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ORIGINAL RESEARCH

Improvement of the motor and functional capacity of post-cerebrovascular accident hemiplegics by exercise retraining combined with a varied exercises program

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Abstract

The study aimed to investigate the effect of exercise retraining combined with a program of varied physical exercises on heart rate, training intensity, aerobic capacity, lower limb strength, and body composition of hemiplegic patient's post-cerebrovascular accident. This was a 12-week follow-up study, of 30 post-stroke hemiplegic patients aged 18 years and over, who were subjected to an effort retraining program, consisting of walking on a treadmill at a progressive speed of 2.7 to 6 km per hour and a slope of 5 to 12% combined with various transfer exercises, going up and down stairs, on an ergometric bike, balance and limb strengthening thighs, Abdo and Buttocks, lasting 60 minutes per session, 3 times a week and from 40 to 75% progressive of the Maximum Heart Rate. We used the paired Student's t-test to compare continuous variables before and after the programs. A significant increase was obtained in 12 weeks of intervention for most of the parameters: +12 (37 vs 49); $p < 0.001$ for balance, +1.4 meters per second (1.39 vs 2.79). $p < 0.001$ for walking speed, +4 degrees (11 vs 15); $p < 0.001$ for step angle, +32 steps per minute (37 vs 69); $p < 0.001$ for walking cadence; +213 meters (143 vs. 356); $p < 0.001$ for the distance covered in six minutes, +3 ml/min/Kg (29 vs 32); $p < 0.001$ for maximum oxygen consumption and +12% (22 vs 34); $p < 0.001$ for lean body mass. On the other hand, the time of the Time up and go test, of the walk on the descent and ascent, and the fat mass, was significantly reduced: -14 seconds (55 vs 41), $p < 0.003$; -16 minutes (67 vs. 51); $p < 0.001$ and -16 minutes (59 vs 43); $p < 0.001$ and - 5% (41 vs 36); $p<0.001$. The exercise training program combined with various physical exercises improves the maximum oxygen consumption of post-stroke hemiplegic patients. The combination of an exercise training approach based on functional and motor improvement should make it possible to optimize post-stroke rehabilitation strategies.

Keywords: Exercise retraining, hemiplegia, motor and functional capacity, varied physical exercises.

Introduction

Cerebrovascular accident is the second leading cause of death and the leading cause of acquired disability in the world. It is defined as a neurological deficit of localized and diffuse vascular origin, the crisis of which lasts more than 24 hours (Kusuayi et al., 2018a; Monod-Broca, 2001). Stroke victims present with somatic limitations, conditions that will alter motor and functional capacity, the performance of activities of

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daily living, and quality of life (Adoukonou et al., 2010). Motor and functional impairments generate significant deconditioning and a state of fatigue in post-stroke patients. In the subacute post-stroke phase, this deconditioning will reduce the capacity for effort, muscle strength, and walking ability. Changes in walking in stroke survivors are the result of biomechanical dysfunctions that reduce performance (Walker et al., 2012; Kim & Johnston, 2011). To restore these motor and functional deficiencies, exercise retraining strongly depends on the level of functional impairment, balance, muscle strength, endurance, and spasticity, but also on the environment and aids. Stroke has many risk factors. Among them are found: arterial hypertension, atherosclerosis, arteriovenous malformations, excess cholesterol, diabetes, obesity, sedentary lifestyle and risky behaviors such as smoking or excessive alcohol consumption (O'Donnell et al., 2016; Bohannon, 1987).

Vascular Hemiplegia is one of the direct consequences of a stroke which is characterized by the obstruction or rupture of a vessel carrying blood to the brain. This results in a lack of oxygen supply endangering the functioning of one or more areas of the brain (Sibley et al., 2009). This leads to the deconditioning of patients with the effort generating cardiovascular and respiratory disorders which is a process involving the interaction of many components, the disturbance of one of which can lead to lameness, a modification of the functional parameters and a loss of autonomy of post-cerebrovascular accident patients. To overcome the latter, the current trend in rehabilitation is exercise training where many studies have shown these favorable effects (Courbon et al., 2006; Donovan et al., 2008; Johnston et al., 2009). The non-existence of this approach to the care of post-cerebrovascular accident hemiplegic patients in rehabilitation centers in the Democratic Republic of Congo motivated us to undertake this study in the Physiology Lab of the effort of the Faculty of Medicine and Medical Fitness and Functional Exercises of University Clinics of Kinshasa to research the effect of exercise retraining combined with a program of varied physical exercises. The study aimed to investigate the effect of exercise retraining combined with a program of varied physical exercises on heart rate, training intensity, aerobic capacity, lower limb strength, and body composition of hemiplegic patient's post-cerebrovascular accident.

Methods

Participants

This is a follow-up study of 30 post-cerebrovascular accident hemiplegic patients, including 21(70%) mean 9(30%) women, with an average age of 40±10 years.

Procedure

These patients were subjected to an effort retraining program, consisting of walking on a treadmill at a progressive speed of 2.7 km to 6 km per hour, a slope of 5 to 12% combined with various physical exercises of transfer, climbing, and descending stairs, on an ergometric bike, balance and strengthening of the upper limbs, lower limbs, Abdo and buttocks, lasting 60 minutes per session from 40 to 75% progressive of the maximum heart rate, with a frequency of 3 times a week for 12 weeks, developed by a team of experts in clinical kinesiology from the Republic Democratic of Congo. The primary judgment criterion is suffering from hemiplegia following an ischemic or hemorrhagic stroke of fewer than 6 months, capable of carrying out a transfer and a displacement alone. All these post-stroke hemiplegic patients benefited from an evaluation before and after the programs. The study was conducted in accordance with the Helsinki Declaration and approved by the Institutional Review Board of Kinshasa University Clinic prior to the registration of participants. The following parameters were evaluated:

Parameters, Tests, and Measurements

Timed Up and Go Test

The walking balance of the hemiplegic subject was measured using a timed test, Timed Up and Go which consists of starting from a seated position, getting up, walking 3 meters facing you, doing a half -turn and coming back to sit, for the person who realizes it. The subjective balance of the patients was measured by the Berg balance scale, which is a self-administered questionnaire of 14 questions with a maximum total score of 56 points.

Six-Minute Walk Test (TDM6)

The six-minute walk test is an objective measure of functional ability in people with significant disabilities (Donovan et al., 2008), performed on a 20-meter flat track, free of obstacles and marked at all 5 meters. The examiner present acted as a timekeeper and could make a chair available if the patient requested it or if it seemed necessary. At the end of the test, the test score corresponded to the distance traveled in 6 minutes and the fatigue perception scale was used to quantify the difficulty felt during the test. Walking speed in seconds, the normal reference value of which is 5.98 km/h or 1.7 meters per second (Donovan et al., 2008).

Temporo-spatial gait test

The length of the step measured by a new tape measure when walking between the distance between the toe of one foot on the ground and the heel of the contralateral foot which lands on the ground, the normal reference value of which is 45 cm, 15 degrees for the step angle made by a goniometer on the line of the step during a half step. 67.4 steps per minute for the walking rate recorded using an Omron brand pedometer measured by the number of heel contacts on the ground of each foot in one minute and 5.98 km / h or 1.7 meters per second for walking speed.

Aerobic capacity test and training load

Aerobic capacity assessed by the method of calculating VO_2 max expressed by the following formula: [VO_2max (ml/kg/min) = 26.9 + (0.014 * Dist. (m) TDM6) – 0.38* BMI (kg/m^2)] (Kusuayi et al., 2018b). The intensity of the training was evaluated by the percentage of the maximum heart rate, expressed by the following equation: % HR max = (HR of exercise - HR of rest / HR max - HR of rest) x 100 (formula from Karvonen, 1957). Patients worked between 60-80% progressive workload. This method is based on HR reserve = [(% desired exercise intensity * (HR max - HR rest) + HR rest] (Heyward, 2010) whose HR max in beats per minute (bpm) was evaluated using the formula (Tanaka, 2001): HR max= 208- (0.7x age). During this test, the patient's tolerance to effort manifested by perceived exaggerated fatigue, dyspnea, vertigo, profuse sweating at least and the evolution of heart rates was monitored by a heart rate monitor, a pulse oximeter and by kinesiologists.

Lower limb strength test

The strength of the lower limbs on the hemiplegic and non-hemiplegic side was measured isometric ally using a Takei A5401 Digital Hand Grip Dynamometer® brand dynamometer. The patient was seated on a chair with the knee flexed at 90°. The dynamometer was attached with a strap to the person's ankle and to the "top" of the evaluator, the patient had to try to develop maximum force forward; with the idea of regaining the 0° position at the knee. Three trials were performed for each limb and the best score was retained.

Body composition test

Total body fat in %, visceral fat in %, and muscle mass in % were measured by the Omron BF-511 Healthcare Netherlands brand weight scale.

Data Collection and Analysis

The data collected was entered and processed using SPSS 21.0 software. Quantitative variables were expressed as means ± standard deviation. The comparison of the means of the continuous variables before and after the program was carried out by the paired Student's t test. A value of $p \leq 0.05$ was considered as statistical significance.

Results

The comparison of motor and functional parameters of post-stroke hemiplegic patients before and after combined exercise training programs is presented in Table 1.

The results of the present study indicated that there was a significant increase was observed: +12 (37 vs 49); $p < 0.001$ for balance, +1.4 meters per second (1.39 vs 2.79). $p < 0.001$ for walking speed, +4 degrees (11 vs 15); $p < 0.001$ for step angle, +32 steps per minute (37 vs 69); $p < 0.001$ for walking cadence; +213 meters (143 vs. 356); $p < 0.001$ for the distance covered in six minutes; +25Kg (20..vs 45); $p < 0.001$ for lower limb muscle strength on the hemiplegic side, + 26 bpm (61vs 87); $p < 0.001$ for heart rate reserve; +15% (35 vs. 50); $p < 0.001$ for workload, +3 ml/min/kg (29 vs 32); $p < 0.001$ for maximum oxygen consumption and +12% (22 vs 34); $p < 0.001$ for lean body mass. On the other hand, the walking balance achieved by the Time up and go test, the walking time on the descent and on the ascent, the heart rate at rest and one minute after the effort, the intensity of the effort and fat mass significantly reduced: -14 seconds (55 vs 41), $p < 0.05$; -16 minutes (67 vs. 51); $p < 0.05$ and -16 minutes (59 vs 43); $p < 0.05$, -6 Bpm (88 vs 82); $p < 0.05$ and -18 Bpm (99 vs 81); $p<0.05$, -9 (16 vs. 7); $p < 0.05$ and - 5% (41 vs 36); $p < 0.05$.

Discussion

Significant improvement in balance, speed, cadence, walking distance, endurance, lower limb muscle strength, cardiovascular capacity, adaptation and exercise tolerance in post-stroke hemiplegics subjected to exercise retraining on a treadmill combined with a varied physical exercise program was revealed.

Table 1
Comparison of motor and functional parameters of post-stroke hemiplegic patients before and after combined exercise training programs.

Variables	Before	After	t	p
Time up and go (sec)	55.00 ± 13.01	41.00 ± 18.04	3.27	0.003*
Berg Balance Scale (points)	37.00 ± 8.03	49.00 ± 14.12	6.96	0.001*
Walking speed (m/sec)	1.39 ± 0.45	2.76 ± 9.80	10.68	0.001*
Step length (m)	1.10 ± 9,00	1.45 ± 10.20	3.75	0.004*
Pitch angle (degree)	11.00 ± 0.70	15.00 ± 0.91	4.38	0.001*
Walking cadence (steps/min)	37.32 ± 20.85	69.02 ± 22.00	8.53	0.001*
TDM6, distance traveled (m)	143 ± 24.25	356 ± 12.51	10.49	0.001*
Walk downhill (min)	67.01 ± 6.79	51.45 ± 10.23	9.77	0.001*
Limb muscle strength (kg)	59.00 ± 0.94	43.00 ± 4.08	9.18	0.001*
Limb muscle strength (kg)	20.00 ± 10.37	45.00±8.60	10.68	0.001*
Resting HR (bpm)	88.00 ± 1.59	82.00 ± 2.50	6.96	0.001*
HR after exercise (bpm)	99.00 ± 1.72	81.00 ± 1.94	10.52	0.001*
Reserve HR (bpm)	61.00 ± 1.23	87.00 ± 1.55	8.53	0.001*
% of Heart Rate max (%)	35.00 ± 9.86	50.00 ± 1.71	7.59	0.001*
Borg scale (point)	16.00 ± 1.92	7.00 ± 2.30	3.34	0.002*
VO_2max (ml/min/kg)	29.45 ± 1.60	32.00 ± 2.50	9.96	0.001*
Lean mass (%)	22.00 ± 2.36	34.00 ± 11.00	3.75	0.001*
Fat mass (%)	41.00 ± 12.11	36.00 ± 9.03	4.62	0.001*

*TDM6: Six-Minute Walk Test; HR: Heart rate. * p<0.05*

Our results correspond to the study by Harari et al. (2004), who observed a significant decrease in the time to achieve the Time up and go test at the end of the exercise training program (Harari et al., 2004) and an increase in Berg Balance Scale score after the program (Chaudhuri & Behan, 2004; Bourgeais et al., 2009). In addition, Barbeau et al. showed that gait training on a treadmill between 0 and 40 percent of body weight facilitates the transfer of gait to the ground in post-stroke patients (Barbeau et al., 2006). One study reported a significant decrease in the energy cost of walking with exercise retraining programs. The latter used different means to evaluate the Six-Minute Walk Test (Adoukonou et al., 2010). The studies used high-intensity exercise training programs of 70% to 80% of max Heart Rate respectively and a score of 13 to 16 out of 20 on the fatigue perception scale, found that training on a treadmill allowed an increase in VO_2 max after 6 months of an intervention program (Johnston et al., 2009; Truelsen, 2010). Thus, if these programs are of low intensity with the Borg scale of 11 to 13, the distance achieved in the minute walk test can also be increased by around 26.6%. Exercise training programs focusing on walking ability in post-stroke patients vary from study to study. This observation could explain the differences between the results obtained in the literature concerning the effects of the latter on endurance and walking speed. Indeed, studies show that there are significant differences from one exercise training program to another in terms of program duration, number of sessions per week and work intensity (Klit et al., 2009; Kessomtini, 2015). The frequency and duration of exercise training sessions improve functional parameters when patients practice exercise training 3 to 4 days per week and the duration of sessions exceeds one hour per day (Toledano et al., 1999). One study reports a significant increase in Heart Rate max of over 4 beats per minute. The cardiovascular capacity of post-stroke patients is therefore more improved with mixed effort training protocols than those centered on walking, cycling, treadmill and walking platform carried out independently (Petrilli et al., 2022; Gallien et al., 2005). Bourgeais et al. proposed a structured exercise training program focusing on muscle strength with elastic bands (2 sets of 10 repetitions). Moreover, it seems that 12 weeks of retraining with mixed effort combined with strength exercises or with spontaneous activities are sufficient to significantly increase the VO_2 max of post-stroke patients (Bourgeais et al., 2009). The frequency and duration of exercise training sessions improve functional parameters when patients practice exercise training 3 to 4 days per week and the duration of sessions exceeds one hour per day (Toledano et al., 1999). One study reports a significant increase in Heart Rate max of over 4 beats per minute. The cardiovascular capacity of post-stroke patients is therefore more improved with mixed effort training protocols than those centered on walking, cycling, treadmill and walking platform carried out independently (Petrilli et al., 2022; Gallien et al., 2005). Bourgeais et al. proposed a structured exercise training program focusing on muscle strength with elastic bands (2 sets of 10 repetitions). Moreover, it seems that 12 weeks of retraining with mixed effort combined with strength exercises or with spontaneous activities are sufficient to significantly increase the VO_2 max of post-stroke patients (Bourgeais et al., 2009).

Conclusion

The effort retraining program combined with various physical exercises improves the temporal-spatial parameters of walking, functional and cardiovascular capacity by increasing the maximum oxygen consumption of post-stroke Hemiplegic patients. The combination of an exercise training approach based on functional and motor improvement should make it possible to optimize post-stroke rehabilitation strategies.

In view of the positive effects of this approach, we suggest that it be tested, validated and promoted in all rehabilitation centers by rehabilitation experts both nationally and internationally.

Authors' Contribution

Study design: GK, Data collection: SNT, Statical Analysis: GK, CBN, Manuscript preparation GK, CKE, Funds collection: CBN, SNT.

Ethical Approval

The study protocol was approved by the Medical Ethics Committee of the Ministry of Public Health of the Democratic Republic of Congo and its approval number is N° 14 / CNES / BN / PMMF / 2022 of 11/20 /2022 association also known as the Declaration of Helsinki.

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Conflict of interest

The authors declare that they have no conflict of interest. They are solely responsible for the writing and content of this article.

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