THE EFFECT OF HIGH-INTENSITY INTERVAL TRAINING ON GAIT PERFORMANCE IN PATIENTS AFTER STROKE

VPLYV VYSOKOINTENZÍVNEHO TRÉNINGU NA VÝKONNOSŤ CHÔDZE U PACIENTOV PO CIEVNEJ MOZGOVEJ PRÍHODE

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ABSTRACT

Background: The provision of rehabilitation services as soon as possible use of the most effective methods, which have scientific evidence, are extremely relevant today.
Objective: To study the effect of high-intensity interval training on gait performance in patients after stroke.
Research sample and method: The study involved 12 males who had suffered a stroke and met the selection criteria. All the males went through a special program that included high-intensity intervals of gait training combined with strength training of lower limbs and functional training.
Results: The results of the final examination showed significant changes in all the studied indicators in all 12 patients. Statistically significant changes were determined in total score of the Berg Balance Scale, which comprised ± 40.5 on average, making a clinically significant change in balance indicators by ± 16 points. According to the Six Minute Walk Test, the number of meters covered in six minutes increased to ± 189.5 meters, which is ± 106.5 meters more and it therefore indicates positive changes in endurance. A Timed Up and Go Test also showed clinically significant changes, since patients performed the task within 14 seconds on average, which is ± 15.5 seconds faster than at the beginning. A 10-Meter Walk Test showed improved results of patients' gait speed, which comprised 10.5 seconds, being ± 11.5 seconds faster in comparison with the initial results.
Conclusion: The program of high-intensity interval training aimed to improve gait performance proved its effectiveness and enables to conduct its further comparisons with other types and methods of physiotherapy after stroke.

Key words: Physiotherapy. Stroke. High-intensity training. Gait after stroke.

ABSTRAKT

Východiská: Poskytovanie rehabilitačných služieb čo najskôr pomocou najefektívnejších metód, ktoré majú vedecké dôkazy, je dnes mimoriadne aktuálne.
Cieľ: Preskúmať vplyv vysokointenzívneho intervalového tréningu na výkonnosť chôdze u pacientov po mozgovej príhode.
Výskumná vzorka a metóda: Vyšetrených bolo 12 mužov, ktorí utrpeli cievnu mozgovú príhodu a splnili výberové kritériá. Všetci muži boli trénovaní v špeciálnom programe, ktorý zahŕňal vysokointenzívne intervaly tréningu chôdze v kombinácii so silovým tréningom dolných končatín a funkčným tréningom.
Výsledky: Výsledky výstupného vyšetrenia ukázali významné zmeny vo všetkých sledovaných ukazovateľoch u všetkých 12 zúčastnených pacientov. Štatisticky významné zmeny boli zistené v celkovej Berg Balance Scale v priemere na ± 40,5, čo je klinicky významná zmena bilančných ukazovateľov o ± 16 bodov; podľa testu 6-minútovej chôdze sa počet prejdených metrov za šesť minút zvýšil na ± 189,5 metra, čo je o ± 106,5 metra viac, čo môže naznačovať pozitívne zmeny vo vytrvalosti; Up & Go Test prešiel aj klinicky významnými zmenami, pacienti dokončili testovaciu úlohu rýchlejšie ako na začiatku, v priemere o 14 sekúnd, ± 15,5 s rýchlejšie; pri rýchlosti chôdze odhadnutej 10-metrovým testom zlepšili pacienti svoje výsledky na 10,5 sekundy o ± 11,5 sekundy rýchlejšie ako počiatočný výsledok.
Záver: Program vysokointenzívneho interaktívneho tréningu na zlepšenie výkonnosti chôdze je účinný a umožňuje ďalšie porovnanie s inými typmi a metódami fyzioterapie po cievnej mozgovej príhode.

Kľúčové slová: Fyzioterapia. Cievna mozgová príhoda. Vysoko intenzívny tréning. Chôdza po cievnej mozgovej príhode.

INTRODUCTION

Stroke is a major healthcare problem in many countries. Every year, stroke affects 62 million people worldwide, 87 % of whom live in low-and middle-income countries (Wang et al., 2020; Dereka, 2020).

Early initiation of rehabilitation, as soon as the stabilization of basic vital functions, namely hemodynamics and respiration, is achieved, has a positive effect on the recovery of functions. Rehabilitation is recommended for all patients with a stroke within first 24 – 48 hours (in case a patient is in stable condition), level of evidence A, but evidence base is not sufficient to select appropriate therapies for the most severe patients (level of evidence B) (Stroke Unit Trialists' Collaboration, 2013; Winstein et al., 2016). First three months after a stroke are the most favorable for the restoration of lost functions. Within six months after stroke onset, patients are at a chronic stage, and the purpose of physiotherapy shifts from recovery to maintaining functionality.

The main demand of patients after stroke based on ICF concept is restoration of their walking skills to perform social interactions at the level of participation (Hebert et al., 2016).

Recovery of walking capacity is one of the main aims in stroke rehabilitation. Being able to predict if and when a patient is going to walk after stroke is of major interest in terms of management of the patients and their family's expectations and in terms of discharge destination and timing previsions (Selves et al., 2020).

Walking after a stroke is characterized by slow speed, poor endurance and low ergonomics Among the rehabilitation programs designed to improve mobility in stroke patients, the most popular is treadmill training, with or without partial body weight support. Improving gait speed in such ways significantly exceeds the results obtained by conventional gait training (Duncan et al., 2011; Horbny et al., 2016). Recently, new training paradigms have been proposed, including the patterns of brisk walking and intensive training (Munari et al., 2018). Compared to other forms of treadmill training, adding treadmill HIIT to conventional inpatient stroke rehabilitation has been shown to provide significantly greater improvements in gait function (Miller at al., 2021). High-intensity treadmill training is safe and feasible and has a positive effect on gait ability, cardiovascular health, and the cost of walking in patients with chronic stroke (Munari et al., 2018). High-intensity interval training (HIIT) is a promising strategy for improving gait and fitness after stroke, but question of optimal parameters remains open (Boyne et al., 2020). Moreover, there is little data on the ability of patients to adapt to speed and load requirements in intensive training. Individual works concern the peculiarities of training depending on primary functional indicators of stroke patients (Vinohradov et al., 2021; Voronova et al., 2021). Thus, particular attention should be paid to selecting parameters of HIIT for patient population in Ukraine, taking into account the level of medical services, in-patient treatment conditions, physiological and personal factors of patients, which is a promising area of research.

OBJECTIVE

To study the effect of high-intensity interval training on gait performance in patients after a stroke.

RESEARCH SAMPLE

The study was conducted at the Life House neurorehabilitation center, Ukraine, and involved 12 males (37 – 50 years) who had suffered from acute cerebrovascular accident. The participants of the research signed an informed consent form. The research was approved by the University Ethics Committee (№ 2/2019) and was conducted in accordance with the international principles of the Helsinki Declaration of the World Medical Association (2013) and in accordance with the Law of Ukraine "Fundamentals of Ukrainian Health Care Legislation" (1992) on ethical norms and rules of medical research with human participation.

All participants had to meet certain selection criteria: gender – males; age – from 37 to 50 years; number of days after stroke – from two weeks, which passed into subacute stage of the disease according to vital signs; number of points on the Berg Balance Scale (BBS), (points) – 21 points and higher; speed of performing a Ten-Meter Walking Test (10MWT), (s) – up to 30 s; number of meters walked during a Six-Minute Walking Test (6MWT), (m) – more than 50 m; neurological deficit in the form of hemiparesis, with preserved movements in the lower limb; those who had consulted a cardiologist and had adjusted treatment according to their comorbidities; those, who had permission of physical medicine and rehabilitation physicians to exercise at the level of 60-80% of the maximum Heart Rate (HR_{max}).

METHODOLOGY

The duration of the physiotherapy course with elements of HIT was 8 weeks. The assessment was conducted at the beginning and end of the period. The training sessions included continuous monitoring of blood pressure (at the beginning, middle and end of the training session) and heart rate (in real time, throughout the training session using a heart rate monitor and a telephone).

During the entire period, the patients trained 5 days a week, 2 times a day for 50 – 60 minutes with a physiotherapy (PT).

High-intensity gait training – practicing walking skills, walking on uneven terrain, walking over thresholds and steps, going up and down stairs, walking outside the room in high-intensity intervals.

The main aspect of this training was interval work at the level of 60 – 80 % of HRmax, which was achieved by increasing walking speed or

providing additional resistance/load/weight during walking with the help of PT and belt.

The process of introducing high-intensity training into the rehabilitation period consisted of three stages.

During the first two weeks, the patients trained for 3 intervals of 1 min during one workout once a day at the level of 60 – 80 % of the heart rate max. For the first 15 minutes the patients walked at a slow pace, with the help and supervision of a specialist if necessary. The next task was to perform 3 intervals of 3 minutes each, where the first minute was preparatory, at 60 % of the heart rate, the second minute of walking was performed intensively at 60 – 80 % of the heart rate, the third minute – at a slow pace with a heart rate of 60 % of the maximum allowable level. The patients had a rest between intervals lasted 10 minutes.

During the 3rd and 4th weeks, the patients trained for 5 intervals. For the first 10 minutes, the patients walked at a slow pace. The next task was to perform 5 intervals of 3 minutes, with the same periodization. The patients had a rest between intervals lasted 5 minutes.

From week 5 to week 8, patients trained for 10 intervals. For the first 5 minutes, the patients walked at a slow pace. The next task was to perform 10 intervals of 3 minutes each, following the same principle as on the previous days. The patients had a rest between intervals lasted 3 minutes.

All statistical analyses were conducted using Statistica 10.0 (StatSoft, USA). Mean ± standard deviation (M ± SD), median (Me), upper and lower quartiles (25 %; 75 %) were measured. The statistical reliability of differences in mean values was estimated by the Student's test, the differences were considered reliable when ($p < 0.5$).

RESULTS

The results of the final examination showed significant changes in all studied indicators in all 12 patients (Table 1).

Changes in the BBS 9 task, which is to safely pick up an object from the floor, indicate good postural responses and the patient's ability to safely and independently maintain a standing position both statically and dynamically.

Changes in the BBS 12 task, which is to alternately place your feet on a step or step platform. Successful completion of this task is a good indicator of an activity such as climbing stairs safely.

Positive changes in BBS 14, which consists of standing on one leg, which is weaker as a result of the stroke. Successful completion of this task is also important for activities such as climbing stairs and for the ability to safely transfer body weight from one leg to the other. (Changes in this score can be found in Table 1).

According to the 6MWT, the number of meters covered in six minutes increased to ±189.5 m, which is ±106.5 m more and therefore indicates positive changes in endurance.

Table 1 The dynamics of the studied parameters Berg Balance Scale, in patients after stroke during physiotherapy using High-intensity interval training, n = 12

Indicator	Before starting the training		After the end of the training		Criterion*	p
	M ± SD	Me (25%; 75%)	M ± SD	Me (25%; 75%)		
BBS 1	3.17 ± 0.39	3.00 (3.00; 3.00)	4.00 ± 0.00	4.00 (4.00; 4.00)	-3.162	0.002
BBS 2	3.58 ± 0.51	4.00 (3.00; 4.00)	4.00 ± 0.00	4.00 (4.00; 4.00)	-2.236	0.025
BBS 3	4.00 ± 0.00	4.00 (4.00; 4.00)	4.00 ± 0.00	4.00 (4.00; 4.00)	0.000	1.000
BBS 4	3.17 ± 0.39	3.00 (3.00; 3.00)	4.00 ± 0.00	4.00 (4.00; 4.00)	-3.162	0.002
BBS 5	3.00 ± 0.00	3.00 (3.00; 3.00)	3.85 ± 0.38	4.00 (4.00; 4.00)	-3.162	0.002
BBS 6	2.42 ± 0.51	2.00 (2.00; 3.00)	4.00 ± 0.00	4.00 (4.00; 4.00)	-3.153	0.002
BBS 7	1.50 ± 0.52	1.50 (1.00; 2.00)	1.50 ± 0.52	1.50 (1.00; 2.00)	0.000	1.000
BBS 8	1.42 ± 0.51	1.00 (1.00; 2.00)	3.42 ± 0.51	3.00 (3.00; 4.00)	-3.464	0.001
BBS 9	0.92 ± 0.51	1.00 (1.00; 1.00)	2.92 ± 0.90	3.00 (2.00; 4.00)	-3.111	0.002
BBS 10	0.83 ± 0.83	1.00 (0.00; 1.75)	2.67 ± 0.89	2.00 (2.00; 3.75)	-3.276	0.001
BBS 11	0.42 ± 0.51	0.00 (0.00; 1.00)	2.33 ± 0.89	2.00 (2.00; 3.00)	-3.134	0.002
BBS 12	0.42 ± 0.79	0.00 (0.00; 0.75)	2.25 ± 0.97	2.00 (2.00; 2.75)	-3.022	0.003
BBS 13	0.00 ± 0.00	0.00 (0.00; 0.00)	1.25 ± 1.06	1.00 (0.25; 2.00)	-2.719	0.007
BBS 14	0.00 ± 0.00	0.00 (0.00; 0.00)	0.83 ± 0.58	1.00 (0.25; 1.00)	-2.887	0.004

Legend: * – Wilcoxon criterion; BBS – Berg Balance Scale, (points)

Positive results in the 6-minute walk test indicate that patients are becoming more enduring, their cardiorespiratory system is improving, and they need to walk more, which in turn is positive for activity and participation in ICF where patients need to walk to the store or pharmacy. The detailed improvement in this test can be found in Graph 2.

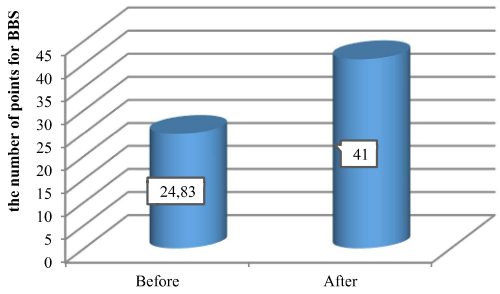
A TUG also showed clinically significant changes, since patients performed the task within 14 s on average, which is ± 15.5 s faster than at the beginning.

Positive changes in the Timed Up and Go test indicate a reduction in the risk of falling, which is one of the highest priority goals in physiotherapy for patients after stroke, fall prevention and patient safety. Performing this test within the normal range indicates that the patient can move safely within the room (Table 2).

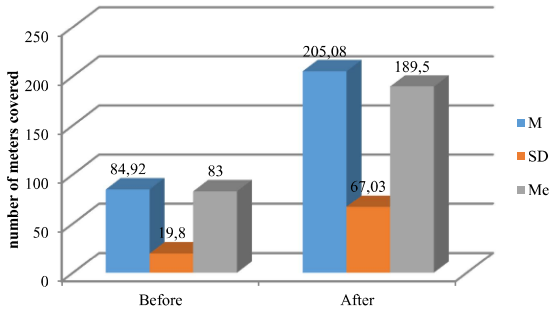
A 10MWT showed improved results of patients' gait speed, which comprised 10.5 s, being ±11.5 s faster in comparison with the initial results.

The 10-meter walk test is an important assessment of walking speed and the ability to start and stop quickly. This is an essential assessment for stroke patients, as the ability to cross the street at a green traffic light or to walk quickly in the subway are important skills for everyday life. The dynamics of changes is shown in the Graph 3.

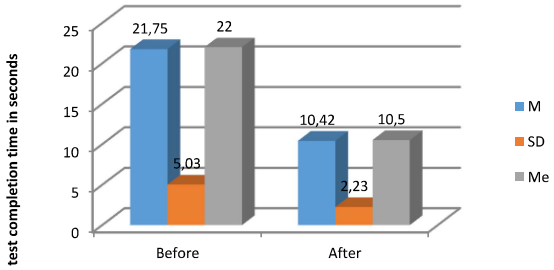
In general, all four of these tests: Berg Balance Scale, 6-minute walk test, Timed Up and Go test, 10-meter walk test, are scientifically justified for use in patients after stroke. Recommendations for use of the instrument from the Neurology Section of the Stroke Taskforce (Strok EDGE). These recommendations were developed by a panel of research and clinical experts using a modified Delphi process.



Graph 1 The dynamics of the studied parameters total score Berg Balance Scale, in patients after stroke during physiotherapy using High-intensity interval training, n=12



Graph 2 The dynamics of the studied parameters Six-Minute Walk Test in patients after stroke during physiotherapy using High-intensity interval training, n=12; *Legend:* * – Wilcoxon criterion; 6MWT – Six-Minute Walk Test, (m)



Graph 3 The dynamics of the studied parameters 10MWT – Ten-Meter Walk Test in patients after stroke during physiotherapy using High-intensity interval training, n=12

Legend: * – Wilcoxon criterion; 10MWT – Ten-Meter Walk Test, (s).

Table 2 The dynamics of the studied parameters Timed Up and Go Test in patients after stroke during physiotherapy using High-intensity interval training, n=12

Indicator	Before starting the training		After the end of the training		Criterion*	p
	M ± SD	Me (25%; 75%)	M ± SD	Me (25%; 75%)		
TUG	31.33 ± 10.34	29.5 (22.75; 39.5)	15.42 ± 4.89	14 (11.5; 19.5)	-3.062	0.002

Legend: * – Wilcoxon criterion; TUG – Timed Up and Go Test, (s).

DISCUSSION

Although HIIT is a new subject-matter to the whole world, many colleagues are introducing this method in the recovery of patients with a stroke.

For example, a study conducted by colleagues from Norway reflects the effectiveness of this type of training in terms of in-patient treatment. Following implementation of high intensity stepping, average steps per day (5777 ± 2784) were significantly greater than during moderate-intensity care (3917 ± 2656; $p < 0.001$). Statistically different and clinically meaningful changes in self-selected speed (0.39 ± 0.28 versus 0.16 ± 0.26 m/s) and fastest gait speed (0.47 ± 0.41 versus 0.17 ± 0.38 m/s; both $p<0.001$) were observed following high-intensity interventions versus usual care and at every assessment throughout the length of stay. The provision of high intensity stepping training applied during inpatient rehabilitation resulted in significantly greater walking and balance outcomes. This training paradigm should be further tested in other contexts to determine the generalizability to real-world and community settings (Moore et al., 2020).

The intervention group from our colleagues (Gjellesvik et al., 2021) showed a significant treatment effect (95% confidence interval [CI]) from baseline to posttest on a 6-minute walk test of 28.3 (CI, 2.80 – 53.77) meters (P = 0.030); Berg Balance Scale 1.27 (CI, 0.17 – 2.28) points (P = 0.025); and Trail Making Test Part B (TMT-B; -24.16 [CI, -46.35 to -1.98] s, P = 0.033). The intervention group showed significantly greater improvement on TMT-B at the 12-month follow-up (25.44 [CI, -49.01 to -1.87] s, P = 0.035). The control group showed significantly greater improvement in total Functional Independence Measure score with a treatment effect of -2.37 (CI, -4.30 to -0.44) points (P=0.016) at 12-month follow-up. No significant differences were identified between groups on other outcomes at any time point. In their conclusion, they showed that HIIT combined with standard care improved walking distance, balance, and executive function immediately after the intervention compared with standard care only. However, only TMT-B remained significant at the 12-month follow-up.

Another study (Miller et al., 2021) used the following algorithm: individuals randomized to the HIT group perform repeated 30 s bursts of walking at their maximum safe speed, alternated with 30-60 s rest periods. During overground HIT, burst speed is increased using visual feedback about the distance covered during each burst and encouragement to increase distance. During treadmill HIT, speed is systematically increased throughout each training session based on performance criteria. Speed is the primary intensity target for the HIT group, and HR is secondary after speed is maximized. This is primarily because the 30 s bursts are not long enough for heart rate to reach a steady state, so it fluctuates between burst and recovery and trends upward over the session (Boyne et al., 2020).

Hugues et al. (Hugues et al., 2021) believe that both low- and high-intensity training can be complementary for brain health.

There are also the following results of meta-analyses conducted by Gomes-Neto et al. (Gomes-Neto et al., 2017), which showed that high-intensity interval training was more effective than continuous moderate-intensity training in increasing peak VO2 increase in patients with coronary heart disease. However, when they analyzed studies with an isocaloric training protocol, the benefit of high-intensity training on peak VO2 increase disappeared. Quality of life showed no difference in the physical, emotional, and social domains between the groups.

In 2014 Gillen et al. (Gillen et al., 2014) found that a growing body of research suggests that high-intensity interval training (HIIT) is an effective exercise strategy for improving cardiorespiratory and metabolic health that is not time-consuming.

In 2016 Hussain et al. (Hussain et al., 2016) compared continuous moderate-intensity training (CMIT), long considered the most effective exercise treatment for the prevention and treatment of cardiovascular disease (CVD), with high-intensity interval training (HIIT), which is considered a potential alternative to CMIT in providing similar benefits. Initially, they found that HIIT induced significant improvements in numerous physiological and health-related measures to a similar, if not greater, extent than BIT. However, despite this, the effectiveness of HIIT in addressing the specific symptoms and risk factors of these cardiovascular pathologies has not been sufficiently studied. HIIT is often perceived as a very strenuous workout, which can make it dangerous for those at risk or suffering from CVD, but these issues have not yet been studied. In addition, the optimal HIIT protocol for each of the CVD cohorts has not been established.

CONCLUSION

The results of the study make it possible to admit that HIIT leads to improved gait indicators in stroke patients. It should be noted that the use of HIIT for stroke patients requires a very specific selection of patients. A number of factors should be taken into consideration, which significantly complicates the intervention.

The results of this study break new ground for further research and comparisons of HIIT with other methods and approaches in post-stroke physiotherapy.

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