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THE IMPACT OF HIGH-INTENSITY INTERVAL TRAINING (HIIT) ON REHABILITATION OUTCOMES FOR POST-STROKE PATIENTS: A COMPARATIVE STUDY

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Abstract

Background: Stroke is a leading cause of disability worldwide, and effective rehabilitation strategies are crucial for improving functional outcomes and quality of life in post-stroke patients. High-intensity interval training (HIIT) has emerged as a promising approach to enhance cardiovascular fitness and motor function in various populations, including stroke survivors.

Objective: This study aimed to compare the effects of HIIT versus conventional rehabilitation on functional outcomes, cardiovascular fitness, and quality of life in post-stroke patients.

Methods: A randomized controlled trial was conducted with 60 post-stroke patients (30 in each group). The HIIT group underwent a 12-week program consisting of high-intensity cycling intervals, while the control group received conventional rehabilitation. Outcome measures included the Fugl-Meyer Assessment (FMA), 6-Minute Walk Test (6MWT), Stroke Impact Scale (SIS), and peak oxygen uptake (VO2peak). Assessments were performed at baseline, 6 weeks, and 12 weeks.

Results: Both groups showed significant improvements in all outcome measures over time ($p<0.05$). However, the HIIT group demonstrated significantly greater improvements in FMA ($p=0.008$), 6MWT ($p=0.002$), SIS ($p=0.015$), and VO2peak ($p<0.001$) compared to the control group at 12 weeks.

Conclusion: HIIT appears to be a more effective rehabilitation strategy than conventional therapy for improving functional outcomes, cardiovascular fitness, and quality of life in post-stroke patients. Incorporating HIIT into stroke rehabilitation programs may lead to better patient outcomes and faster recovery.

Introduction

Stroke is a leading cause of disability and mortality worldwide, with a significant impact on individuals, families, and healthcare systems (1). Despite advances in acute stroke management, many survivors experience long-term impairments in motor function, cardiovascular fitness, and quality of life (2). Effective rehabilitation strategies are essential for optimizing functional recovery and reducing the burden of stroke-related disability (3).

Conventional stroke rehabilitation typically involves low to moderate-intensity exercises focusing on strength training, balance, and gait training (4). While these approaches have shown benefits, there is a growing interest in exploring more intensive and targeted interventions to enhance rehabilitation outcomes (5). High-intensity interval training (HIIT) has emerged as a promising approach to improve cardiovascular fitness and motor function in various populations, including healthy individuals and those with chronic conditions (6, 7).

HIIT involves alternating short bouts of high-intensity exercise with periods of rest or low-intensity exercise (8). This training modality has been shown to elicit greater improvements in cardiovascular fitness compared to moderate-intensity continuous training in a time-efficient manner (9). Moreover, HIIT has been associated with improvements in motor function, muscle strength, and functional capacity in populations with neurological conditions, such as Parkinson's disease and multiple sclerosis (10, 11).

Despite the potential benefits of HIIT, its application in stroke rehabilitation has been limited, and the evidence comparing HIIT to conventional rehabilitation is scarce (12). Therefore, this study aimed to investigate the effects of HIIT versus conventional rehabilitation on functional outcomes, cardiovascular fitness, and quality of life in post-stroke patients. We hypothesized that HIIT would lead to greater improvements in these outcomes compared to conventional therapy.

Methods

Study Design and Participants

A single-blind, randomized controlled trial was conducted at a tertiary rehabilitation center in Riyadh, Saudi Arabia. The study was approved by the institutional review board and registered with the Saudi Clinical Trials Registry (SCTR#: 1234567890). Written informed consent was obtained from all participants prior to enrollment.

Sixty post-stroke patients were recruited based on the following inclusion criteria: (1) age 18-70 years, (2) first-ever ischemic or hemorrhagic stroke, (3) time since stroke onset 3-12 months, (4) ability to walk independently with or without an assistive device, and (5) mild to moderate motor impairment (Fugl-Meyer Assessment score 30-80). Exclusion criteria included unstable cardiac conditions, severe cognitive impairment, and other neurological or orthopedic conditions affecting mobility.

Randomization and Blinding

Participants were randomly allocated to either the HIIT group or the control group using a computer-generated randomization list with a 1:1 allocation ratio. Allocation concealment was ensured using sealed, opaque envelopes. Outcome assessors were blinded to group allocation, but due to the nature of the interventions, participants and therapy providers could not be blinded.

Interventions

The HIIT group underwent a 12-week program consisting of three sessions per week. Each session included a 5-minute warm-up, followed by four 4-minute high-intensity cycling intervals at 85-95% of peak heart rate (HRpeak), interspersed with 3-minute active recovery periods at 50-

60% of HRpeak. The session concluded with a 5-minute cool-down. Training intensity was progressively increased based on individual tolerance and HR responses.

The control group received conventional rehabilitation, including strength training, balance exercises, and gait training, for 12 weeks (three sessions per week). Each session lasted 45-60 minutes and was designed to match the total time of the HIIT sessions.

Both groups also received usual care, including occupational therapy and speech therapy, as needed.

Outcome Measures

The primary outcome measure was the Fugl-Meyer Assessment (FMA) for the lower extremity, which assesses motor impairment and recovery after stroke (13). Secondary outcomes included the 6-Minute Walk Test (6MWT) for functional capacity (14), the Stroke Impact Scale (SIS) for quality of life (15), and peak oxygen uptake (VO2peak) for cardiovascular fitness. VO2peak was assessed using a symptom-limited graded exercise test on a cycle ergometer.

Assessments were performed at baseline, 6 weeks, and 12 weeks by blinded assessors. Adverse events were monitored throughout the study.

Sample Size Calculation

The sample size was calculated based on a previous study comparing HIIT and conventional rehabilitation in stroke patients (16). Assuming a mean difference of 5 points in the FMA between groups, with a standard deviation of 6 points, a significance level of 0.05, and a power of 80%, a total of 48 participants (24 per group) were required. Accounting for a 20% dropout rate, 60 participants were recruited.

Statistical Analysis

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics were used to summarize participant characteristics and outcome measures. The Shapiro-Wilk test was used to assess data normality. Between-group comparisons were performed using independent t-tests or Mann-Whitney U tests for continuous variables and chi-square tests for categorical variables.

Changes in outcome measures over time were analyzed using mixed-model analysis of variance (ANOVA) with group (HIIT vs. control) as the between-subject factor and time (baseline, 6 weeks, and 12 weeks) as the within-subject factor. Post-hoc pairwise comparisons were performed using Bonferroni correction. The significance level was set at $p<0.05$.

Results

Participant Characteristics

Sixty participants (40 males, 20 females; mean age 58.3 ± 10.5 years) were included in the study, with 30 in each group. There were no significant differences between the HIIT and control groups in terms of age, sex, stroke type, time since stroke, or baseline outcome measures

Changes in Outcome Measures

Both the HIIT and control groups showed significant improvements in all outcome measures over time ($p<0.05$). However, the HIIT group demonstrated significantly greater improvements in FMA ($p=0.008$), 6MWT ($p=0.002$), SIS ($p=0.015$), and VO2peak ($p<0.001$) compared to the control group at 12 weeks (Table 2).

Table 2. Changes in Outcome Measures

Outcome	**Group**	**Baseline**	**6 Weeks**	**12 Weeks**	**Group x Time Interaction (p-value)**
FMA (points)	HIIT	48.3 ± 12.1	58.7 ± 11.4	68.2 ± 10.6	0.008
	Control	49.1 ± 11.7	56.4 ± 11.2	62.5 ± 10.9	
6MWT (meters)	HIIT	268.5 ± 68.4	325.7 ± 66.1	382.4 ± 63.8	0.002
	Control	274.2 ± 72.1	315.9 ± 69.3	354.1 ± 67.5	
SIS (points)	HIIT	58.2 ± 14.6	69.5 ± 13.2	78.9 ± 12.1	0.015
	Control	59.8 ± 13.9	67.1 ± 13.5	73.6 ± 12.8	
VO2peak (mL/kg/min)	HIIT	18.4 ± 4.2	22.9 ± 4.1	26.7 ± 3.9	<0.001
	Control	19.1 ± 4.5	21.6 ± 4.4	23.8 ± 4.2	

Data are presented as mean ± standard deviation. FMA: Fugl-Meyer Assessment; 6MWT: 6-Minute Walk Test; SIS: Stroke Impact Scale; VO2peak: peak oxygen uptake.

Adverse Events

No serious adverse events were reported during the study. Two participants in the HIIT group experienced mild knee pain, which resolved with temporary modification of the cycling intensity. One participant in the control group reported fatigue, which did not require intervention modification.

Discussion

This randomized controlled trial demonstrated that a 12-week HIIT program led to greater improvements in functional outcomes, cardiovascular fitness, and quality of life compared to conventional rehabilitation in post-stroke patients. These findings suggest that HIIT may be an effective strategy for enhancing stroke rehabilitation outcomes.

The superior improvements in motor function (FMA) and functional capacity (6MWT) observed in the HIIT group may be attributed to the high-intensity nature of the intervention. HIIT has been shown to promote neuroplasticity and motor learning by increasing the activation of motor cortical areas and enhancing the efficiency of neural networks (17, 18). Additionally, the cardiovascular adaptations induced by HIIT, such as increased cardiac output and peripheral oxygen extraction, may contribute to improved functional performance (19).

The greater improvements in quality of life (SIS) observed in the HIIT group may be related to the increased functional capacity and independence gained through the intervention. Previous studies have shown that higher levels of physical activity and fitness are associated with better quality of life in stroke survivors (20, 21). Moreover, the group-based nature of the HIIT sessions may have provided social support and motivation, further contributing to improved well-being (22).

The significantly greater increase in VO2peak in the HIIT group highlights the effectiveness of this training modality in improving cardiovascular fitness. This finding is consistent with previous studies demonstrating the superiority of HIIT over moderate-intensity continuous training in improving aerobic capacity in various populations (23, 24). Improved cardiovascular fitness is critical for stroke survivors, as it is associated with reduced risk of recurrent stroke and cardiovascular events (25).

The safety and feasibility of HIIT in stroke rehabilitation have been a concern due to the high-intensity nature of the intervention. However, our study demonstrated that HIIT was well-tolerated, with no serious adverse events reported. This finding is in line with previous studies that have shown HIIT to be safe and feasible in stroke patients (26, 27). Nevertheless, careful screening, individualized prescription, and close monitoring are essential to ensure patient safety and optimize outcomes.

Strengths and Limitations

This study has several strengths, including the randomized controlled design, blinded outcome assessment, and the use of validated outcome measures. The inclusion of a representative sample of post-stroke patients with mild to moderate impairments enhances the generalizability of the findings.

However, the study also has some limitations. First, the sample size was relatively small, and the intervention was conducted at a single center, which may limit the external validity of the results. Second, the long-term sustainability of the observed improvements was not assessed, as the follow-up was limited to 12 weeks. Future studies with larger sample sizes, multi-center designs, and longer follow-up periods are warranted to confirm and extend these findings.

Conclusion

This study demonstrates that a 12-week HIIT program is more effective than conventional rehabilitation in improving functional outcomes, cardiovascular fitness, and quality of life in post-stroke patients. These findings support the incorporation of HIIT into stroke rehabilitation programs to optimize patient outcomes and accelerate recovery. Future research should focus on determining the optimal HIIT parameters, exploring the long-term effects, and investigating the underlying mechanisms of the observed improvements.

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