CASE STUDY

Web-Based Game-Focused Exercise in the Home Setting as an Alternative to Hospital-Based Exercise for Stroke Survivors: A Case Study

Mohd Naqiuddin Johar[1], Nor Azlin Mohd Nordin[2]

[1] Physiotherapy Unit, Hospital Putrajaya, Jalan P9, Presint 7, 62250 Wilayah Persekutuan Putrajaya
[2] Physiotherapy Program, Centre for Rehabilitation and Special Needs Studies, Faculty of Health Sciences, Universiti Kebangsaan Malaysia, Jalan Raja Muda Abdul Aziz, 50300 Kuala Lumpur, Malaysia

ABSTRACT

Stroke survivors require continuous exercise therapy to minimize post stroke weakness and functional decline that eventually affect their motivation level and quality of life. However, frequent hospital-based therapy has become less feasible during COVID-19 pandemic due to fear of infection and other restrictions. Therefore, an alternative exercise method is needed in a home setting. One approach, namely game-focused exercise, has received much attention in recent research, and good evidence has been documented. However, the delivery of game-focused exercises in a home setting with a remote supervision from therapists has not been well researched. This case study dicusses the effects of a web-based, game-focused exercise conducted in the survivor's home setting on the motivation level and quality of life. The case was a 58-year-old post-stroke patient, with good cognitive status (Montreal Cognitive Assessment score = 28) who was recruited to undergo the intervention from February to March 2021. The subject performed a game-focused exercise program using a web-based Checkercise® board for 40 minutes per session, twice a week for eight weeks. The intended outcome of the intervention was measured using the Intrinsic Motivation Inventory (IMI) and Short Form-36 (SF-36) questionnaire. The study results have shown that web-based Checkercise® is doable in the home setting and yielded satisfactory outcomes, with improvement in overall motivation level by 30%, mainly in the subscales of interest/enjoyment, perceived competence, and perceived choice. Further, the subject demonstrated a better health state, illustrated by the lower score in the pressure/tension subscale (22% reduction) of the IMI and increased physical and mental health components score of the SF-36, by 29% and 60%. In conclusion, web-based, game-focused exercise using the Checkercise® board is beneficial in enhancing post-stroke motivation level and quality of life, and may be considered as a therapy option for this population during COVID-19 pandemic time.

Keywords: Stroke, game-focused exercise, web-based, home-based

Corresponding Author:
Mohd Naqiuddin Johar
Email: naqiuddinjohar@moh.gov.my
Tel: 0383124258

INTRODUCTION

Stroke is a major cause of disability in many countries. It was reported that, in 2019, there were nearly 12.2 million incident cases of stroke,101 million prevalent cases of stroke and 143 million disability-adjusted life-years (DALYs) due to stroke globally (Feigin et al. 2021). Annually, about 15 million new cases were reported worldwide, with 5 million survivors left permanently disabled, placing a burden on family and community (World Health Organization 2021). This substantial number of people with a stroke-related disability who require continuous and long-term rehabilitation and healthcare support places a great burden on the healthcare system in most Asian countries including Malaysia (Wijaya et al. 2019). Rehabilitation remains the mainstay of treatment to combat post-stroke disability. Physiotherapy, being a main part of the multidisciplinary rehabilitation program is important, aiming at improving post-stroke physical functions with the use of multiple modalities such as therapeutic exercise, electrophysical agents, manual therapy, virtual reality therapy, mirror therapy, robotic therapy, biofeedback electromyograph therapy and acupuncture (American Heart Association Stroke Council 2016; Australian Government National Health and Medical Research Council 2017; Heart and Stroke Foundation of Canada 2016; Kementerian Kesihatan Malaysia 2012). During hospitalization for acute and sub-acute stroke, the service is provided and normally continued in out-patient settings once the stroke patient is discharged.

Due to the coronavirus disease 2019 (COVID-19) pandemic, rehabilitation facilities have become less accessible for patients with a stroke where reports have shown that as much as 39% of stroke survivors who had a stroke in 2019 claimed deprived of rehabilitation therapies, including physiotherapy (Stroke Association 2020). Lack of intensive rehabilitation hinders the opportunity for recovery especially during the critical time window of endogenous plasticity and improvement post-stroke (Lee et al. 2015). Functional impairments caused by stroke lead to dependency in daily living activities, which consequently reduces the motivation level (Mahmoud et al. 2016) and health related quality of life (Kwon et al. 2018).

One solution to these problems is the use of tele-stroke rehabilitation in the patients' home environment as an alternative to hospital-based rehabilitation. Many studies have analysed the effectiveness of tele-rehabilitation, with the majority reporting that tele-rehabilitation is comparable to in-clinic rehabilitation in terms of improving motor, language, and cognitive functions (Laver et al. 2020). The online rehabilitation program includes telephone-based, web-based video conferencing and virtual reality-based exercise. However, web-based video conferencing was the most utilized tele-rehabilitation, and this approach has been reported to contribute towards better motivation level (Chemtob et al. 2019; Yeh et al. 2011) and improved quality of life (Wu et al. 2020) after stroke, which can be detected using Brunel Mood Scale and Treatment Self-Regulation Questionnaire and Stroke Specific Quality of Life, respectively.

Another approach that is considered motivating is game-focused exercise. Therapeutic exercise with a focus on gaming is the most utilized physiotherapy modality for stroke survivors in the recent times. The game actions performed by stroke survivors in the game-focused stroke rehabilitation interact with game challenges such as soccer, boxing, athletics, and others. It can be delivered either through robotic-assisted (Bustamante Valles et al. 2016; Kim et al. 2015; Nijenhuis et al. 2015; Olafsdottir et al. 2020; Park et al. 2019; Wolf et al. 2015) or virtual based therapy (Standen et al. 2017; Wittmann et al. 2016); with the individual session normally conducted in the form of home-based exercise. Gamification improves attitudes towards and enjoyment of exercise and shapes behavior in terms of increase in exercise activity (Goh & Razikin 2015).

To date, despite being increasingly used in physiotherapy, both tele-rehabilitation and game-focused exercise has never been combined to provide a new training experience for stroke survivors undergoing rehabilitation in a home setting. Combining the two training programs may create a more enriched environment and yield favourable outcomes. In this case study, we report the use of a web-based, game-focused exercise on a 58-year-old post-stroke patient, who was referred for physiotherapy in a state hospital of Kelantan, Malaysia. The case study aims to determine the effects of a web-based, game-focused exercise conducted in the survivor's home setting on motivation and quality of life.

THE CASE STUDY

The subject was diagnosed with left cerebrovascular accident (CVA) and associated right hemiparesis for three months prior to enrolment into the study. He had ischemic stroke secondary to uncontrolled hypertension. There was no other history of other medical conditions except hypertension. He was prescribed with aspirin and metoprolol once daily and he is currently on a regular follow-up for the ischemic stroke. His main functional problems at the initial physiotherapy session were: (1) difficulty with high level walking tasks such as ascending and descending stairs and walking outdoor due to right-sided weakness and fatigue, and (2) some unsteadiness during prolonged standing. However, he had never used or was prescribed any ambulatory aids since diagnosed with stroke. He claimed that his fitness level has declined since the stroke onset, and he currently performs once per week walking exercise for about 20 to 30 minutes per session in his residential area.

Due to the COVID-19-related Movement Control Order (MCO) imposed by the government and fear of infection, he was not keen to attend face-to-face hospital based-physiotherapy. Thus, as an alternative intervention, we prescribed a home exercise program for him with the use of a newly designed web-based game-focused exercise termed as Checkercise® board (Figure 1). The Checkercise® board is specifically designed to facilitates stroke survivors' recovery and contains exercises in the form of games similar to the 'snake and ladder' game board which comprised of fate, competition and reward elements.

Prior to starting the exercise, his functional status was screened, and he has shown the ability to: (1) walk continuously for ten meters independently without a walking aid, (2) perform basic activities of daily living such as walking, stepping up and turning without a walking aid, and (3) hold a glass full of water in the non-affected hand. He has no other co-morbidities which limit exercise participation such as orthopedic conditions resulting in joint deformities. He is slightly overweight, with a body mass index calculated as 26.3 kg/m^2. His vision and hearing sensation were normal. He has a good cognitive function, which is indicated by a Montreal Cognitive Assessment score of 28.

The subject performed the web-based Checkercise® board exercises at a metronome pace, two times per week, under remote monitoring by the researcher (Figure 2 and 3). Exercise adherence and the level of exercise intensity (e.g. low, moderate, vigorous) were monitored using practice sessions checklist and Borg Scale Rate of Perceived Exertion, respectively. Table I shows the exercise program details which were based on frequency, intensity, time and type (FITT) principle. The exercise duration for each task was two minutes interspersed by two minutes rest with a total of ten exercises to be performed in each exercise session for an estimated duration of 40 minutes. All selected exercises focused on advanced and challenging task-

Figure 1: Some examples of exercises included in the Checkercise® board

oriented activities to trigger automatic responses, divided attention and multi-tasking ability.

As mentioned earlier, the design of the Checkercise® board is similar to the 'snake and ladder' game board. To use the Checkercise® board, the subject was first required to report his pre-exercise vital sign. To 'start', he had to roll a dice by pressing 'dice symbol' Exercises performed would depend on where his counter landed on the board each time the dice was rolled, as each space shows a different exercise task. There was also a possibility of being penalized during the training if their counter landed on 'penalty spaces', such as spaces which indicate 'slide back a few spaces, and 'move to a certain board number'. The game-based circuit exercises were considered completed when his counter arrived at a space that indicated 'finish'. Eventually, he had to report post-exercise rate of perceived exertion using a Borg Scale after completing each exercise video.

In this case, we decided to focus on two outcomes, namely motivation level and self-rated quality of life. Two standardized tools were used to assess the

Table I: Description of the web-based game-focused exercise (Checkercise® board)

Formula	Resistance exercise	Balance exercise	Aerobic exercise
	Repeated sit to stand	**Walking on balance beam**	**Alternate jab**
Frequency	2 sessions/week	2 sessions/week	2 sessions/week
Intensity	Speed at 50 beats per minute	Speed at 30 beats per minute	Speed at 100 beats per minute
Time	1 minute	1 minute	1 minute
Technique	Alternate seated to standing (without load)	Walking on balance beam (follow rhythm)	Repeated jab punching (follow rhythm)
Progression	Alternate seated to standing (lifting up 2 kg of dumbbell)	Tandem walking (follow rhythm)	Repeated double jab punching with defense (follow rhythm)
	Repeated partial squat	**Figure of 8 walking**	**Alternate hook**
Frequency	2 sessions/week	2 sessions/week	2 sessions/week
Intensity	Speed at 30 beats per minute	Speed at 45 beats per minute	Speed at 100 beats per minute
Time	1 minute	1 minute	1 minute
Technique	Standing, partial squats with arm support as needed (without load)	Figure of 8 walking (follow rhythm)	Repeated hook punching (follow rhythm)
Progression	Standing, partial squats with arm support as needed (Lifting up 2 kg of dumbbell/speed at 50 beats per minute)	Figure of 8 walking while holding cup of water	Repeated alternate hook with kicking (follow rhythm)
	Repeated step up & down	**Walking with instruction**	**Double jab & hook**
Frequency	2 sessions/week	2 sessions/week	2 sessions/week
Intensity	Speed at 70 beats per minute	-	Speed at 100 beats per minute
Time	1 minute	1 minute	1 minute
Technique	Standing, alternate steps-ups on the 8-inches step (without load)	Walking & stop (closed eyes in static standing)	Repeated double jab punching with hook (follow rhythm)
Progression	Standing, alternate steps-ups on the 8 inches step board (Lifting up 2 kg of dumbbell/speed at 75 beats per minute)	Walking while sudden change instruction	Repeated double jab punching with hook & squat (follow rhythm)
	Standing; repeated hip raise	**Walk & touch cones**	**Double jab**
Frequency	2 sessions/week	2 sessions/week	2 sessions/week
Intensity	Speed at 45 beats per minute	Speed at 20 beats per minute	Speed at 100 beats per minute
Time	1 minute	1 minute	1 minute
Technique	Standing, alternate raises hip (without load)	Walk & touch cones cuboid shape (follow rhythm)	Repeated double jab punching with defense & kick (follow rhythm)
Progression	Standing, alternate raises hip (Lifting up 2 kg of dumbbell/speed at 50 beats per minute)	Walk & touch cones hexagon shape (follow rhythm)	Repeated double jab punching with squat (follow rhythm)
	Standing; repeated heel raise	**Backward walking**	**Cross straight**
Frequency	2 sessions/week	2 sessions/week	2 sessions/week
Intensity	Speed at 70 beats per minute	Speed at 45 beats per minute	Speed at 100 beats per minute
Time	1 minute	1 minute	1 minute
Technique	Standing, alternate raises heel (without load)	Backward walking (follow rhythm)	Repeated cross straight punching (follow rhythm)
Progression	Standing, alternate raises heel (Lifting up 2 kg of dumbbell/speed at 75 beats per minute)	Backward walking (follow rhythm for 2 minutes)	Repeated 4 times cross straight punching with squat (follow rhythm)

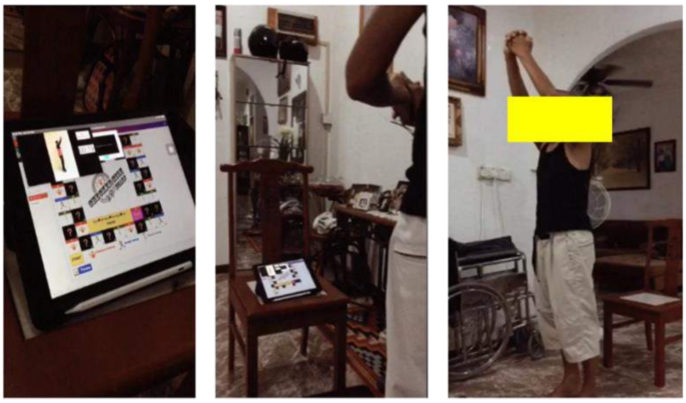

Figure 2: Photos of the subject performing web-based game-focused exercise at home

targeted outcomes, which were Intrinsic Motivation Inventory (IMI) and Short Form-36 (SF-36) Bahasa Malaysia version. The inventory consists of four subscales with a total of 22 questions that were calculated separately; 1) interest and enjoyment (seven questions); 2) perceived competence (five questions), perceived choice (five items) and pressure and tension (five items). The IMI has an adequate reliability value, indicated by Cronbach's α coefficient (ICC = 0.85) (McAuley et al. 1989). The score ranges from 1 to 7 (1 indicates 'not at all true'; 4 indicates 'somewhat true'; 7 indicates 'very true') and a higher total score signifies a higher level of motivation level (high 7.00-4.67; average 4.66-2.34; low 2.33-1.00) except for the pressure and tension subscale (the lower score the better). As for the SF-36 Bahasa Malaysia version, the questionnaire contains eight health state domains (36 questions)

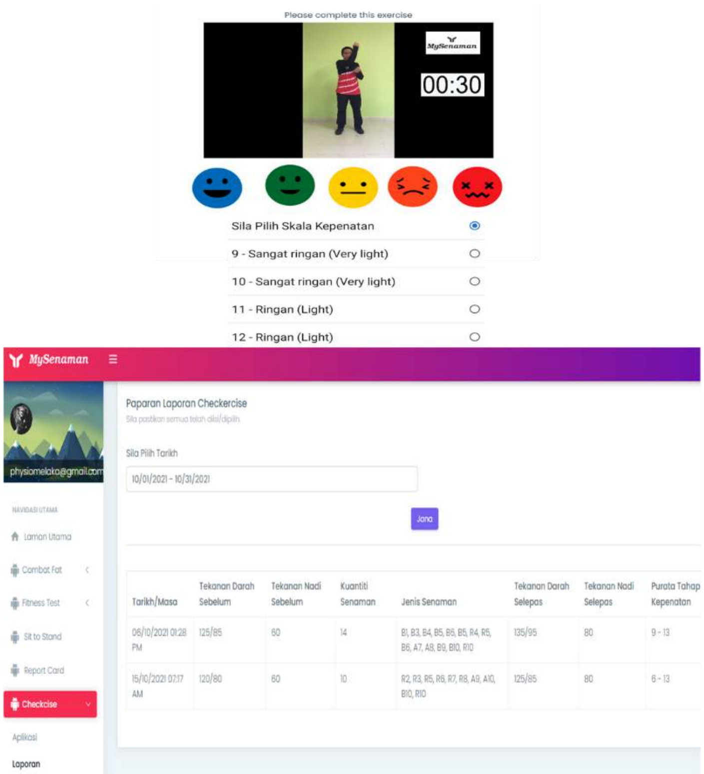

Figure 3: The web-based game-focused exercise monitoring platform

namely: (1) physical health component represented by physical functioning (ten questions), role limitation due to physical health (four questions) and pain (two questions), (2) mental health component represented by social functioning (two questions), role limitation due to mental problem (three questions) and emotional wellbeing (five questions), and (3) physical and mental health component represented by general health (five questions) and energy/fatigue four questions). The SF-36 was shown to have moderate to high test-retest reliability in stroke survivors (0.57 < ICC < 0.8) (Dorman et al. 1998) and adequate to good correlation with the EuroQol (r = 0.66), EuroQol-5 Dimensions (EQ-5D) (r = 0.68) (Katona et al. 2015) and Health Related Quality of Life in Stroke Patient (0.47 < r < 0.79) (Ojo Owolabi 2010). The total score ranges from 0 to 100, with higher scores indicating a better quality of life.

Table II: Changes in all outcomes post-intervention (week 8)

Measures	Baseline	Week 8	Changes
Short Form-36			
a. Physical component	38.3	49.2	29%
b. Mental component	43.7	70	60%
c. Overall	55	70	27%
Intrinsic Motivation Inventory			
1. Interest/enjoyment	4.6	6.5	41%
2. Perceived competence	4.6	6.4	39%
3. Perceived choice	4.4	5.2	18%
4. Pressure/tension	3.6	2.8	22%

At the start of the intervention, the subject's general score of IMI indicated that he has an average level of motivation, in the subscales of interest/enjoyment (4.6/7), perceived competence (4.6/7) and perceived choice (4.4/7). He scored 3.6/7 in the pressure/tension subscale, indicating moderate stress level. On the SF-36 assessment, his physical and mental component scores were only 38.3 and 43.7 out of 100, respectively with an overall score of 55. Through the trial, the subject was able to perform all 16 web-based sessions with a 100% attendance rate. He reported no complains of any adverse effects between or after each exercise session. The subject perceived the web-based application as easy to use and provided interesting experience, which helped him adhere to his exercise therapy. After eight weeks of intervention, the subject showed improvement in overall motivation level by 30%, with a significant increase in the score of interest/enjoyment (6.5/7), perceived competence (6.4/7), and perceived choice (5.2/7) subscales, with a change of 1.9 points, 1.8 points and 0.8 points, respectively, in these subscales. Further, the subject felt less pressure/tension with a 22% reduction in the score of this subscale. Increment in physical and mental component of SF-36 by 29% and 60% was also found, with his overall score perceived as 70 out of 100 at week 8 of exercise. The subject's changes in all outcomes post-intervention are shown in Table II.

DISCUSSION

The purpose of this case study was to evaluate changes in motivation level and quality of life of a stroke survivor following a web-based game-focused exercise using a Checkercise® board. Due to the unavailability of similar combined training interventions in previous studies, we cannot compare our results directly with past research. However, we will discuss our findings with reference to studies with similar training components.

We found improvement in our subjects' motivation level, as indicated by favourable changes in all IMI subscales score following the web-based exercise using Checkercise®. This finding is consistent with the results of 21 chronic stroke survivors in an earlier study by Nijenhuis and co-researchers (2015) following virtual reality-based therapy for six weeks. Similar to us, the researchers used IMI as the outcome measure for motivation level. Our study findings also support the findings of another study (Yeh et al. 2011) which demonstrated positive improvement in motivation level among individuals with stroke, traumatic brain injury and spinal cord injury, assessed using the Brunel Mood Scale. They pointed out that a video conferencing was beneficial in improving balance among 14 participants who enrolled in the study. Chemtob and colleagues (2019) likewise reported improvement in the motivation level of 24 individuals with spinal cord measured using the Treatment Self-Regulation Questionnaire after one hour of weekly tele-rehabilitation session using video conferencing for eight weeks compared to a standard routine.

We believe that the improvement in our subject's IMI score was partly contributed by the interesting and enriched exercise environment induced by the game-focused exercise. Each exercise task in the Checkercise® board offers a rather challenging experience as subject needs to response to multisensory stimuli and cueing, cognitive stimuli, and perform various limb integration movements to optimize neurology recovery potentials (Nithianantharajah & Hannan 2006). Training in such an enriched environment can promote neuroplasticity (Livingston-Thomas et al. 2016) and facilitate personalized motivation and cease stress and anxiety among stroke survivors (Hordacre et al. 2016; Rosbergen et al. 2017).

We also found that our subject exhibited an improvement in the better quality of life as measured using a SF-36 following the eight-week intervention. Corroborating our findings, Wu and colleagues (2020) described results after a tele-stroke rehabilitation using web-based video conferencing designed for 61 community-dwelling stroke survivors for a 12-week period compared to a telephone- based program. They detected a significantly greater improvement in quality of life, measured using a Stroke Specific Quality of Life scale. In another randomized controlled trial in the United States, Forducey and colleagues (2012) evaluated the effects of a 6-week telephone-based education on 32 subacute and chronic stroke survivors compared to the usual face-to-face session. They reported that the telephone-based education resulted in improved quality of life, which was assessed using a Short Form-12 quality of life questionnaire.

The element of enriched exercise environment could also be a factor affecting stroke survivors' activity engagement in rehabilitation sessions (Janssen et al. 2014). It has also been found that significant improvements in functional and cognitive ability were gained following enriched training environment and sustained up to three to six months post-intervention (Khan et al. 2016; Rosbergen et al. 2017). As functional and cognitive ability are pre-requisite to satisfactory quality of life, these could explain the positive change in the score of SF-36 in our subject. Active participation of our stroke survivor in the web-based Checkercise® program may have also enhanced his self-management ability. Self-management ability significantly influences goal setting and achievement for self-management behaviour, emotional state and functional mobility (Hwang et al. 2021). We believe that with the increased in self-management ability, our subjects are more efficient in his daily activities, hence improved sense of general state and perceived quality of life (French et al. 2016).

Our study is subjected to one main limitation. As a case study, its findings could not represent or be applicable to any other stroke patients. A stroke patient with different socio-demography and medical backgrounds may respond differently to the web-based game-focused intervention. However, our study has somehow demonstrated that a carefully selected stroke survivor could be effectively trained to use of a web-based exercise application and successfully completed a challenging, enriched exercise program with a minimal remote supervision. Web-based exercise using the Checkercise® board could be performed as a daily routine in the home environment without professional supervision, especially for those who may have difficulty receiving rehabilitation at the centre for various reasons. This advanced therapy is suitable among stroke survivors with higher-functionality level in regaining their pre-morbid life state.

CONCLUSION

We demonstrated that a web-based, game-focused exercise using the Checkercise® board is beneficial in enhancing post-stroke motivation level and quality of life and may be considered a therapy option for stroke survivors during the COVID-19 pandemic time.

ACKNOWLEDGEMENTS

The authors would like to thank the subject who have voluntarily involved in this case study, and the National

Medical Research Review, Kementerian Kesihatan Malaysia for approving the actual main study (NMRR-20-2715-57464).

CONFLICT OF INTEREST

The authors declare no conflict of interest.

FUNDING

This study did not receive any funding.

REFERENCES

1. American Heart Association Stroke Council. (2016). Guidelines for adult stroke rehabilitation and recovery. *Stroke, 47*(6): e98–e169.
2. Australian Government National Health and Medical Research Council. (2017). *Clinical Guidelines for Stroke Management 2017.* Australian Clinical Practice Guidelines. https://www.clinicalguidelines.gov.au/portal/2585/clinical-guidelines-stroke-management-2017
3. Bustamante Valles, K., Montes, S., Madrigal, M. D. J., Burciaga, A., Martínez, M. E., & Johnson, M. J. (2016). Technology-assisted stroke rehabilitation in Mexico: A pilot randomized trial comparing traditional therapy to circuit training in a Robot/technology-assisted therapy gym. *Journal of NeuroEngineering and Rehabilitation, 13*(1).
4. Chemtob, K., Rocchi, M., Arbour-Nicitopoulos, K., Kairy, D., Fillion, B., & Sweet, S. N. (2019). Using tele-health to enhance motivation, leisure time physical activity, and quality of life in adults with spinal cord injury: A self-determination theory-based pilot randomized control trial. *Psychology of Sport and Exercise, 43,* 243-252.
5. Dorman, P., Slattery, J., Farrell, B., Dennis, M., & Sandercock, P. (1998). Qualitative comparison of the reliability of health status assessments with the EuroQol and SF-36 questionnaires after stroke. *Stroke, 29*(1), 63-68.
6. Feigin, V. L., Vos, T., Alahdab, F., Amit, A. M. L., Bärnighausen, T. W., Beghi, E., Beheshti, M., et al. (2021). Burden of neurological disorders across the United State from 1990-2017: A global burden of disease study. *JAMA Neurology, 78*(2), 165-176.
7. Forducey, P. G., Glueckauf, R. L., Bergquist, T. F., Maheu, M. M., & Yutsis, M. (2012). Telehealth for persons with severe functional disabilities and their caregivers: Facilitating self-care management in the home setting. *Psychological Services, 9*(2), 144-162.
8. French, B., Thomas, L., Coupe, J., McMahon, N., Connell, L., Harrison, J., Sutton, C., et al. (2016). Repetitive task training for improving functional ability after stroke. *Cochrane Database of Systematic Reviews, 11*(11), CD006073.
9. Goh, D.HL. & Razikin, K. (2015). Is gamification effective in motivating exercise? In: Kurosu, M. (eds) Human-Computer Interaction: Interaction Technologies. HCI 2015. *Lecture Notes in Computer Science, vol 9170*. Springer, Cham.
10. Heart and Stroke Foundation of Canada. (2016). Canadian stroke best practice recommendations: Stroke rehabilitation practice guidelines, update 2015. *International Journal of Stroke, 11*(4), 459-484.
11. Hordacre, B., Immink, M. A., Ridding, M. C., & Hillier, S. (2016). Perceptual-motor learning benefits from increased stress and anxiety. *Human Movement Science, 49,* 36-46.
12. Hwang, N.-K., Park, J.-S., & Chang, M.-Y. 2021. Telehealth interventions to support self-management in stroke survivors: A systematic review. *Healthcare, 9*(4), 472.
13. Janssen, H., Ada, L., Bernhardt, J., McElduff, P., Pollack, M., Nilsson, M., & Spratt, N. J. (2014). An enriched environment increases activity in stroke patients undergoing rehabilitation in a mixed rehabilitation unit: A pilot non-randomized controlled trial. *Disability and Rehabilitation, 36*(3), 255-262.
14. Katona, M., Schmidt, R., Schupp, W., & Graessel, E. (2015). Predictors of health-related quality of life in stroke patients after neurological inpatient rehabilitation: A prospective study. *Health and Quality of Life Outcomes, 13*(1).
15. Kementerian Kesihatan Malaysia. (2012). *Clinical Practice Guidelines: Management of stroke 2nd edition*. *Kementerian Kesihatan Malaysia*.
16. Khan, F., Amatya, B., Elmalik, A., Lowe, M., Ng, L., Reid, I., & Galea, M. P. (2016). An enriched environmental programme during inpatient neuro-rehabilitation: A randomized controlled trial. *Journal of Rehabilitation Medicine, 48*(5), 417-425.
17. Kim, G. J., Rivera, L., & Stein, J. (2015). Combined clinic-home approach for upper limb robotic therapy after stroke: A pilot study. *Archives of Physical Medicine and Rehabilitation, 96*(12), 2243-2248.
18. Kwon, S., Park, J.-H., Kim, W.-S., Han, K., Lee, Y., & Paik, N.-J. (2018). Health-related quality of life and related factors in stroke survivors: Data from Korea National Health and Nutrition Examination Survey (KNHANES) 2008 to 2014. (C.-Y. Lin, Ed.). *PLOS ONE, 13*(4), e0195713.
19. Laver, K. E., Adey-Wakeling, Z., Crotty, M., Lannin, N. A., George, S., & Sherrington, C. (2020). Tele-rehabilitation services for stroke. *Cochrane Database of Systematic Reviews, 2020*(1).
20. Lee, K. B., Lim, S. H., Kim, K. H., Kim, K. J., Kim, Y. R., Chang, W. N., Yeom, J. W., et al. (2015). Six-month functional recovery of stroke patients: A multi-time-point study. *International Journal of Rehabilitation Research, 38*(2), 173-180.
21. Livingston-Thomas, J., Nelson, P., Karthikeyan, S., Antonescu, S., Jeffers, M. S., Marzolini, S., & Corbett, D. (2016). Exercise and environmental enrichment as enablers of task-specific neuroplasticity and stroke recovery. *Neurotherapeutics, 13*, 395-402.
22. Mahmoud, S., Ahmed, N., & Elaziz, A. (2016). Impact of stroke on life satisfaction and psychological adjustment among stroke patients during rehabilitation. *Life Science Journal, 13*(3), 1097-8135.
23. McAuley, E. D., Duncan, T., & Tammen, V. V. (1989). Psychometric properties of the intrinsic motivation inventoiy in a competitive sport setting: A confirmatory factor analysis. *Research Quarterly for Exercise and Sport, 60*(1), 48-58.
24. Nijenhuis, S. M., Prange, G. B., Amirabdollahian, F., Sale, P., Infarinato, F., Nasr, N., Mountain, G., et al. (2015). Feasibility study into self-administered training at home using an arm and hand device with motivational gaming environment in chronic stroke. *Journal of NeuroEngineering and Rehabilitation, 12*(1), 89.
25. Nithianantharajah, J. & Hannan, A. J. (2006). Enriched environments, experience-dependent plasticity and disorders of the nervous system. *Nature Reviews Neuroscience, 7*(9), 697-709.
26. Ojo Owolabi, M. (2010). Psychometric properties of the HRQOLISP-40: A novel, shortened multiculturally valid holistic stroke measure. *Neurorehabilitation and Neural Repair, 24*(9), 814-825.

27. Olafsdottir, S. A., Jonsdottir, H., Bjartmarz, I., Magnusson, C., Caltenco, H., Kytö, M., Maye, L., et al. (2020). Feasibility of ActivABLES to promote home-based exercise and physical activity of community-dwelling stroke survivors with support from caregivers: A mixed methods study. *BMC health services research, 20*(1), 562.
28. Park, J. S., Lee, G., Choi, J. B., Hwang, N. K., & Jung, Y. J. (2019). Game-based hand resistance exercise versus traditional manual hand exercises for improving hand strength, motor function, and compliance in stroke patients: A multi-center randomized controlled study. *Neuro Rehabilitation, 45*(2), 221-227.
29. Rosbergen, I. C. M., Grimley, R. S., Hayward, K. S., Walker, K. C., Rowley, D., Campbell, A. M., McGufficke, S., et al. (2017). Embedding an enriched environment in an acute stroke unit increases activity in people with stroke: A controlled before-after pilot study. *Clinical Rehabilitation, 31*(11), 1516-1528.
30. Standen, P. J., Threapleton, K., Richardson, A., Connell, L., Brown, D. J., Battersby, S., Platts, F., et al. (2017). A low-cost virtual reality system for home-based rehabilitation of the arm following stroke: A randomised controlled feasibility trial. *Clinical Rehabilitation, 31*(3), 340-350.
31. Stroke Association. 2020. *Stroke recoveries at risk.*
32. Wijaya, H. R., Supriyanto, E., Salim, M. I. M., Siregar, K. N., & Eryando, T. (2019). *Stroke management cost: Review in Indonesia, Malaysia and Singapore.* AIP Conference Proceedings, Vol. 2092, 30022. American Institute of Physics Inc.
33. Wittmann, F., Held, J. P., Lambercy, O., Starkey, M. L., Curt, A., Höver, R., Gassert, R., et al. (2016). Self-directed arm therapy at home after stroke with a sensor-based virtual reality training system. *Journal of NeuroEngineering and Rehabilitation, 13*(1), 75.
34. Wolf, S. L., Sahu, K., Bay, R. C., Buchanan, S., Reiss, A., Linder, S., Rosenfeldt, A., et al. (2015). The HAAPI (Home Arm Assistance Progression Initiative) trial: A novel robotics delivery approach in stroke rehabilitation. *Neurorehabilitation and Neural Repair, 29*(10), 958-968.
35. World Health Organization. (2021). *Stroke, cerebrovascular accident.* World Health Organization. http://www.emro.who.int/health-topics/stroke-cerebrovascular-accident/index.html
36. Wu, Z., Xu, J., Yue, C., Li, Y., & Liang, Y. (2020). Collaborative care model based telerehabilitation exercise training program for acute stroke patients in China: A randomized controlled trial. *Journal of Stroke and Cerebrovascular Diseases, 29*(12).
37. Yeh, S. C., McLaughlin, M., Nam, Y., Sanders, S., Chang, C., Kennedy, B., Flynn, S., et al. (2011). *Emotions and telerehabilitation: Pilot clinical trials for virtual telerehabilitation application using haptic device and its impact on post stroke patients' mood and motivation.* Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), Vol. 6774 LNCS, 119-128. Springer, Berlin, Heidelberg.