ORIGINAL ARTICLE

Psychosocial Benefits of Game-Based Circuit Exercise in Stroke Survivors: A Pre-Post Experimental Study in A Malaysia Setting.

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ABSTRACT

Background & Objectives: Stroke frequently leads to long-term functional impairments and reduced psychosocial well-being, underscoring the need for engaging and effective rehabilitation strategies. Emerging evidence suggests that game-based exercise may enhance motivation, self-efficacy, and adherence, yet its psychosocial effect in stroke survivors remains underexplored. Game-based circuit exercise integrates task-oriented training with interactive elements that may promote active participation and meaningful engagement. This study examines the psychosocial benefits of a game-based circuit exercise intervention among stroke survivors, with specific emphasis on motivation level and self-efficacy, using a pre–post experimental study design. **Methods:** This trial involved 44 subacute post-stroke participants (mean age ± SD = 58.61 ± 9.91 years; mean Montreal Cognitive Assessment score = 26.43 ± 3.32) and was conducted at Hospital Putrajaya, Malaysia, between June 2021 and March 2023. All participants completed supervised game-based circuit exercise sessions twice weekly for 12 weeks. Motivation and self-efficacy outcomes were assessed using the Intrinsic Motivation Inventory (IMI) and the Stroke Self-Efficacy Questionnaire (SSEQ). Measurements were obtained at baseline and at 12 and 36 weeks of intervention. A paired t-test was used for data analysis. **Results:** Post-training, IMI-interest and IMI-competence scores increased significantly ($p<0.001$), with gains of 6% and 9%, respectively, while mean SSEQ scores improved by 12% from baseline ($p<0.001$). Participants also reported reduced pressure/tension, as evidenced by a 12% decrease in this subscale ($p<0.05$), with a small effect size of 0.3. In contrast, IMI-perceived choice did not change significantly between baseline and 12-week post-intervention ($p>0.05$). At six-month follow-up, participants showed sustained significant improvements in interest/enjoyment, perceived competence, reduced tension, and clinically meaningful gains in self-efficacy ($p<0.05$) with medium effect sizes of 0.2 to 0.3, while perceived choice remained stable. **Conclusion:** Overall, the game-based circuit exercise generated psychosocial benefits that persisted well beyond the active training period.

Keywords: stroke, motivation, self-efficacy, game-based circuit exercise

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INTRODUCTION

It was reported that, in 2021, there were 93.8 million prevalent cases of stroke, 11.9 million incident cases of strokes and 160.5 million disability-adjusted life-years (DALYs) due to stroke globally (GBD 2021 Stroke Risk Factor Collaborators 2024). The World Stroke Organization Global Stroke Fact Sheet 2025 reports that stroke remains a major cause of disability worldwide, with estimated disability-adjusted life years (DALYs) of 11.4 million in the Americas, 17.3 million in Africa, 18.1 million in Europe, and 112.8 million in Asia (Feigin et al. 2025). From the same database, Malaysia showed a rising trend with 401,000 prevalent cases, 45,000 incident cases, 593,000 DALYs lost, and 23,000 deaths due to stroke in 2021 (GBD 2021 Stroke Risk Factor Collaborators 2024). The survival rates after six months of stroke event were between 62.7% to 95% (Chan et al. 2021; Jaya et al. 2002; Wahab et al. 2024), with more than half achieving functional independence (Chan et al. 2021; Jaya et al. 2002).

Stroke survivors with low motivation and depressive symptoms exhibit greater dependency in activities of daily living (Ezema et al. 2019; Ghaffari et al. 2021; Hamre et al. 2021). Functional impairments caused by stroke lead to dependency in daily living activities, which consequently reduce motivation levels (Mahmoud et al. 2016) and self-efficacy (Jones & Riazi

2011). Declines in self-efficacy and reduced social participation further impede the post-stroke recovery process in this population (Szczepańska-Gieracha & Mazurek, 2020).

Rehabilitation remains the mainstay of treatment to combat post-stroke disability. Physiotherapy, as a core component of multidisciplinary rehabilitation, plays a critical role throughout the post-stroke recovery continuum, 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).

Therapeutic exercise remains one of the most widely implemented physiotherapy interventions for stroke survivors, and evidence consistently supports its effectiveness in improving physical function and quality of life (Alatawi 2021; Ali et al. 2021; Amanzonwé et al. 2023; Mpemba et al. 2020). These exercises may be delivered individually or in groups, with group-based programmes commonly structured as circuit training. Circuit-based sessions typically comprise multiple stations incorporating mobility, strengthening, and aerobic exercises, each performed for approximately 5 to 10 minutes depending on the total number of stations (usually 4 to 10), with 2 to 3 minutes of rest between stations. Participants rotate through the stations sequentially (National Institute for Health and Care Excellence 2017), generally in groups of at least three (English et al. 2014) and under therapist supervision (American Heart Association/American Stroke Association 2016). This mode of delivery has also been shown to be efficient, reducing therapist time while enhancing social interaction among stroke survivors (van de Port et al. 2008).

The integration of therapeutic exercise with game-based elements has gained increasing attention as a contemporary physiotherapy intervention for stroke survivors. Gamification improves attitudes towards and enjoyment of exercise and shapes behavior, leading to increased exercise activity (Goh & Razikin, 2015). Movements performed during game-based exercise often mirror sport-related actions such as kicking, punching, and running. Such a program may be delivered using robotic-assisted exercise systems (Carrillo et al. 2023; Park et al. 2024; Wang et al. 2021) or virtual reality–based therapy platforms (Chang et al. 2022; Domínguez-Téllez et al. 2020; Lin et al. 2023; Mazeas et al. 2022). Although neither study evaluated motivation or self-efficacy, all studies employed methodologies to assess the effects of game-based interventions on various outcomes, including upper limb function (n = 29 studies) (Carrillo et al. 2023; Domínguez-Téllez et al. 2020), lower limb function (n=16 studies) (Chang et al. 2022), gait (n=59 studies) (Park et al. 2024; Wang et al. 2021), physical activity (n=16 studies) (Mazeas et al. 2022), cognition, mobility and emotion (n=29 studies) (Lin et al. 2023) and quality of life (n=15 studies) (Domínguez-Téllez et al. 2020).

To date, despite being increasingly used in physiotherapy, both circuit exercise and game-based exercise have never been combined to provide a new training experience for stroke survivors undergoing rehabilitation. Combining the two training programs may create a more enriched environment and yield favorable outcomes. Similarly, the Checkercise® board is specifically designed to help stroke survivors' recovery and contains circuit exercises in the form of games similar to the 'Snakes and Ladders' game board, which has fate, competition, and reward elements. Therefore, this study aimed to evaluate the psychosocial benefits of a game-based circuit exercise intervention among stroke survivors, with specific emphasis on motivation and self-efficacy. Furthermore, the study determined the sustainability of intervention-related improvements up to six months post-intervention.

MATERIALS & METHODS

Study design and setting

The present study employed a pre–post experimental design, which was conducted at Hospital Putrajaya, a principal stroke referral facility in Putrajaya, the federal administrative capital of Malaysia. Ethical approval for the study was granted by the National Medical Ethics and Research Committee, Malaysian Ministry of Health (study ID: NMRR–20–2715–57464), in compliance with the Declaration of Helsinki.

Study participants

Participants were recruited between June 2021 and March 2023. The sample size for the study was calculated using G*Power 3.1.9.2 software. Selecting a paired samples t-test as the intended test, study power of 80% or 0.8, and estimating a large effect size (Cohen f=0.4). The minimum number of participants required for this study was 44. Drop-outs were not considered in the sample size estimation because an intention-to-treat analysis was intended, in which all participants recruited at baseline would be analysed at the completion of the trial.

A total of 44 stroke survivors were recruited for this trial, comprising 33 individuals with ischaemic stroke and 11 with infarct-related stroke, with a mean age of 58.61 ± 9.91 years and a mean body mass index of 26.7 ± 6.1 kg/m². Inclusion criteria were: (1) a clinically confirmed diagnosis of haemorrhagic or ischaemic stroke by a physician, (2) age between 40 and 80 years and (3)

basic functional mobility, including ambulation and stair negotiation with or without walking aids as well as unilateral upper-limb ability sufficient to manipulate a full glass of water. Exclusion criteria were; (1) a Montreal Cognitive Assessment (MoCA) score 22.1 or below indicating cognitive impairment, (2) medical conditions likely to restrict physical performance such as severe musculoskeletal pathology, unstable angina or uncontrolled hypertension, (3) chronic central nervous system disorders other than stroke including Parkinson's disease or polyneuropathy, (4) a Modified Rankin Scale (mRS) score of 4 or higher indicating moderate–severe to severe disability, (5) participation in home-based physiotherapy or receipt of traditional therapeutic services following inpatient discharge and (6) the presence of visual field defects.

Intervention

Figure 1: Design of the Checkercise® board

All participants engaged in game-based circuit exercises using a newly developed gaming board, Checkercise®, which incorporates a design modelled after the classic "Snakes and Ladders" game (Figure 1). The exercise protocol, structured according to the frequency, intensity, time, and type (FITT) principle and differentiated by difficulty level, is summarised in Table 1.

Table 1: Description of the Checkercise® board exercises

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

The Checkercise® board, measuring 100 × 100 cm, served as the primary equipment for the game-based circuit exercise. The board was mounted on a magnetic display and used in combination with coloured magnetic markers, dice, an electronic metronome, and the Borg Rating of Perceived Exertion scale. Each session commenced and concluded with participants taking turns to roll the dice. Magnetic markers were advanced according to the number rolled, and each square on the board corresponded to a specific exercise task, which participants performed based on the square on which their marker landed. A metronome provided an audible rhythm to guide exercise tempo, and perceived exertion was continuously monitored using the Borg scale. For safety and feasibility, participants were allowed rest intervals between stations under close physiotherapist supervision, with a standard 2-minute rest to prevent fatigue accumulation and ensure optimal performance. Landing on a designated “chance” square resulted in either a penalty (e.g., move back one space) or a reward (e.g., advance to the next space), and the game progressed until participants reached the final square. The Checkercise® circuit was conducted in groups of four to six stroke survivors per session, organised into pairs to form two teams. Each station consisted of two minutes of exercise followed by two minutes of rest to accommodate rotation between teams.

To incorporate fun elements, Checkercise® was delivered through competitive challenges. These features, embedded within the gameplay, were designed to enhance participants’ motivation and enjoyment during the intervention. In general, the Checkercise® board introduces a novel integration of resistance, balance, and aerobic exercises within a gamified framework. Resistance exercises emphasize inter-limb coordination through tasks such as dumbbell lifting during seated-to-standing transitions, squats with step-ups and step-downs, and hip and heel raises. Balance exercises involve dual-task dynamic movements and visual cueing, including walking to touch cones, walking with head turns, and navigating figure-of-eight patterns while carrying a partially filled cup, all performed concurrently with cognitive challenges. Aerobic exercises comprise progressive boxing sequences, ranging from basic punches (jab, hook, and cross-straight) to complex combinations involving coordinated upper- and lower-limb movements, such as hook with kick, jab with squat, and cross-straight with squat. Metronome beats were incorporated throughout the Checkercise® exercise program to enhance participants’ attentional focus during task execution.

The integration of inter-limb coordination, dual-task dynamic movements, visual cueing, boxing maneuvers and auditory stimuli in this study contributed to a more enriched and stimulating rehabilitation environment. A pilot study was undertaken to evaluate the feasibility and potential effects of a game-based circuit exercise using the Checkercise® board on physical function and quality of life among stroke survivors. The study was conducted at the Physiotherapy Unit, Hospital Raja Perempuan Zainab II, Kota Bharu, between August 2019 and October 2020 (Johar et al. 2022). 30 stroke survivors with mild to moderate disability (mRS scores 1 to 3) and a mean age of 58.9 ± 6.6 years participated. The intervention comprised 40-minute Checkercise® sessions delivered twice weekly over 12 weeks. Following the intervention, significant improvements were observed in lower-limb strength, as measured by the 30-second chair stand test [$t(1,29) = 66.69$, $p<0.05$, $d=0.5$], postural stability using the Dynamic Gait Index (DGI) [$t(1,29) = 56.44$, $p<0.05$, $d=0.5$] and aerobic endurance assessed via the 6-minute walk test (6mWT) [$t(1,29) = 48.70$, $p<0.05$, $d=0.6$], corresponding to gains of 9%, 7% and 23%, respectively. Quality of life (QoL) also improved significantly, with moderate effect sizes for the Short Form-36 (SF-36) physical ($d=0.44$), mental ($d=0.43$), and combined component scores ($d=0.48$). No adverse effects were observed, and the majority of participants enjoyed the exercise program. These findings indicate that Checkercise® circuit training is feasible and enhances physical performance and QoL among stroke survivors, supporting its potential incorporation into post-stroke rehabilitation programs.

Instruments

To determine the effectiveness of the interventions, the motivation level concerning experimental tasks was assessed using a Multidimensional Intrinsic Motivation Inventory (IMI). 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 (high 7.00-4.67; average 4.66-2.34; low 2.33-1.00). Whereas, self-efficacy was assessed using the Stroke Self-Efficacy Questionnaire (SSEQ), which evaluates confidence in performing daily activities and self-management tasks following stroke. The instrument comprises 13 items across two domains: activities (items 1 to 8) and self-management (items 9 to 13). Responses are rated on a 3-point scale ranging from 0 (“not at all confident”) to 3 (“very confident”), with total scores approaching 0 indicating low self-efficacy and scores approaching 39 indicating high self-efficacy. The SSEQ demonstrates good construct validity, showing correlations with related measures including the Falls Efficacy Scale, Modified Rivermead Mobility Index, Hospital Anxiety and Depression Scale, and Rosenberg Self-Esteem Scale ($-0.63< r <0.75$) (Riazi et al. 2014). Measurements were performed at baseline (pre-assessment), post-intervention (12 weeks), and at 12 and 24-week follow-

up intervals by the same tester. To mitigate assessor bias, baseline (pre-assessment) data were withheld from the assessor during post-intervention and follow-up assessments.

Statistical analysis

All data were analyzed using the Statistical Package for the Social Sciences (SPSS) version 25.0.

Data from both outcomes were normally distributed, as indicated by the Shapiro-Wilk test ($p>0.05$), confirming the appropriateness of subsequent parametric statistical analyses. A paired t-test was conducted to examine the effects of the game-based circuit exercise on the outcome measures at baseline, 12 weeks, and 36 weeks. The level of significance was set at $p<0.05$, and Cohen (d) was used to determine the effect size of either small (0.2), medium (0.5), or large (0.8) (Cohen 2013).

RESULTS

Participant flow in each study phase

Participant flow across all study phases is detailed in the flow chart (Figure 2). During the trial, two participants dropped out of the intervention due to logistical issues. The two participants were included in the final analysis using an intention-to-treat approach, i.e., their baseline scores were carried forward as outcome scores.

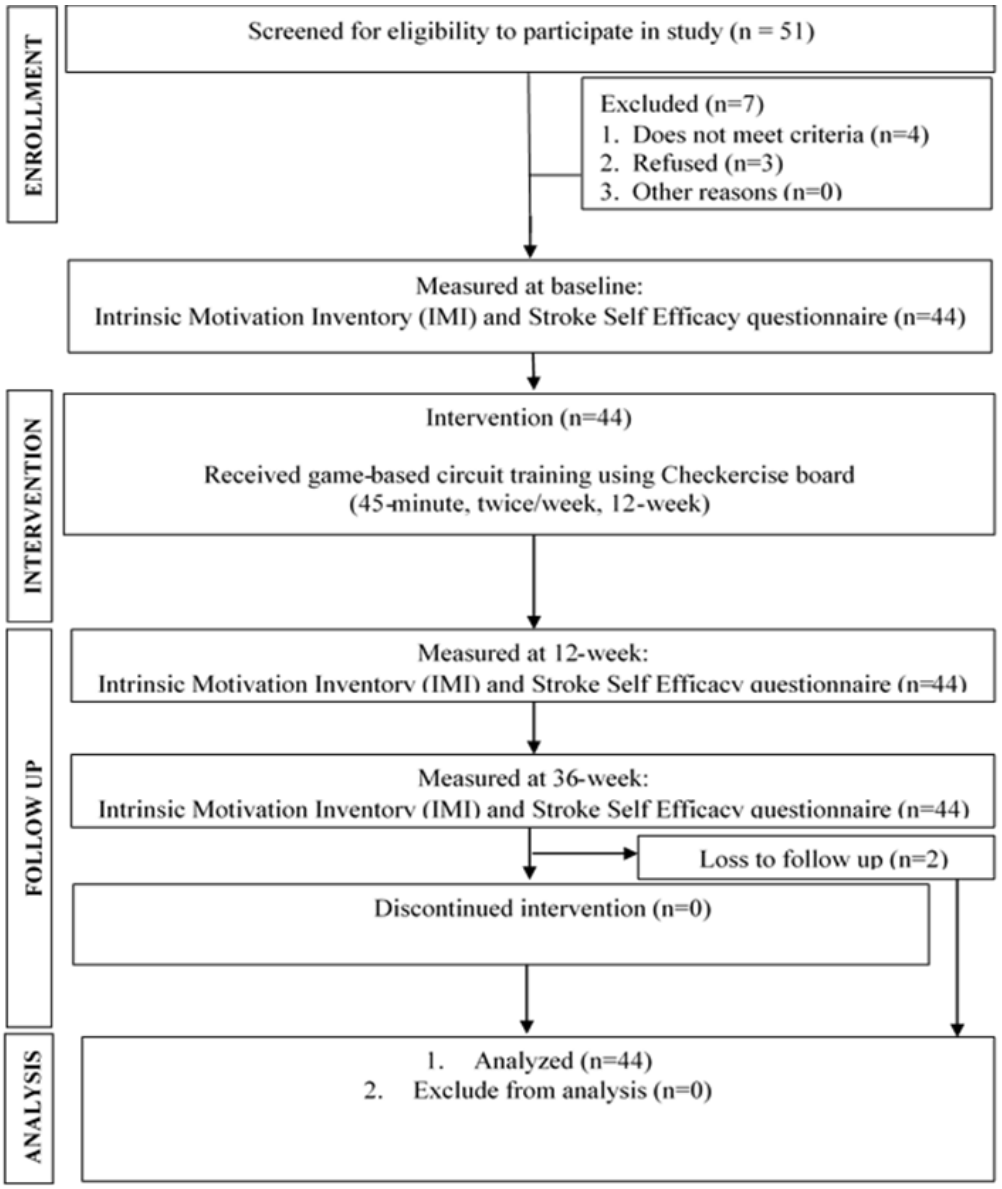

Figure 2: Flow Chart of the Study

Baseline characteristics

Table 2: Socio-demography and baseline (pre-assessment) basic clinical data for the study participants

Variables	
Age (years)	58.61 ± 9.91
Gender (Female)	25%
Cognitive, MOCA	26.43 ± 3.32
Type of stroke (Ischemic)	25%
mRS (Moderate disability)	18.18%
Side of hemiparesis (Right)	50%
Side of dominance (Right)	95%
Body mass index (kg/m^2)	26.67 ± 6.1
Post-stroke duration (weeks)	7.3
IMI	
a. Interest/enjoyment	5.95 ± 0.82
b. Perceived competence	5.62 ± 0.99
c. Perceived choice	4.36 ± 0.96
d. Pressure/tension	2.76 ± 1.07
SSEQ	98.84 ± 21.23

All data are presented as mean ± standard deviation, except for ethnicity, gender, age, type of stroke, mRS (modified Rankin Scale), and side of hemiparesis are demonstrated in the number of participants (%). Values are presented as mean ± standard deviation; IMI, Intrinsic Motivation Inventory; SSEQ, Stroke Self Efficacy questionnaire

Table 2 presents the socio-demographic and baseline (pre-assessment) clinical data for the study participants. The participants had a mean age of 58.61+9.91 years, and their mean Montreal Cognitive Assessment (MoCA) score was 26.43+3.32. The majority of the participants were male (75%), presented with an overweight status (more than 25 kg/m² of body mass index) and mild disability (scores of mRS 2 or less). The mean time post-stroke was 7.3 weeks.

Table 3 provides the descriptive and statistical indices for IMI and SSEQ outcomes. A paired t-test demonstrated significant improvements in IMI-interest scores, $t(43) = 4.49$, $p<0.001$, and IMI-competence scores, $t(43) = 4.76$, $p < 0.001$, both reflecting medium effect sizes ($d=0.50$ to 0.58). The results indicated absolute gains of 0.36 and 0.52 points, corresponding to increases of 6% and 9% in the interest and competence subscales, respectively. Similarly, a significant reduction in IMI-pressure/tension scores was observed, $t(43) = -2.60$, $p<0.05$, corresponding to a small effect size ($d=0.31$), reflecting reductions of 12% (absolute losses of 0.33 points). In contrast, the findings indicate that IMI-choice scores did not show meaningful improvement across the assessment periods ($p>0.05$).

Changes in SSEQ following intervention

A paired t-test demonstrated a significant increment on SSEQ scores, $t(43) = 6.457$, $p<0.001$, with medium effect size partial $d = 0.62$, with gains of 12% (absolute improvements of 12.21 points), exceeding the minimum clinically important difference (MCID) of 3.3 points for stroke survivors (Wu et al. 2024), thereby demonstrating both statistical significance and clinical meaningfulness.

Sustainability of effects at six months post-intervention

At the six-month follow-up, participants exhibited sustained and statistically significant improvements in IMI-interest scores, with higher values at 36 weeks (6.50+0.65) compared with post-intervention scores (6.31+0.72; $p<0.05$), and demonstrated a 3% increase (absolute gain of 0.19 points). IMI-competence scores demonstrated a comparable pattern, showing significantly higher scores at 36 weeks (6.38+0.74) than at post-intervention (6.14+0.79; $p<0.05$), corresponding to a 5% increase (absolute gain of 0.24 points). IMI-pressure/tension scores were significantly reduced at 36 weeks (2.16+1.10) relative to post-intervention values (2.43+ 1.06; $p<0.05$), representing an 11% reduction (absolute decrease of 0.27 points). However, no significant changes were observed in IMI-perceived choice scores between the post-intervention and 36-week assessments ($p>0.05$). Finally, SSEQ scores increased significantly at 36 weeks (115.07+17.21) compared with post-intervention scores (111.05+18.25; $p<0.05$), marking a 4% improvement (absolute gain of 3.99 points), which exceeded the established MCID of 3.3 points for stroke survivors (Wu et al. 2024), thereby demonstrating both statistical significance and clinical meaningfulness.

DISCUSSION

The purpose of this study was to evaluate changes in motivation level and self-efficacy of a stroke survivor following a game-based circuit exercise using a Checkercise® board. The findings indicate that the game-based circuit exercise effectively enhanced participants' motivation and psychological responses over time, with significant and sustained improvements observed in IMI-interest and IMI-competence scores from baseline through the 12 and 36-week assessments. These results align with Self-Determination Theory (Ryan & Deci, 2000), which underscores the roles of enjoyment and perceived competence in fostering intrinsic motivation and long-term engagement.

Table 3:Comparison of changes in IMI and SSEQ between at baseline (pre-assessment) and week 12 and 36 after intervention

Outcome	12-week post-intervention					6-month post intervention			
	Week-0 (Baseline)	**12-week post-intervention**	**Mean change**	**95% CI**	***p* value (*d*)**	**12-week post-intervention**	**36-week follow-up**	**95% CI**	***p* value (*d*)**
IMI									
a. Interest/ enjoyment	5.95±0.82	6.31±0.72	6%	0.2-0.52	*0.001 (0.5)	6.31±0.72	6.5±0.65	0.04-0.35	*0.015 (0.28)
b. Perceived competence	5.62±0.99	6.14±0.79	9%	0.3-0.73	*0.001 (0.58)	6.14±0.79	6.38±0.74	0.06-0.42	*0.009 (0.32)
c. Perceived choice	4.36±0.96	4.49±0.98	3%	-0.08-0.35	0.225	4.49±0.98	4.7±1.04	-0.03-0.45	0.085
d. Pressure/ tension	2.76±1.07	2.43±1.06	12%	-0.57-0.07	*0.013 (0.31)	2.43±1.06	2.16±1.1	-0.52-0.02	*0.034 (0.25)
SSEQ	98.84±21.23	111.05±18.25	12%	8.39-16.02	*0.001 (0.62)	111.05±18.25	115.07±17.21	0.72-7.33	*0.018 (0.23)

Values are presented as mean ± standard deviation; statistically significant, *$p < 0.05$ by paired *t* test; large effect size, #$d > 0.8$; IMI, Intrinsic Motivation Inventory; SSEQ, Stroke Self Efficacy questionnaire.

Although IMI-choice scores did not show statistically significant changes, the modest upward trend suggests potential clinical relevance and highlights the need for additional autonomy-supportive strategies such as personalised task options or adjustable difficulty to meaningfully strengthen perceived autonomy. The intervention also produced significant reductions in IMI-pressure/tension scores, indicating decreased psychological stress and enhanced affective experience during participation, consistent with prior evidence that gamified, task-oriented rehabilitation promotes mastery, reduces cognitive load, and mitigates performance-related pressure. Collectively, these findings indicate that game-based circuit exercise may enhance sustained motivational engagement, strengthen perceived competence, and reduce tension among stroke survivors, thereby supporting long-term rehabilitation adherence and outcomes in accordance with Flow State Theory (Mirvis & Csikszentmihalyi, 1991).

We found improvement in our participants' motivation level, as indicated by favorable changes in all IMI subscales scores following the game-based circuit exercise. Comparable studies have demonstrated that six weeks of exercise using robotic devices and augmented reality can enhance motivation among stroke survivors. In the study by Nijenhuis et al. (2015), tele-rehabilitation (n=21; mean age=59+13 years) and treadmill-based gait training (n=3; mean age=55.3+4.5 years) (King et al. 2012), each produced significant improvements in motivation ($p<0.05$), as measured by the IMI. Moreover, these positive effects were sustained for up to two months post-intervention (Nijenhuis et al. 2015). However, interventions involving robotic and augmented reality devices are costly and require maintenance by skilled personnel.

Based on the findings, Checkercise® may be considered a viable adjunct therapy within stroke rehabilitation programmes, however further long-term studies are warranted. The greater increase in motivation observed among participants engaging in the game-based circuit exercise is likely attributable to the competitive and progressively challenging elements embedded within Checkercise®. These elements were operationalised by systematically increasing the difficulty and complexity of each exercise task, thereby creating an engaging and enjoyable environment that encouraged stroke survivors to remain committed to the programme. Checkercise® is designed for four participants divided into two teams, with the team that reaches the 'finish line' first winning. Each space on the Checkercise® board represents a specific exercise, organised sequentially from the simplest to the most complex and demanding. Examples of progressive difficulty include repeated double-jab punches, followed by combinations of double jabs with hooks, and subsequently double jabs and hooks combined with lower limb movements such as hip raises or squats. Teams may also incur penalties if their game piece lands on designated penalty spaces, which may require moving backward or relocating to another specified space. These gamified features enrich the exercise environment, thereby enhancing motivation and engagement among stroke survivors.

Beyond the foundational elements of circuit exercise embedded within the Checkercise® board, we posit that the enjoyment elicited through game-based exercise contributes substantially to the positive intervention outcomes reported, consistent with previous findings (Navarro et al. 2020). Gamification has been shown to improve attitudes toward exercise and enhance enjoyment, thereby increasing engagement in physical activity (Mazeas et al. 2022). In a relaxed, socially interactive environment, participants strive to outperform other groups, with team achievements announced at the end of each session (Verrienti et al. 2023). We believe that the game components integrated into our circuit exercise similarly foster these beneficial effects.

In an enjoyable exercise setting, participants are more likely to compete, persist, and perform at their best, which in turn may stimulate functional recovery through enhanced neuroplasticity. The Checkercise® board incorporates game-based elements specifically designed to evoke enjoyment within an existing circuit exercise format. As a game-based exercise modality, Checkercise® makes rehabilitation sessions more engaging and motivating for stroke survivors, encouraging them to remain active. Exercising in such a pleasurable environment not only promotes neuroplasticity but also enhances motivation while reducing stress and anxiety throughout the rehabilitation period (Tham et al. 2023).

Progressive increases in exercise complexity within virtual reality therapy, such as modifications in movement speed, hand positioning, and performance thresholds required to unlock subsequent levels, duration of each level, and embedded learning supports, have been shown to exert strong intrinsic effects on motivation and enhance the effectiveness of stroke rehabilitation (Fluet et al. 2024; Strong et al. 2022). Stroke survivors in both studies demonstrated marked improvements in IMI scores, with levels substantially higher than baseline following virtual reality therapy. These studies involved the home virtual rehabilitation system (n=33; mean age=57±13 years) (Fluet et al. 2024) and virtual reality mirror therapy (n=10; mean age=50.8 years) (Strong et al. 2022). Although neither study assessed long-term outcomes, both employed methodologies comparable to the present study, particularly the stepwise progression of exercise complexity, including increased punching tempo, task-specific hand-position changes guided by metronome rhythm, and structured learning support.

In addition, competitive elements have been shown to elicit significantly greater enjoyment ($p<0.05$) compared with non-competitive control conditions (n=43; mean age=51.7±18.1 years) (Navarro et al.

2020), aligning with the present findings on the motivational effects of Checkercise®. Participant feedback regarding the Checkercise® sessions was highly positive and encouraging, with remarks such as “The program is very enjoyable, easy to follow, community-friendly, and offers a unique form of exercise,” and “Fun, unpredictable exercise.”

The significant increase in SSEQ scores over time indicates that the game-based circuit exercise intervention effectively enhanced participants’ self-efficacy in performing daily activities and managing post-stroke challenges. The substantial improvements observed at 12, 24, and 36 weeks, all of which exceeded the minimum clinically important difference (MCID), demonstrate that these gains were both statistically significant and clinically meaningful. The stability of self-efficacy scores across the follow-up period further suggests that the intervention's benefits were maintained even after supervised training ceased, highlighting the potential for long-term behavioral and psychosocial change. Participants with an internal locus of control (Rotter 1966) believe that their recovery depends on their own efforts, such as consistent participation in game-based circuit exercise. This belief motivates them to take an active role in the rehabilitation process, set personal goals, and strive to overcome physical limitations.

This result is consistent with a previous study by Kiper et al. (2022), which demonstrated that two weekly upper-limb exercise sessions delivered in an immersive serious-game therapeutic environment incorporating psychotherapeutic elements (n=60; mean age=65.5+6.7 years) over a ten-week period produced significant improvements in self-efficacy, as measured by the Generalized Self-Efficacy scale. These outcomes were comparable to those of a conventional exercise program comprising Autogenic-Schulz training, aerobic exercises, balance training, and proprioceptive neuromuscular facilitation ($p > 0.05$). However, serious games often fall short in addressing the functional rehabilitation needs of individuals post-stroke.

In contrast, Checkercise® was found to be more practical and relevant in meeting these functional rehabilitation requirements, as it extends beyond entertainment-focused elements to provide meaningful exercise engagement. Active participation in the intervention may have further enhanced participants’ self-management abilities. Self-management capacity plays a significant role in goal setting and achievement as well as in regulating emotional state and functional mobility (Hwang et al. 2021). We believe that the observed improvement in self-management ability enabled participants to perform daily activities more efficiently, thereby enhancing their overall well-being and perceived QoL (French et al. 2016).

The auditory cues embedded in Checkercise® gameplay, including verbal instructions, sound effects, and metronome rhythms, help stimulate cognitive functions such as executive functioning and attention. These cues are further augmented through directional changes, abrupt stopping tasks and rotational movements, thereby increasing the overall task complexity. Checkercise® also incorporates a metronome feature, allowing participants to select their preferred beep sound. The metronome enhances rhythmic perception, enabling participants to synchronize upper- and lower-limb movements with the auditory tempo.

Memorizing the sequence of limb movements requires complex motor agility and engages cognitive processes, including executive functioning and attention. Wright et al. (2017) reported significant improvements in gait speed and balance among stroke survivors following two blocks of rhythm-based walking exercises conducted at home over three weeks, accompanied by music overlaid with auditory metronome cues (n=12; mean age=56+11 years) ($p<0.05$). These improvements persisted for up to 3 weeks post-intervention, indicating sustained effects on self-efficacy among stroke survivors.

This study has one primary limitation. Only stroke survivors with high levels of independence were recruited, while individuals with a Modified Rankin Scale (mRS) score of 4 or higher, indicating moderate–severe to severe disability, were excluded. Stroke survivors with different levels of independence may respond differently to the game-based circuit exercise intervention. Nevertheless, our findings demonstrate that carefully selected stroke survivors can be effectively trained to engage in a game-based circuit exercise program and successfully complete a challenging, enriched exercise regimen under therapist supervision.

CONCLUSION

We demonstrate that game-based circuit exercise using the Checkercise® board is a viable approach for enhancing post-stroke motivation and self-efficacy, with benefits sustained for up to 6 months post-intervention. Future, larger scale studies are warranted to validate the findings observed in this case study.

Acknowledgements
We thanked the participants who have voluntarily participated in this case study, and the National Medical Research Review (NMRR), Kementerian Kesihatan Malaysia, for approving the main study (NMRR–20–2715–57464).

Conflict of Interest
The authors declare no conflict of interest.

Funding
This study did not receive any funding.

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