CASE STUDY

Cognitive-Focused Game-Based Compared to Game-Based Circuit Exercise for Two Stroke Survivors: A Case Report

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ABSTRACT

Stroke survivors require continuous exercise therapy to minimize post-stroke cognitive impairment, eventually affecting their functional decline and motivation. Game-based cognitive training has received much attention in past research, and good evidence has been documented. Meanwhile, adding cognitive training into an exercise in the form of circuit exercise has been recommended to improve strength, endurance, cognition, and sleep quality and reduce depression post-stroke. Therefore, this study aimed to determine the effects of a cognitive-focused game-based circuit exercise on functions, notably lower limb strength, postural stability and aerobic endurance and the motivation level of stroke survivors in comparison to game-based circuit exercise. This research was a case study involving two chronic stage post-stroke survivors (age = 54 to 58 years old; Montreal Cognitive Assessment score = 26 to 28) conducted between January and March 2023. The participants performed a 40-minute cognitive-focused or game-based circuit exercise using Othellocise or Checkercise® board, respectively. Both therapies continued twice per week for eight weeks. Lower limb strength, postural stability and aerobic endurance were measured using the 30-second chair rise test, Dynamic Gait Index and 6-minute walk test. The outcome of the intervention concerning motivation level was measured with the use of the Intrinsic Motivation Inventory. Cognitive-focused game-based circuit exercise using Othellocise was found to be feasible. It yielded satisfactory outcomes with improved functions compared to game-based circuit exercises using Checkercise® (9% in lower limb strength vs 10%, 10% in postural stability vs 33%, 41% in aerobic endurance vs 21%). Overall motivation level increased by 30% vs 12% for the domain of interest/enjoyment, perceived competence and perceived choice subscales. Further, subjects felt less pressure/tension, with a 63% vs 22% reduction in this subscale. The increased of Montreal Cognitive Assessment was 8% vs 4%. In conclusion, cognitive-focused game-based Othellocise is potentially improving the functions and motivation levels of stroke survivors and may be used as a therapy option for this population.

Keywords: Stroke; Cognitive-focused game-based exercise; Game-based exercise

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INTRODUCTION

Stroke is highly prevalent globally and is an essential cause of cognitive impairment. This increasing burden of stroke significantly impacts the incidence and prevalence of post-stroke cognitive impairment (Cherkos et al. 2023; Fuad et al. 2020; Kaddumukasa et al. 2023). After a stroke, impaired cognitive and motor functions are the main factors causing a significant decline in performance in activities of daily living (Lee et al. 2021). The interaction between cognitive and motor functions is essential in achieving rehabilitation goals in stroke survivors (Einstad et al. 2021; Mori et al. 2021). Thus, mutual, simultaneous improvement of cognitive and motor function can be essential for improving overall function in stroke survivors.

Cognitive training has been proven to improve mild cognitive impairment after stroke. Game-based cognitive training through mobile phone software applications (Malisa & Kirana 2021), computerized virtual reality (Liu et al. 2023) and serious gaming system (Jung et al. 2020) have detected significant improvements in cognition, measured using The Functional Assessment of Cancer Therapy-Cognitive (FACT-Cog), Montreal Cognitive Assessment (MoCA), trail-making test-A, digit symbol substitution test, digital span test, verbal fluency test and Mini-Mental State Examination.

A meta-analysis study concluded that physical exercise significantly improves cognitive function in stroke survivors (Hernadenz & Gonzales-Galvez 2021). Adding cognitive training into an exercise in circuit training has been recommended to improve strength, endurance, cognition, and sleep quality and reduce depression post-stroke (Kim & Cho 2022; Koch et al. 2020). Combining the two training programs may create a more enriched environment and yield favorable outcomes. Our novelty is to merge the two pieces of training and evaluate the effectiveness of cognitive game-focused circuit exercises on stroke survivors' functions and motivation levels. In this case report, we described the cognitive-focused game-based circuit exercise in a 54-year-old Malay adult as compared to the game-based circuit exercise in a 58-year-old Malay adult referred to the physiotherapy department of a state hospital in Wilayah Persekutuan Putrajaya, Malaysia, for rehabilitation.

CASE REPORT

Two individuals in the sub-acute phase post-stroke participated. Both had experienced their stroke at least three months prior to the study. They were randomly assigned to the cognitive-focused or game-based circuit exercise. Both had cerebral vascular accidents. One was female, and the other male. Prior to exercise, they were: 1) able to walk continuously for ten meters independently without a walking aid, 2) able to perform basic instrumental activities of daily living such as walking, stepping up and turning with or without a walking aid, 3) able to hold a glass full of water in the non-affected hand, 4) clear from any orthopaedic conditions resulting in joint deformities such as severe osteoarthritis or rheumatoid arthritis, or visual field defects.

Mr A was a 58-year-old male who had sustained a multifocal cerebral infarction 4 months before. He had an active movement of his involved upper and lower extremities. Receptively his communication was intact. His mobility goal was to walk on uneven surfaces. He has excellent cognitive function with MoCA scoring of 28/30. At the same time, Mrs B was a 54-year-old female who sustained a right paro-sagittal infarct stroke 6 months, three months prior to the start of the study (months post-stroke). She worked as a teacher when she experienced her stroke after finishing her class. At the time of the study, she was deployed to office light duty work and described herself as “not being very physically active”. Her communication was receptively intact. Her mobility goals were to walk with more control and shop in a busy, distracting “environment”. She has mild cognitive impairment with MoCA scoring of 26/30. Their baseline characteristics are shown in Table 1.

Participants were tested before training and three months after training. Lower limb strength was collected using the 30-second chair rise test. In the stroke population, interrater reliability and intrarater reliability were 0.88 and 0.94 and 0.87 and 0.91 for the 30-second chair rise test, respectively (Johansen et al. 2016). Postural stability was assessed using the Dynamic Gait Index (DGI). In the stroke population, interrater reliability was 0.98 (Alghadir et al. 2018). Aerobic endurance was measured as the distance during the 6-minute walk test. In the stroke population, test-retest reliability was 0.98 for the 6-minute walk test (Macchiavelli et al. 2021). The other outcome measure used was Intrinsic Motivation Inventory (IMI) to assess motivation level. The inventory consists of four subscales with a total of 22 questions that were calculated separately; 1) interest and enjoyment (eight 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 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). Outcome measures were administered by the same tester who was blinded to the group assignment and the details of the intervention.

Table 1: Characteristics of the participants

Baseline variables	Measure	
	Mr A	Mrs B
Age (years)	58	54
Montreal Cognitive Assessment scoring	28	26
Body mass index (kg/m^2)	26.3	25.7
Stroke type	Infarct	Infarct
Post-stroke time (months)	3	6
Side of hemiparesis	Right	Left
Side of dominance	Right	Right

During intervention, the participants were first required to report their pre-exercise vital sign. Mr A trained using a game-based circuit exercise from the Checkercise® board, similar to the 'snake and ladder' game board (Figure 1). To 'start', he had to roll a dice. 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 penalised 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 was completed when his counter arrived at a space that indicated 'finish'.

Figure 1: Some examples of exercise included in Checkercise® board (no cognitive-focused when exercising)

Meanwhile, Mrs B trained using cognitive-focused game-based circuit exercises using an Othellocise board. It was a strategy board game for two players (black and white), played on a six-by-seven board. The game begins with six discs in the middle of the board, as shown below (Figure 2). After placing the disc, backflip all the opponent's discs so there is at least one straight (horizontal, vertical or diagonal). Participants alternated, taking turns to move. There was also a possibility of being penalised during the training if their counter landed on 'penalty spaces', such as spaces which indicate 'you loss one move' and 'repeat exercise'. The game was considered to end when the board was filled. The participant with the most discs on the board wins. The game is a draw if both participants have the same number of discs. Figure 3 shows Mrs B played cognitive-focused game-based circuit training using an Othellocise board with the other stroke patient.

Figure 2: Some examples of exercise included in Othellocise board board (include cognitive-focused when exercising)

Figure 3: Cognitive-focused game-based circuit exercise using Othellocise board

Participants performed the game board at a metronome pace, two times per week for eight weeks, under close monitoring by the researcher. Exercise adherence and the level of exercise intensity (e.g. low, moderate, vigorous) were monitored using the sessions attendance checklist and Borg Scale Rate of Perceived Exertion, respectively. Table 2 shows the frequency, intensity, time and type (FITT) principle of the Othellocise and Checkercise® board to be provided to the participants. Exercise duration in each space is two minutes interspersed by two minutes rest with ten exercises to be performed on average for 40 minutes. All selected exercises focused on advanced and challenging task-oriented training to trigger autonomic responses divided attention and multi-tasking ability among stroke patients.

In the beginning, repetition on the 30-second chair rise test, scoring of DGI, distance walked (in meters) on the 6-minute walk test, and motivation level was recorded. After eight weeks of intervention, lower limb strength increased for both participants (10% for Mr A and 9% for Mrs B). Aerobic endurance increased modestly (between 21% and 41%) for both participants post-testing. Scores for the DGI increased for both participants (33% for Mr A and 10% for Mrs B) at post-testing. Mr A increased motivation level from 2% to 22%, while 13% to 63% for Mrs B. Mr A showed improvement in overall motivation level by 12% in the domain of interest/enjoyment (from 6.7 to 6.8/7), perceived competence (from 6.6 to 6.8/7), and perceived choice (from 4.4 to 5.2/7) subscales. This was based on score changes of 0.1 points, 0.2 points and 0.8 points, respectively, in all subscales. Further, Mr A felt less pressure/tension with a 22% reduction in this subscale. In comparison, Mrs B showed improvement in overall motivation level by 30% in the domain of interest/enjoyment (from 6.1 to 6.9/7), perceived competence (from 5.4 to 6.8/7), and perceived choice (from 5.0 to 5.8/7) subscales. This was based on score changes of 0.8 points, 1.4 points and 0.8 points, respectively, in all subscales. Further, Mr A felt less pressure/tension, with a 63% reduction in this subscale. The increased of MoCA on Mr A and Mrs B was 4% and 8%, respectively. Performance changes in all outcomes post-intervention are shown in Table 3.

Figure 4 shows the diagram of participant flow in each study phase. During the trial, the participants performed all 16 sessions with a 100% attendance rate. No complaints of any adverse effect between or after the finished exercise. Participants perceived positive experiences with the intervention, which helped them sustain their rehabilitation.

DISCUSSION

This study aimed to evaluate changes in functions and motivation levels of stroke survivors following a cognitive-focused game-based circuit exercise using an Othellocise board compared to a game-based circuit 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 have noted participants' cognitive level improvement, as indicated by an overall increase in

Table 2: Description of similar circuit exercises in both Othellocise board and 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 dumbell/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)
Formula	**Resistance exercise**	**Balance exercise**	**Aerobic exercise**
	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 steps-ups on the 8-inches step board (without load)	Walk & touch cones cuboid shape (follow rhythm)	Repeated double jab punching with defense & kick (follow rhythm)
Progression	Standing, alternate steps-ups on the 8-inches step board (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)

Table 3: Changes in all outcomes post-intervention

Outcome	Mr A			Mrs B		
	Measure		Improvement	Measure		Improvement
	Before	After		Before	After	
30-second chair rise test (repetition)	10	11	10%	11	12	9%
Dynamic Gait Index	15	20	33%	21	23	10%
6-minute walk test (meters)	280	340	21%	270	380	41%
Intrinsic Motivation Inventory						
a. Interest/enjoyment	6.7	6.8	2%	6.1	6.9	13%
b. Perceived competence	6.6	6.8	3%	5.4	6.8	26%
c. Perceived choice	4.4	5.2	18%	5.0	5.8	16%
d. Pressure/tension	3.6	2.8	22%	3.2	1.2	63%
Montreal Cognitive Assessment	28	29	4%	26	28	8%

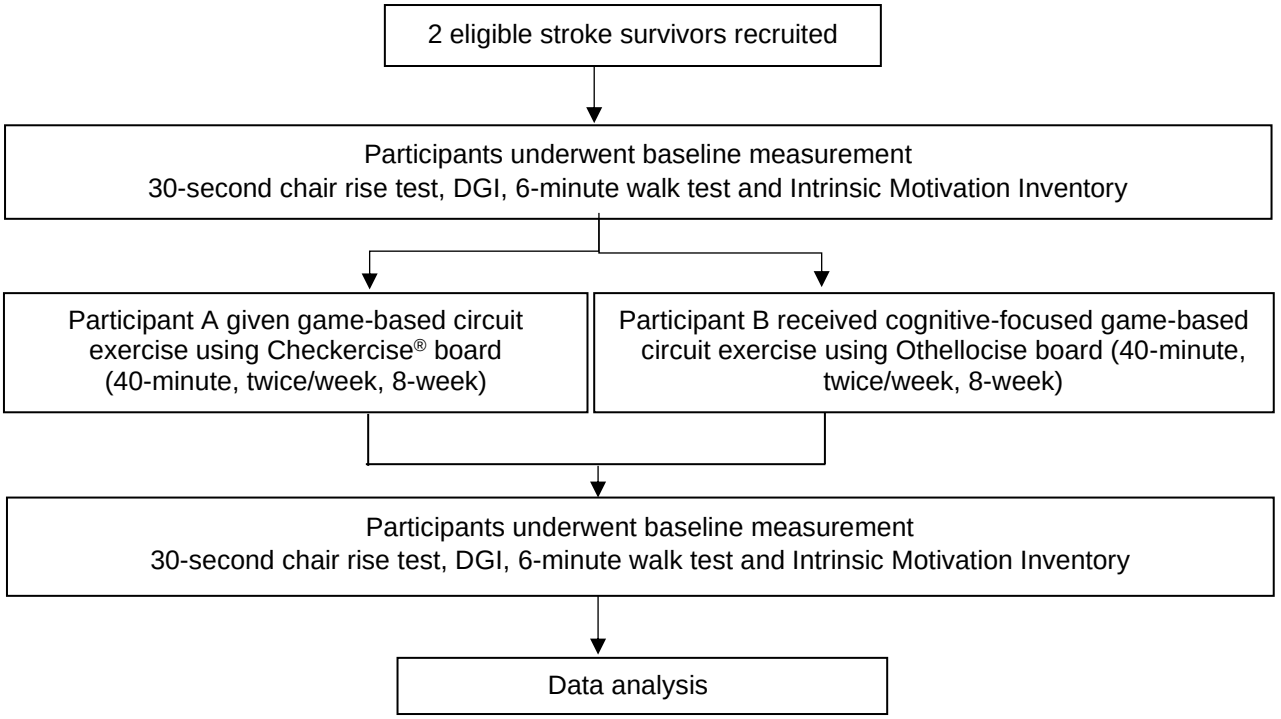

Figure 4: Diagram showing the participants flow in each study phase

MoCA score following our cognitive-focused game-based circuit exercise using an Othellocise. This finding is consistent with the results of 50 chronic stroke survivors in an earlier study by Jung and co-researchers (Jung et al. 2020) following a serious game for twelve weeks. The outcome measure used in the study was the Mini Mental State Examination, Digit Forward span and Digit Backward span. Our study also supports the findings of another study (Liu et al. 2023) which demonstrated improvement in cognition among stroke survivors with mild cognitive impairment, assessed using the MoCA, trail-making test-A, digit symbol substitution test and digital span test. They pointed out that virtual reality improved cognitive levels among 30 participants. Malisa and colleagues (Malisa & Kirana 2021) likewise reported improvement in the cognitive function of 30 stroke survivors with cognitive dysfunction using The Functional Assessment of Cancer Therapy-Cognitive after 30-minute sessions once a day, three times weekly using android-based brain games for four weeks as compared to the standard routine.

We believe that the improvement in the participant's functions, notably lower limb strength, postural stability and aerobic endurance score in our study, was obtained through the engagement imposed on the new enriched environment when exercised using Othellocise. Our results also found that the participant exhibited better postural stability as measured using a DGI following the eight-week interventions. In this sense, corroborating our findings, Her and colleagues (Her et al. 2011) described results after a motor dual task incorporated with cognitive dual-task training designed for 38 community-dwelling stroke survivors for six weeks compared to motor dual task and cognitive dual task alone. They detected significant improvements in balance and functional status, measured using the Berg Balance Scale and Functional Independence Measurement. Participants' improvement in the motor dual task incorporated with cognitive dual-task training was significantly better than those of the other two groups. Another randomized controlled trial in South Korea, presented by An and colleagues (An et al. 2014) addressed the effect of an 8-week motor dual task incorporated with cognitive dual-task training on 33 subacute and chronic stroke survivors compared to motor dual task and cognitive dual task alone. They reported that motor dual task incorporated with cognitive dual-task training improved aerobic endurance and gait speed, observed in a 6-minute walk test and 10-meter walk test, respectively.

The nature of each exercise task in the Othellocise board offers a more enriched environment by adding multisensory stimuli and cueing, limb integration and cognitive stimulation to increase neuroplasticity potentials further (Nithianantharajah & Hannan 2006). Training in an enriched environment can promote neuroplasticity (Livingston-Thomas et al. 2016), in addition to facilitating personalized motivation and ceasing stress and anxiety among stroke survivors (Hordacre et al. 2016; Rosbergen et al. 2017). An enriched environment could also affect stroke survivors' activity engagement (Janssen et al. 2014). It has also been proven that significant improvements in functional and cognitive ability following an enriched environment were sustained until three to six months (Khan et al. 2016; Rosbergen et al. 2017). Active participation of stroke survivors in cognitive-focused game-based circuit exercises using an Othellocise may enhance compliance and stimulate self-management. Self-management

positively affected goal achievement for self-management behavior, emotional state, mobility of clinical outcomes, and acceptance in stroke survivors (Hwang et al. 2021). With increased self-management through the infusion of enriched elements, survivors are expected to be more motivated to partake in home rehabilitation in which repetitive task training alone was optimized. Effects of repetitive task training involve the active practice of task-specific motor activities appear to be sustained up to six months post-treatment (French et al. 2016).

Our study is subjected to several limitations. The small size of the two participants and the absence of a control group limit the generalizability of our study results. Due to this, our findings have to be interpreted with caution.

CONCLUSION

We demonstrated that cognitive-focused or game-based circuit exercise using Othellocise board is potentially improving the functions and motivation level of stroke survivors and may be used as a therapy option for this population. Future studies with larger samples are recommended to confirm these study findings.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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