balaguer, C., Jardón, A. 2018. A Review of Robotics in Neurorehabilitation: Towards an Automated Process for Upper Limb. *Journal of Healthcare Engineering*, 2018(111):1–19.
- Rodríguez, M. T. S., Vázquez, S. C., Casas, P. M., de la Cuerda, R. C. 2018. Neurorehabilitation and apps: A systematic review of mobile applications. *Neurología (English Edition)*, 33(5):313–326.
- Sherrington, C., Hassett, L., van den Berg, M., Lindley, R., Crotty, M., McCluskey, A., van der Ploeg, H., Smith, S., Schurr, K. 2018. The effectiveness of affordable technology in rehabilitation to improve mobility and physical activity: Amount (activity and mobility using technology) rehabilitation trial. *Annals of Physical and Rehabilitation Medicine*, 61:e86–e86.
- Steenkamp, H., Warren, G., Kruger, P., Boghosi, G. 2003. Statistical Results of an Analysis of the Physiotherapy Department in the Johannesburg Hospital. *South African Journal of Physiotherapy*, 59(2):12–15.
- Westlake, K. P., Patten, C. 2009. A pilot study of Lokomat versus manual-assisted treadmill training for locomotor recovery post-stroke. *Journal of neuro-engineering and rehabilitation*, 6(1).
- Yang, W. C., Wang, H. K., Wu, R. M., Lo, C. S., Lin, K. H. 2016. Home-based virtual reality balance training and conventional balance training in Parkinson's disease: A randomised controlled trial. *Journal of the Formosan Medical Association*, 115(9):734–743.